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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 directly to the Editor-in-Chief. Complete instructions to authors concerning the required camera-ready copy are presented at the end of this issue.

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PRESIDENT'S MESSAGE / MESSAGE DU PRÉSIDENT

It is a pleasure to provide editorial comments for Canadian Acoustics, having recently returned from a very successful Acoustic Week in Canada conference in Vancouver this past October (AWC 2008). The conference attracted an impressive number of technical papers, exhibitors and participants. Again this year, there were three captivating plenary presentations, on the First Sounds of Speech by John Esling, on Studying the Sea with Sounds by Stan Dosso, and on Microsounds and Soundscapes by Barry Truax. A number of social events from the Annual Banquet to the visit and organ recital at Christ Church Cathedral in Downtown Vancouver rounded up the conference. I am always fascinated by the wide range of topics covered at our annual meetings, and the very diverse and broad membership base within our Association. It is always a pleasure to discuss acoustical matters and socialize with other researchers, consultants, equipment and material manufacturers, students and all others sharing a common interest in acoustics. Many thanks to Murray Hodgson, the Vancouver conference chair, Kimary Shahin, Linda Rammage, Mark Cheng, Mark Bliss, Christine Harrison, Hind Sbini, Bernadette Duffy and all others on the local Organizing Committee for keeping this spirit alive.

AWC 2009 will be held in a different, but equally exciting, setting in Niagara-on-the-Lake, October 14-16, 2009. The local Organizing Committee is led by our Journal Editor, Ramani Ramakrishnan, and we can look forward to a strong technical meeting with carefully selected social events again next year. Please mark down this event immediately in your calendar and consult the current and future issues of Canadian Acoustics for more information.

Many thanks to Nicole Collison and Alberto Behar, who have just completed their terms as Directors, for their contributions to the running of the Association. At the same time, I would like to welcome our two new elected Directors, Sean Pecknold from DRDC Atlantic and Robert Racca from JASCO Research.

On behalf of our Journal Editor, I would also like to thank Stephen Bilwachuck for all his efforts maintaining the News section of Canadian Acoustics over the past years. Jérémie Voix will now lead this section with a new focus on highlighting Canadian-based news items, special activities, events, standards, working group activities and much more arising from the field of Acoustics and of direct interest to our readers. We want to hear from CAA members about any such exciting or important news, so please contact Jérémie Voix (jvoix@sonomax.com) if you have an item to contribute. Finally, given the growing interest in Bio-Acoustics within our Association, Jahan Tavakkoli from Ryerson University is joining the Editorial Board to spearhead this topic and attract papers for the Journal.

C'est encore une fois un grand plaisir que d'écrire quelques mots pour l'Acoustique Canadienne, tout particulièrement suite au grand succès du dernier congrès à Vancouver en octobre dernier lors de la Semaine Canadienne d'acoustique. Le congrès a rassemblé un nombre impressionnant de présentateurs, d'exposants et de participants. Encore cette année, nous avons eu droit à trois présentations plénières des plus captivantes dans des domaines aussi variés que l'étude des premiers sons de la parole chez l'humain par John Esling, l'étude des fonds et courants marins par le son avec Stan Dosso et la microstructure des sons et l'écologie du paysage sonore par Barry Truax. Un ensemble d'activités sociales comme le banquet annuel et la visite et récital d'orgue à la cathédrale Christ Church de Vancouver ont complété le programme du congrès. À chaque année, je suis fasciné par l'étendue des sujets traités lors du congrès et l'éventail d'expertise des membres formant notre association. Ce fut encore une fois un grand plaisir que de dialoguer avec les autres chercheurs, consultants, fabricants de matériaux et d'équipements, étudiants et autres participants, tous démontrant un grande passion pour l'acoustique. Maints remerciements à Murray Hodgson, président du congrès de Vancouver, Kimary Shahin, Linda Rammage, Mark Cheng, Mark Bliss, Christine Harrison, Hind Sbini, Bernadette Duffy ainsi qu'aux autres membres du comité organisateur pour un congrès des plus mémorables.

La Semaine Canadienne d'acoustique 2009 se tiendra dans un endroit tout aussi enchanteur à Niagara-on-the-Lake du 14 au 16 octobre prochain. Le congrès sera présidé par Ramani Ramakrishnan, le rédacteur en chef de notre revue l'Acoustique Canadienne. Nous pouvons anticiper un congrès scientifique des plus stimulants encore l'an prochain et des activités sociales bien choisies. Veuillez inscrire cet événement dans notre agenda et consulter la présente revue et les parutions futures de l'Acoustique Canadienne pour plus de renseignements.

Je tiens à remercier nos deux directeurs sortants, Nicole Collison et Alberto Behar, pour leurs précieux services au sein du conseil d'administration de l'Association ces dernières années. Du même coup, j'en profite pour souhaiter la bienvenue à nos deux nouveaux directeurs élus, Sean Pecknold de RDDC Atlantique et Robert Racca de JASCO Research.

Au nom de notre rédacteur en chef, j'aimerais aussi remercier Stephen Bilwachuck pour tout son travail au cours des dernières années à la mise à jour de la rubrique « Nouvelles » de l'Acoustique Canadienne. Jérémie Voix va maintenant assurer la relève et prendre une nouvelle direction pour cette rubrique afin de mettre en valeur les nouvelles, événements spéciaux, activités de groupes de travail ou de normalisation et de toute autre activité dans le domaine de l'acoustique au Canada. Veuillez communiquer avec Jérémie Voix (jvoix@

Finally, I would like to offer a special thank you to David Quirt, our very dedicated and capable Executive Secretary for the past 6 years, who has chosen not to seek re-election at the last AGM. I can attest that Dave was a very much appreciated Executive member and a great source of knowledge into the inner workings of our Association. Unfortunately, we do not have a replacement for Dave as of this writing and for Geoff Morrison, our Website maintainer for the past two years, who also expressed his wish to be replaced.

So, please do not hesitate to contact any of us members of the Executive or Board of Directors if you want to contribute more actively to the CAA, in any capacity.

Christian Giguère
CAA President

sonomax.com) si vous désirez transmettre d'importantes nouvelles ou activités pouvant intéresser nos lecteurs. Aussi, suite à un intérêt soutenu pour le domaine de la bio-acoustique au sein de notre Association, Jahan Tavakkoli de l'université Ryerson se joint à l'équipe de rédaction de l'Acoustique Canadienne pour mettre en valeur ce domaine et solliciter des articles.

Enfin, je tiens à remercier tout spécialement notre Secrétaire sortant, David Quirt, pour six années de travail acharné au sein de notre Association. Je peux témoigner que David fut très un membre très apprécié au sein du comité exécutif et un rouage important pour le bon fonctionnement de notre Association. Malheureusement, nous n'avons pas encore un remplaçant pour David au moment d'écrire cet éditorial ni non plus pour Geoff Morrison, notre Webmestre au cours des deux dernières années.

Alors, n'hésitez pas à communiquer avec un membre du comité exécutif ou du conseil d'administration si vous souhaitez contribuer plus activement à l'ACA, quelque soit la tâche.

Christian Giguère
Président de l'ACA

THE RACAD SPEECH CORPUS OF NEW BRUNSWICK ACADIAN FRENCH: DESIGN AND APPLICATIONS

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ABSTRACT

The RACAD (*Reconnaissance automatique de l'acadien)* speech corpus contains high quality audio recordings that can be used to develop recognition systems for the regional varieties of French spoken in the province of New Brunswick, Canada. Its design is informed by linguistic analyses of Acadian French. The corpus contains sentences read by 140 speakers who were selected according to age, gender and geographical region. This paper presents a preliminary application of the corpus in automatic speech recognition research; it outlines an original global monophone recognition model that is designed to handle linguistic variability. Global phone and word recognition rates for this model are satisfactory (about 90%), but they vary considerably across geographical locations. Possible applications of the RACAD corpus in acoustic phonetic and socio-phonetic studies of dialect variation are also described in this paper.

RÉSUMÉ

Dans le but de développer des systèmes de reconnaissance automatique des variétés de français parlées dans la province du Nouveau-Brunswick, au Canada, un corpus d'enregistrements de haute qualité, le corpus RACAD (*Reconnaissance automatique de l'acadien)*, a été recueilli. Ce corpus est constitué de phrases lues par 140 locuteurs. Suivant la méthodologie employée dans les études linguistiques portant sur le français acadien, les locuteurs ont été sélectionnés d'après leur âge, leur sexe et leur appartenance géographique. Cet article décrit une première application du processus de reconnaissance automatique de la parole à partir de ce corpus; il présente un modèle monophone global qui tient compte de la variabilité linguistique dans le RACAD. Les résultats montrent que les taux de reconnaissance globale des phones et des mots sont satisfaisants (environ 90%), mais que ces taux varient entre les diverses régions géographiques. Des applications possibles du RACAD, dans des analyses de phonétique acoustique et de sociophonétique de la variation régionale, sont aussi décrites dans le présent article.

1. INTRODUCTION

Early studies involving automatic speech recognition of French tended to focus primarily on mainstream dialects of the language. In the BREF corpus of French (Gauvain *et al* 1990), all speakers are from areas in and around Paris, a region that is generally considered to speak a variety of speech that is "close" to standard or referential French. With ongoing research (Gauvin & Lamel 1992; Lamel & Gauvin 1992, 1993; Lamel *et al* 1991), the situation has evolved considerably so that present-day systems are able to accommodate different dialects of French. For example, the Microsoft® Speech Recognition engine on Windows® Vista® is available for Canadian French; Nuance®'s "Dragon Naturally Speaking" and "OpenSpeech" support standard French as well as certain dialects spoken in Québec, Belgium, Luxembourg and Switzerland. Nevertheless, the performance of these systems tends to degrade when used by French speakers from other dialect regions.

The TIMIT corpus of American English (Fisher *et al* 1986) was one of the first spoken language corpora designed for speech recognition research that took into account regional linguistic variation. This corpus consists of sentences produced by 630 speakers, both males and females, from eight different dialect regions of the United States. While the TIMIT corpus has been criticized (Keating *et al* 1994; Clopper & Pisoni 2006) because the regional labels assigned to speakers do not correspond exactly to the dialect areas identified in more recent linguistic studies of American English (Labov *et al* 2006), the corpus does provide for a wide range of regional linguistic variation. Indeed, this corpus has contributed to significant developments in speech recognition research since the 1980s. In addition, TIMIT has been used in related research areas such as perceptual dialect categorization experiments (Clopper & Pisoni 2004) and linguistic phonetic studies of the phonetic characteristics of American English, such as variation in the pronunciation of the word 'the' (Keating *et al* 1994).

The TIMIT corpus of American English served as the basis for the design of RACAD, a corpus that is developed for research on the automatic speech recognition of the regional dialects of French spoken in the province of New Brunswick (Canada). RACAD stands for *Reconnaissance automatique de l'acadien* ("Automatic speech recognition of Acadian French"). The main goal of this paper is to outline the design and applications of the RACAD speech corpus.

We begin with an overview of regional linguistic variation in New Brunswick Acadian French and then describe the speech corpus, noting its relation to TIMIT. We present two experiments that test an original global monophone recognition model. Finally, we mention research applications of the corpus in the areas of acoustic phonetics and language variation.

2. French in New Brunswick

Approximately 32.4% of New Brunswick's total population of nearly 730,000 (Statistics Canada 2006 census figures) are francophones and, for the most part, these individuals identify themselves as speakers of a dialect known as *français acadien*, Acadian French. The linguistic structure of Acadian French differs from other dialects of Canadian French such as *français québécois*, which is spoken in the neighbouring province of Québec. Both historically and linguistically, New Brunswick Acadian French is closely related to varieties of French that are found in different parts of Atlantic Canada, namely, Newfoundland, Nova Scotia, Prince Edward Island and, to a certain extent, the Magdalen Islands and areas on the Gaspé Peninsula (in the province of Québec).

There are three main geographic regions in New Brunswick where French is either the majority language or where it has a dominant presence (Arseneault 1999). These regions are shown on the map in Figure 1: the "Northeast" is a large area that includes the Acadian Peninsula (the triangle formed by Shippagan, Néguac and Paquetville) and the central northern part of the province, sometimes referred to as the "North" (Johnson & McKee-Allain 1999), situated between the communities of Allardville and Campbellton; the "Northwest" mainly occupies the region around the city of Edmundston and includes part of the so-called "Madawaska Republic"; the "Southeast" comprises rural towns and villages in the southeastern part of the province and the urban area of Moncton/Dieppe. Other regions of New Brunswick have considerably fewer native speakers of French and are predominantly English speaking. It is noteworthy that New Brunswick is an officially bilingual (French-English) province and that this status ensures that services such as education, health and justice are offered in both French and English languages.

Regional linguistic variation in New Brunswick Acadian French has been the focus of only a very small number of studies. These studies are based on partial sociolinguistic and dialectological surveys, and they identify several regional differences. Phonetic variation of the /r/ consonant (Cichocki 2006) follows a North-Northeast-Southeast regional distribution. Speakers in parts of the Northwest region have a separate linguistic identity, called *brayon*, and impressionistic phonetic studies point to phonetic features – for example, the /wa/ glide-vowel sequence in words such as 'moi' *me*, 'toi' *you* – that distinguish it from other regions of New Brunswick (Holder *et al* 1992). Lexical research on fishing terminology (Péronnet *et al* 1998) has established the presence of a major Northeast-Southeast division. A morpho-syntactic study of the usage of prepositions and relative pronouns (Péronnet & Kasparian 1998) suggests a three-way Northeast-Northwest-Southeast breakdown.

In addition, phonetic features can vary considerably within localities. In the town of Tracadie-Sheila located on the Acadian Peninsula in the Northeast region, phonetic variation has been shown to correlate with demographic factors such as speaker age and gender (Flikeid 1984).

In general, Acadian French has a number of distinctive phonetic features (see the overview in Lucci 1973). The /r/ phoneme has at least three realizations including alveolar, uvular and retroflex pronunciations. There are affricate consonants; for example, [dʒ] occurs in the phonemic sequence /dj/ (as in 'diable' *devil* [djab, dʒab]) and in /g/ (as in 'guerre' *war* [gɛʀ, dʒar]). The fricative /h/, that is silent in many varieties of French, is often pronounced (as in 'hareng' *herring* [arɑ̃, harɑ̃]). The nasal vowels /ɑ̃/ and /ɔ̃/ are often neutralized (as in 'saumon' *salmon* [somõ, somɑ̃]). Noteworthy prosodic features are long nasal vowels, lengthened vowels in the penultimate position of a prosodic phrase, and frequent occurrences of level-high and rising-falling intonation contours (Cichocki 1996, 2002).

In sum, an important consideration in designing the RACAD corpus was to elicit features of pronunciation that are related to regional and social variation. This design feature is intended to inform future research about the possible influence of linguistic variation on the performance of automatic speech recognition systems.

3. Corpus Design

3.1 Speakers and regions

The participants in this project were 140 speakers from the three main francophone regions of New Brunswick. Sampling numbers reflect overall francophone population sizes in these regions. To include social variation, the corpus was designed to represent gender and age: there are equal numbers of males and females, and there are two age groups, younger speakers between 18 and 24 years of age and older speakers between 41 and 55 years of age. Speakers come from a variety of socioeconomic backgrounds; no particular social group – such as teachers or professional speakers – was targeted. Table 1 shows the number of speakers by region, with a breakdown by locality, gender and age.

Figure 1. Map of New Brunswick showing the three main regions and eleven localities surveyed in the RACAD speech corpus

The total number of speakers (140) was determined by the requirements of the protocol for selecting speech materials (see below) and by the time constraints needed for travel for on-site data collection and for in-laboratory segmentation and labeling. While a corpus such as TIMIT has more speakers (630), it represents a considerably larger population and a greater geographic area. In this respect, it is felt that a sample of 140 speakers is sufficient to represent the francophone population of New Brunswick and, at the same time, to meet the requirements of research in automatic speech recognition.

In order to ensure a representation of regional linguistic differences, all participants are native speakers of Acadian French and all had grown up in or near one of the localities selected for this research. The map in Figure 1 locates the communities studied with respect to the three main francophone regions. Each region is represented by more than one locality. The recent in-migration from the northern areas of New Brunswick to the Southeast, in particular to the urban Moncton-Dieppe area, was excluded from the research design. While this in-migration is of current social and economic interest (Beaudin & Forgues 2006), its inclusion would have required a more detailed sampling design than was possible in this study.

Table 1. Distribution of speakers in the RACAD speech corpus by age, gender, region and locality

Region and locality	younger females	older females	younger males	older males	total
Northeast					65 (46.4%)
Acadian Peninsula Shippagan	4	4	4	3	15 (10.7%)
Paquetville	4	3	4	4	15 (10.7%)
Néguac	2	3	2	3	9 (6.4%)
North Allardville	3	4	4	4	15 (10.7%)
Campbellton	3	2	3	3	11 (7.9%)
Northwest					26 (18.6%)
Edmundston	6	6	5	5	22 (15.7%)
St-Quentin	1	1	1	1	4 (2.9%)
Southeast					49 (35.0%)
Bouctouche	2	2	2	2	8 (5.7%)
Richibouctou	1	2	2	2	7 (5.0%)
Cap-Pelé	3	2	2	3	10 (7.1%)
Moncton/Dieppe	6	6	6	6	24 (17.1%)
Total	35 (25%)	35 (25%)	35 (25%)	35 (25%)	140 (100%)

3.2 Speech materials and recording conditions

The text material in the RACAD corpus consists of 212 read sentences. Selection of these materials mirrors the protocol used in the TIMIT corpus of American English. Two "calibration" or "dialect" sentences, which were meant to elicit specific dialect features, were read by all 140 speakers. These sentences are given in (1):

(1) a *Je viens de lire dans «L'Acadie Nouvelle» qu'un pêcheur de Caraquet va monter une petite agence de voyage.*

(1) b *C'est le même gars qui, l'année passée, a vendu sa maison à cinq Français d'Europe.*

The remaining 210 sentences were selected from published lists of French sentences, specifically the lists in Combescure (1981) and Lennig (1981). These sentences are not representative of particular regional features but rather they correspond to the type of phonetically balanced materials used in coder rating tests or speech synthesis applications where it is important to avoid skew effects due to bad phonetic balance. Typically, these sentences have between 20 and 26 phonemes each. The relative frequencies of occurrence of phonemes across the sentences reflect the distribution of phonemes found in reference corpora of French spoken in theatre productions; for example, /a/, /r/ and schwa are among the most frequent sounds. The words in the corpus are fairly common and are not part of a specialized lexicon.

Of these 210 sentences, 70 so-called shared sentences were each read by 14 speakers and the remaining 140 sentences were read by a single speaker. Assignment of sentences to speakers was made randomly. Thus, each speaker read 10 different sentences: the two dialect sentences, seven of the shared sentences, and one individual sentence. The entire corpus has a total of 1400 sentences.

Prior to the recording, the interviewer explained the purpose of the RACAD speech corpus and gave each participant a written description of the study, including name and contact information in the case of concerns, complaints or consequences. Everyone participated in the reading task on a voluntary basis and provided only basic demographic information about their locality of residence, gender and age. All speakers signed a consent form acknowledging their willingness to participate in the study.

The interviewer was a young female student from New Brunswick who is a native speaker of Acadian French. It was decided that interviews should be carried out by someone who is an "insider" in order to avoid the so-called "outsider" effect, whereby speakers may modify their speech to accommodate (by convergence to or by divergence from) a speaker (interviewer) who speaks a dialect different from their own dialect (Flikeid 1997; Giles & Powesland 1998).

Speakers were recorded individually in the field, that is, in their home locality. A quiet location, familiar to the speaker, was chosen for the recording. Speakers read the stimulus sentences from cards that were arranged in random order. Where there were hesitations or repetitions, the interviewer requested a new reading of the sentence. Total duration of each speaker's recording varied between 55 and 90 seconds. To obtain high quality audio recordings, equipment used included a portable Sony digital recorder and a Shure unidirectional microphone; the sampling rate was 16 kHz.

Table 2. List of phones used in the RACAD speech corpus

Phone	Example	Phone	Example
sp	*(short pause)*	d	*dans*
	(silence)	n	*nom*
a	*patte*	s	*sans*
aa	*pâte*	z	*zone*
ax	*justement*	l	*long*
eh	*seize*	sh	*champ*
eu	*deux*	zh	*gens*
ey	*ses*	nj	*oignon*
iy	*si*	ng	*camping*
oe	*neuf*	y	*ion, pierre*
oh	*comme*	w	*coin*
ow	*gros*	k	*quand*
uy	*du*	g	*grand*
uw	*doux*	r	*rond*
p	*pont*	hy	*juin*
b	*bon*	a^	*vent*
m	*mont*	ey^	*vin*
f	*femme*	oe^	*brun*
v	*vent*	ow^	*bon*
t	*temps*		

3.3 Speech Database

The corpus of digital speech samples is organized largely according to TIMIT protocol. A hierarchical file structure identifies each audio file by locality, speaker and sentence number. Associated with each speaker's realization of a sentence are a wave file and two transcription files: a time-aligned orthographic word transcription, and a time-aligned phonetic transcription. Segmentation used in the phonetic transcription followed standard acoustic phonetic criteria. The corpus can be searched by segment, word or sentence as well as gender, age and region.

The phonetic transcriptions are broad and are given in the (standard) French SAPI (Speech Application Programming Interface) phone set. The phone set used in labeling the corpus consists of 39 of the possible 46 phones found in recognition systems from Microsoft® Corporation. The list of phones is given in Table 2.

4. A SPEECH RECOGNITION SYSTEM FOR THE RACAD CORPUS

As noted in the introduction, materials from the RACAD corpus are intended primarily for the development of original recognition systems for New Brunswick Acadian French. In this section, we outline one such system and then discuss two experiments that gauge how well the system performs with respect to regional variation. Both the automatic speech recognition system (described below) and the parameterization method were designed by using the Hidden Markov Model Toolkit (HTK) which runs on a Linux platform (Cambridge University, 2007). The HTK toolkit is a general-purpose tool designed for the creation of Hidden Markov Models (HMM). It lends itself perfectly to the creation and evaluation of automatic speech recognition engines.

4.1 Parameterization Model

The parameterization method developed is a single-Gaussian global model. Mel-frequency cepstral coefficients (MFCCs) are chosen as the basis for data parameterization. The model uses MFCCs, delta coefficients (D) that are the derivatives of the MFCCs, and logarithmic energy. Speech is sampled at 16 kHz. A Hamming window is used every 30 msec. For each 10 msec frame, 12 MFCCs and 12 delta vectors are computed. The latter represent the first order regression for each MFCC and are calculated by equation (2), where d_t is the delta coefficient at time t and $c_{t\pm\Theta}$ represents the static coefficient at instant $t \pm \theta$. The value of the delta window θ was set to 3.

$$d_t = \frac{\sum_{\Theta=1}^{\Theta} \theta(c_{t+\theta} - c_{t-\theta})}{2\sum_{\Theta=1}^{\Theta} \theta^2} \qquad (2)$$

A log energy parameter is computed for each type of parameter: one for the 12 MFCCs, one for the 12 delta vectors. These represent the log of the sum of the squares of the parameters. They are calculated using equation (3), where E represents the log energy and s_n represents the n^{th} vector for n=1 to N. This gives a total of 26 parameters per window. Intensive cross-validation experiments were carried out in order to determine the optimal number of parameters.

$$E = \log \sum_{n=1}^{N} s_n^2 \qquad (3)$$

4.2 Speech Recognition Platform

The model was trained using 93 speakers, for a total of 911 sentences from the RACAD corpus. The rationale for determining this number of speakers follows the general practice among speech recognition researchers to use a greater number of speakers for training a system than for testing it. In the present research, we selected two-thirds of the speakers for training (93 from the pool of 140 individuals) and one-third for testing (47 out of 140). It is noteworthy that the technical quality of the data is the same in both the training and testing subsets of the corpus.

Thirty-nine HMM models were created to represent each of the French phones. The optimization of the HMMs was then performed through nine Baum-Welch re-estimations as well as through an alignment of speech data after the seventh re-estimation using the Viterbi algorithm. During the training phase, a bigram and a word network, estimated from the entire corpus, were created in order to improve speech recognition accuracy.

4.3 Two Experiments: Model Efficiency and Regional Variation

We carried out two experiments to test the proposed global model. The first experiment assessed the model's general performance. The second investigated the impact of regional variation on the model by testing it in three different localities.

In the first experiment, the parameterization engine was tested using data from the 47 speakers that had not been used to train the model. This gave a total of 469 sentences for testing. The global phoneme recognition rate for the model was 93.23%, which is a satisfactory recognition performance. In addition, testing the engine for word recognition showed a recognition rate of 89.29%. These results show that the proposed global model is satisfactory for the purposes of automatic speech recognition of the French spoken in New Brunswick.

The second experiment asked the following question: Does the global model "understand" one region better than another? Three localities were selected for this study: Shippagan (in the Northeast), Edmundston (in the Northwest), and Moncton/Dieppe (Southeast). These cities are located near the geographic extremities of New Brunswick, and they represent what are perceived as different regional varieties of New Brunswick Acadian French.

The engine was tested using data from the testing subset of the corpus, that is, the one-third of the data that had not been used in training the engine. The following numbers of speakers had been selected (randomly) in each locality: 5 out of 15 in Shippagan (49 sentences), 7 out of 22 in Edmundston (70 sentences), and 8 out of 24 in Moncton/Dieppe (80 sentences). The number of sentences tested varies from region to region because the number of speakers is not constant across regions.

Table 3. Word recognition rate globally and by locality

Global	Shippagan (Northeast)	Edmundston (Northwest)	Moncton/ Dieppe (Southeast)
89.29%	91.61%	81.37%	81.82%

As shown in Table 3, the results indicate considerable variation among the three localities. Shippagan received a much better recognition rate (91.61%) than either Edmundston (81.37%) or Moncton/Dieppe (81.82%). Furthermore, the size of the difference in the rates between Shippagan and the other two localities – about 10% – suggests that recognition differences are not due to random error.

We note that no statistical analyses were carried out to test these between-locality differences. The recognition rates are based on Hidden Markov Models that model and capture all of the variation present in the data; thus, these models produce the same recognition rates and leave confidence intervals of zero. Future experiments, in which different subsets of speakers can be selected for training and testing the model, will allow us to determine whether the between-locality differences observed in this preliminary study are indeed statistically significant.

The variability in the recognition rates among the three localities raises several questions about the role of linguistic variation in speech recognition. Some of these questions are linguistic: Which phones contain variations that are too large for the model to take into account? How different are these "difficult" phones in the pronunciation of Moncton/Dieppe and Edmundston speakers from the pronunciation of Shippagan speakers? Are there fewer of these "difficult" phones in the region that is most easily understood?

Other questions are of a sociolinguistic nature: Do recognition rates correlate with speakers' age, gender, region or locality? For example, are recognition rates for females speakers' data better than those for males speakers' data? Are older speakers more easily "understood" than younger speakers? Is there greater phonetic variation within larger localities such as Moncton/Dieppe than in the more rural areas such as the Northeast and Northwest?

The main implication of the results of the second experiment described here is that regional linguistic variation appears to be an important consideration in designing speech recognition systems.

5. Other Research Applications of the RACAD Speech Corpus

The RACAD corpus has several strengths: it contains recordings that are of a high quality, these recordings were made by a reasonably large number of speakers, the choice of speakers represents differences due to region, age and gender, and the dialect is a minority variety that differs from mainstream varieties. The speaker demographic features and the presence of considerable regional variation provide an interesting set of perspectives for speech science applications, such as automatic speech recognition, to this variety of French.

The attention to recording quality and to demographic factors makes the RACAD corpus attractive to other areas of speech research. One of these is the acoustic phonetic analysis of New Brunswick Acadian French. The phonetic characteristics of the realizations of certain phonemes in Acadian French can be compared with those found in other dialects, including mainstream varieties.

A second area of application is in studies of linguistic variation. Because it contains speech samples of many speakers who are from well-defined regional, age and gender backgrounds, the corpus can provide data for sociolinguistic and dialectological studies that examine the fine phonetic details of speech variation. Increasingly, instrumental socio-phonetic studies are paying particular attention to vocalic, consonantal and prosodic variation (Foulkes & Docherty 2006; Thomas 2002), allowing researchers to pursue questions about the relation between phonetic detail and social and geographical information. As well, materials from the corpus are well suited for perceptual dialect categorization experiments and automatic dialect classification studies.

Other research applications of the RACAD corpus in linguistics are limited. One weakness of the corpus is the small amount of speech data recorded for each speaker. This limits studies of variation within one speaker's production. Nor does this allow detailed phonetic studies that focus on minimal pairs or that examine a large number of specific environments of a particular phoneme (that is, specific combinations or sequences of phones). A second weakness is the absence of stylistic variation. Speakers in the corpus had only one task, reading sentences, this to the exclusion of other styles such as reading a longer text or the kind of casual, spontaneous speech that is often of interest in sociolinguistic research. Nevertheless, the data are naturalistic because they were obtained in the field as opposed to a laboratory setting.

6. Conclusion

The RACAD speech corpus contains recordings of 140 native speakers from the three main francophone regions of New Brunswick. The design of the corpus was informed by linguistic studies of Acadian French based in sociolinguistics and dialectology. The major application for this corpus is in research on automatic speech recognition. The preliminary global monophone speech recognition model described in the present study is successful at both phone and word recognition tasks; however, success varies across geographical regions. Data from the RACAD corpus are a potential resource for acoustic-phonetic and socio-phonetic studies that examine dialect variation.

Acknowledgments

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NOISE EXPOSURE OF OPERA MUSICIANS

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ABSTRACT

A previous noise exposure survey involving the Canadian Opera Company (COC) orchestra followed several musicians over the course of two operas (Lee, Behar, Wong, and Kunov, 2005) and found that the musicians were not at risk. Since then, the COC has moved to a new building. Thus, a new study was conducted to examine whether the new venue would have an effect on noise exposure. Measurements were taken during three performances of five different operas using five dosimeters attached to music stands located throughout the orchestra pit. While the exposure levels were found to be different across operas and instrument sections, these effects were independent. In general, the exposure levels were slightly lower in the new building for all musicians with woodwinds showing a large decrease. These decreases are likely due to a larger and less enclosed orchestra pit along with fewer brass musicians playing under the pit roof. While the present study did not find evidence for a risk of hearing loss for work performed in the new venue, the musicians engage in a variety of activities outside the COC that when added to their COC work may pose a risk of noise induced hearing loss.

RÉSUMÉ

Une précédente étude sur l'exposition sonore des musiciens de l'orchestre du *Canadian Opera Company* (COC) avait suivi plusieurs musiciens pendant deux opéras (Lee, Behar, Wong et Kunov, 2005). Elle avait conclue que les musiciens ne couraient aucun danger. Depuis, le COC a déménagé dans un nouvel immeuble. Une nouvelle étude a donc été effectuée pour examiner si la nouvelle salle avait une incidence sur l'exposition sonore des musiciens. Les données ont été capturées pendant trois performances de cinq opéras différents en utilisant cinq dosimètres fixés à des lutrins dispersés dans la fosse d'orchestre. Il a été trouvé que les niveaux d'exposition calculés différaient d'un opéra à l'autre et d'un endroit à l'autre dans la fosse; ces effets restaient indépendants. En général, le niveau d'exposition était plus bas dans le nouvel immeuble pour tous les musiciens. Une diminution significative a été remarquée pour les instruments à vent en bois. Cette diminution est principalement attribuée à une fosse plus grande et plus ouverte en plus d'avoir moins de cuivres jouant sous la voûte de la fosse. Même si cette étude n'a pas trouvé d'évidence de risque de perte auditive pour tout travail effectué dans la nouvelle salle, il est à noter que les musiciens du COC jouent aussi dans d'autres salles et que l'ajout des ces activités en plus de leur travail au COC peut créer un risque d'une perte auditive.

1 INTRODUCTION

Perhaps more than any other profession, a professional musician relies on his or her ability to hear to earn a living. Musicians are also clearly passionate about listening to and enjoying music so a loss of hearing would have a more significant impact on both the livelihood and quality of life of a musician when compared to the general public. Many researchers have investigated the risks of noise induced hearing loss faced by musicians due to their occupation. These studies often follow one of two approaches: measurement of musicians' audiometric thresholds or measurement of sound levels during rehearsals and performances.

In a review of studies dealing with noise exposure of orchestra musicians, Behar, Wong and Kunov [1] found that a majority of studies concluded that players were not at risk [2, 3, 4, 5]. However, other studies reviewed in the same paper concluded the opposite [6, 7]. One of the measurement problems identified was the difficulty in properly measuring the noise exposure as well as determining the real length of time musicians are exposed to sound levels due to music playing. Behar et al. also noted problems in several studies including lack of proper measuring techniques as well as inconsistent analysis of the raw data.

Most orchestra players perform in concert halls, where performers are located on a stage in front of or surrounded by the audience. However, in the case of opera and ballet, musicians play in a pit, enclosed by hard, acoustically reflecting surfaces and often located partially below stage overhangs. The sound levels generated in such an environment are expected to be higher than those found in auditoriums.

To investigate this, a study was performed previously by some of the authors measuring the noise exposure levels of musicians of the *Canadian Opera Company* (COC) in 2003 [5]. At that time the venue of the Company was the *Hummingbird Centre for the Performing Arts*, a multifunctional hall not particularly suitable for opera or for ballet, located in Toronto, Canada. In 2006, the COC moved to a new home, the *Four Seasons Centre for the Performing Arts,* designed specifically for opera and ballet. This venue, which seats approximately 2000, was designed in the traditional horseshoe style with several rows of balconies as opposed to the slightly larger, fan-shaped *Hummingbird Centre* that has only one large balcony on the back of the hall. Thus, it was logical to perform a follow-up study to assess if a change in the architecture of the hall had an effect on the noise exposure of players.

As discussed below, the conditions were not easy to replicate: the operas tested were not the same and the measuring technique had to be modified. However, results indicate that the change in the venue has reduced the noise exposure of the players.

1.1 Risk criteria

To our knowledge, there is currently no country that has legislation setting limits for maximum noise exposure levels for musicians. However, the European Union (EU) is working towards such legislation. Since July 2007, the Ontario Health and Safety Act specifies that the maximum noise exposure level for an 8 hour work day, L_{ex}, should be 85 dBA. This is in line with the European Union legislation for industrial workers, and is recommended by the USA National Institute of Safety and Health (NIOSH) and the American Conference of Governmental Industrial Hygienists (ACGIH).

In the present study, L_{eq} is used to denote the level of a constant sound source that would provide the same total A-weighted acoustic energy as the measured sound source over the same duration as the measurement. Since the musicians in the COC are contracted for 300 hr/year, as opposed to the 2000 hr/year (equivalent to 8 hr/day) that the noise exposure legislation is based on, comparing the measured L_{eq} values to 85 dBA is inappropriate. Instead a criterion of 93 dBA was used for this study. Exposure to this level for 300 hours would result in the same total A-weighted acoustic energy as being exposed to 85 dBA for 2000 hours. Thus, if the average of the Leq measurements is above 93 dBA, the musicians can be considered to be at risk.

Many of the musicians play in other orchestras outside of their work at the COC or teach music. These, along with the other noisy activities of everyday life, may increase an individual musician's risk for noise induced hearing loss. However, as this study was limited to only assess the risk from playing in the COC orchestra, we are forced to assume that the musicians are in a quiet environment outside of the time they spend with the COC. This assumption may or may not be valid for each individual. Based on our measurements it is also possible to develop guidelines for maximum exposure times (based on the provincial limit) that a musician can make use of to help assess his or her own risk.

2 PROCEDURE

Measurements were taken during five operas performed by the COC during the 2007 season: *Faust*, *Lady Macbeth of Mtsensk*, *La Traviata*, *Luisa Miller*, and *Elektra*. Noise exposures were measured during three performances of each opera. All performances were held in the *Four Seasons Centre for the Performing Arts*.

2.1 Measuring instruments

Five Quest Type Q-300 dosimeters were used to measure the exposure level during each performance. The dosimeters were set to measure L_{eq} following the guidelines in CSA Standard Z107.56-94 [8]. The entire study spanned approximately four months. The data from the first two operas (*Macbeth* and *Faust*) were collected over a nine day period at the end of January/beginning of February, 2007, while the data from the last three operas (*La Traviata*, *Luisa Miller*, and *Elektra*) were collected over a ten day period during the month of May, 2007. The dosimeters were calibrated in our laboratory before the first two operas and again before the last three operas. As well, before each measurement, the calibration of each dosimeter was checked as per the manufacturer's instructions using a Quest Type QC-10 calibrator. No additional calibration was needed throughout the study.

2.2 Dosimeter locations

In the previous COC study [5], the dosimeters were worn by each musician with the microphones placed on his/her shoulder following the procedures described in CSA Standard Z107.56-94 [8]. For the present study the musicians were not willing to wear the dosimeters again as they found their use uncomfortable, especially with the microphone cable taped to the back of their shirts. As a compromise, it was decided to affix the dosimeters to the bottom of each music stand with the microphone positioned approximately 1 m above the floor.

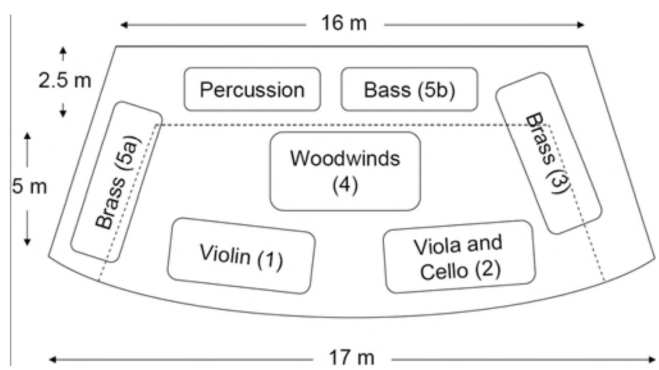

Figure 1. Approximate dosimeter locations used in the study. Each location corresponds approximately to the middle of an instrument section: violin (1), viola and cello (2), brass (3), woodwind (4), brass (5a), double bass (5b). The dimensions of the opera pit are also given.

For each opera, five dosimeters were set up in the orchestra pit. The locations corresponded approximately to the middle of instrument sections (see Figure 1). Four of the five dosimeter locations were common to all operas: violins (1), viola and cello (2), brass (3), and woodwinds (4). In one of the operas (*Faust*), the fifth dosimeter was located with the double bass instruments (5b). In the other four operas, the fifth dosimeter was located in a second group of brass instruments (5a). As the orchestra size varied with the different operas, the exact dosimeter location would vary slightly. However, the relative distribution of dosimeter locations remained the same.

2.3 Measurement procedure

Approximately 15 minutes before the start of each performance, the dosimeters were attached to the stands and the data gathering was started. The start-time for each dosimeter was recorded manually. The majority of the musicians would arrive in the orchestra pit very shortly after the dosimeters were set up and would start warming and tuning up. At the end of the performances, the dosimeters were switched off shortly after the musicians left the orchestra pit for the night (approximately 15 minutes after the end of each performance). The time each dosimeter was stopped along with the measured L_{eq} was also recorded manually.

3 RESULTS AND DISCUSSION

The results of the mean L_{eq} as a function of both opera and instrument section can be seen in Table A in the appendix. The first analysis conducted on the results was to determine if the different operas and instrument sections had an effect on the exposure level and to determine if these effects were independent. To test this hypothesis, an ANOVA was conducted with opera and instrument section as factors on L_{eq}. While a significant main effect for both opera ($F(4,54) = 23.04$, $p < 0.001$) and section ($F(4,54) = 20.73$, $p < 0.001$) was found, the interaction of opera x instrument section was not significant ($F(12,54) = 1.618$, $p = 0.114$). Thus, while the average L_{eq} varied significantly across operas and instrument sections, the effects of both variables were independent.

3.1 L_{eq} and Opera

Across operas, the L_{eq} ranged from 82.2 dBA for *La Traviata* to 89.7 dBA for *Elektra*. The mean L_{eq} for each opera can be seen in Figure 2. One possible explanation for this wide range in exposure levels observed across operas is the difference in the orchestra size, as can be seen Table 1. When the orchestra size is compared the mean Leq in Figure 3, it is clear that as the number of musicians increased, the mean L_{eq} increased as well.

If the number of uncorrelated, equal sound-level sources is doubled the level should increase by 3 dB. Thus, one would expect that the noise exposure level should increase by approximately 3 dB as the number of musicians is doubled. The mean L_{eq} as a function of the $\log_2$ of the number of musicians is plotted in Figure 3. The slope of the fitted regression line suggests an approximate increase of 7 dB as the number of musicians is doubled. Thus, the size of the orchestra does not entirely explain the change in exposure level across operas. Other factors, such as the style and musical choices of the different composers of each opera, are likely involved.

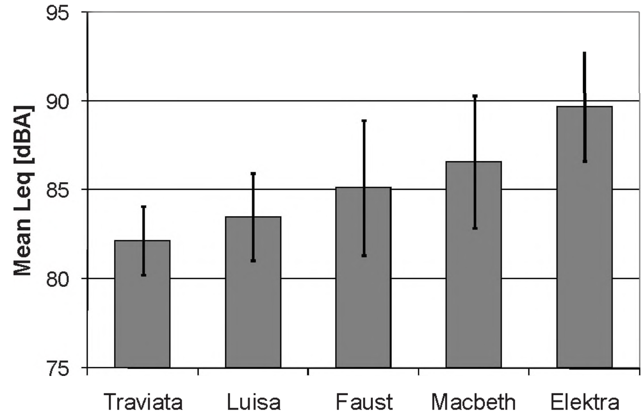

Figure 2. Mean L_{eq} for each opera. The error bars show the standard deviation.

Table 1. Orchestra size for each opera

Opera	Number of Musicians
La Traviata	63
Luisa Miller	63
Faust	64
Macbeth	93
Elektra	109

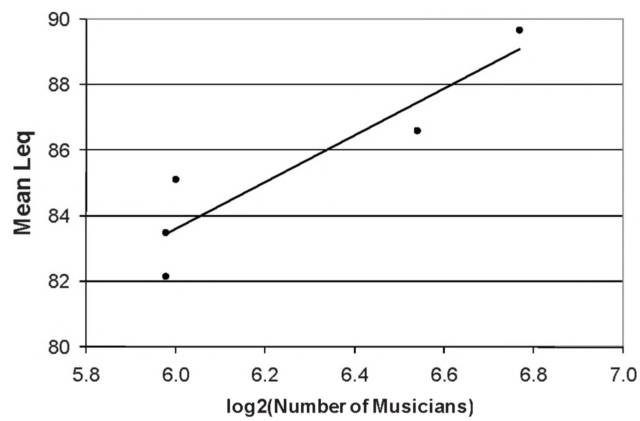

Figure 3. Mean L_{eq} as a function of the $\log_2$ of the number of performing musicians. The plotted regression line was found to have a slope of approximately 7 dB per doubling of the number of musicians.

3.2 L_{eq} and instrument section

Across instrument sections, the L_{eq} ranged from 82.7 dBA for Woodwinds to 87.9 dBA for Brass. The mean L_{eq} for each section can be seen in Figure 4. Several studies have found that the exposure levels are largest for brass musicians when compared to other instrument sections [5, 9]. An ANOVA was conducted and no significant interaction between opera and instrument section was found ($F(12,54) = 1.618$, $p = 0.114$). In other words, the pattern of exposure levels with instrument section was the same across all the operas, so for louder or quieter operas, the change in exposure level was the same for all instruments. As all of the mean Leq were lower than the criteria of 93 dBA described earlier, none of the musicians are at risk of hearing loss due to just their activity in the COC.

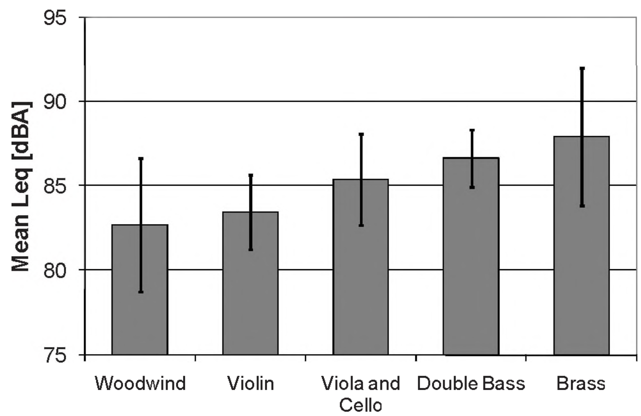

Figure 4. Mean L_{eq} for each instrument section. The error bars show the standard deviation.

3.3 Safe exposure durations

Given the characterization of exposure levels as a function of instrument section, it is possible to calculate exposure times that would equal the exposure from 85 dBA for 8 hr per day/40 hr per week/2000 hr per year as described previously in Section 2. A table of the calculated maximum exposure durations for each instrument section is shown in Table 2. It should be noted that the exposure durations assume that the musician is not exposed to any other significant sound source for the remaining period of time.

Table 2. Maximum exposure durations based on provincial limit.

Section	Hours/ Day	Hours/ Week	Hours/ Year
Woodwind	13.7	68	3417
Violin	11.4	57	2846
Viola and Cello	7.4	37	1838
Double Bass	5.5	28	1373
Brass	4.1	20	1022

NOTE: The number of hours per day/week/year of exposure for an Lex of 85 dBA assuming the rest of the day/week/year is spent in quiet. Exposure without hearing protection for durations longer than those given in the table would exceed the risk criterion given by ISO 1999 [11] while exposure for shorter durations would comply with provincial occupational noise regulations.

The maximum exposure durations assume the musician is in a quiet environment for the remaining hours of the day/week/year. As many of the musicians engage in other potentially noisy activity (playing in other orchestras, teaching, rehearsing, etc), it is impossible to assess their total risk unless the exposure levels (L_{eq}) and durations of these other activities are known. However, based on the data in Table 2 and similar data published for other activities (e.g., Behar et al. [10]) a musician can get a rough estimation of whether he or she is overexposed.

3.4 Comparison of L_{eq} between venues

One of the main goals of this study was to examine differences in noise exposure between the two venues. Using the data from the previous study, the mean L_{eq} for each instrument section was calculated. The mean L_{eq} as a function of instrument section for both venues is plotted in Figure 5.

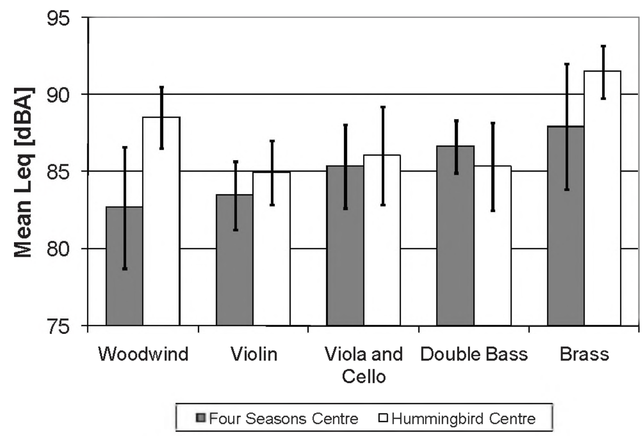

Figure 5. Mean L_{eq} for each instrument section for the *Four Seasons Centre* and *Hummingbird Centre*. The error bars show the standard deviation.

In general, the exposure levels in the *Hummingbird Centre* are higher than those in the *Four Seasons Centre*. It is tempting to conclude that the smaller orchestra pit in the *Hummingbird Centre* leads to an increase in the exposure levels. However, as discussed earlier, the techniques used when performing both measurements were slightly different: in the first study, the microphones of the dosimeters were attached to the players; in the present study, they were attached to the stands. As well, the two operas measured in the previous study (*Madame Butterfly* and *The Italian Girl in Algiers*) are different from those in the present study. Therefore it cannot be concluded if the overall differences in exposure levels between venues are only due to differences in architecture, the measurement technique, or the differences in the operas performed. However, the pattern of exposure levels for each instrument section is different between the two venues. In the previous study, the woodwinds were found to have the second highest mean L_{eq}, whereas in this study they were found to have the lowest.

An ANOVA was conducted with building and instrument section as factors on L_{eq}. A significant main effect for both building ($F(1,133) = 11.592$, $p = 0.001$) and instrument section ($F(4,133) = 17.416$, $p < 0.001$) was found. Importantly, a significant interaction of building x instrument section was also found ($F(3,133) = 4.049$, $p = 0.004$). This confirms that the pattern of results for the instrument sections is different between the two venues. Since no interaction was found between opera and instrument section for the data from the *Four Seasons Centre*, this suggests that the interaction with instrument section is due to differences between the venues as opposed to the different operas played at each venue.

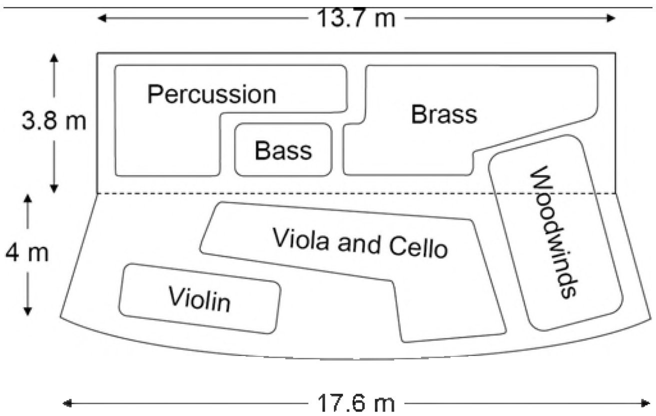

Figure 6. General layout of the orchestra and dimensions of the orchestra pit in the *Hummingbird Centre* (adapted from Lee et al. [5]).

A diagram of the general orchestra layout along with the dimensions of the orchestra pit in the Hummingbird Centre can be seen in Figure 6. From a comparison of Figures 1 and 6 it can be seen that the general layout of the orchestra is slightly different between the two venues. In the *Four Seasons Centre* the woodwinds have been shifted from the one side to the middle of the orchestra pit. As well, some of the brass musicians have been shifted forward along the sides. The previous study suggested that musicians' exposure level is related to their proximity to the brass instruments. In the present study the strings are closer to some of the brass than they were in the previous study but the noise exposure levels in the current study are lower. Further, the proximity of the woodwinds to the brass is about the same in both studies but the noise exposure levels of the woodwinds in the current study are significantly lower. Inspection of the dimensions of the *Four Seasons Centre* orchestra pit shows that it is both larger and is less enclosed than it's counterpart in the *Hummingbird Centre*. It is likely that a combination of these two factors along with fewer brass musicians playing under the enclosed part of the pit is the cause for the observed reduction in exposure levels for other musicians.

4 CONCLUSIONS AND RECOMMENDATIONS

Two conclusions can be drawn from this study: The first is that, assuming they remain in a quiet environment outside of their COC activities (performances and rehearsals), musicians are not at risk of hearing loss in their new venue. However, if they perform for more than the times shown in Table 2 they could exceed provincial occupational noise limits. Since even these limits allow some hearing loss, the musicians should be educated about the meaning of Table 2 and the precautions they should be taking to protect their hearing. The second conclusion is that the exposure levels were generally lower in the new building compared to the older venue with the level of the woodwind section showing the largest decrease. The decrease in exposure level is likely due to a less enclosed pit with fewer brass musicians playing under the roof of the pit. However, the decrease could also be due to the different microphone location.

COC musicians report that they frequently perceived the noise levels as too loud and feel that their hearing has decreased. As well, some mentioned that they have acquired tinnitus which they attribute to performing in the orchestra. While the present study did not find evidence for a risk of hearing loss, these concerns raised by the musicians should not be ignored. As previously mentioned, the musicians engage in a variety of activities outside the COC that when added to their COC work may pose a risk of noise induced hearing loss.

Thus, it is recommended that musicians should undergo periodic audiometric testing, probably every two years, to provide a longitudinal record of their hearing status. An audiogram may not be sensitive enough to pick up the initial stages of a noise induced hearing loss (i.e., the loss of some of the outer hair cells) but it is currently the only accepted standard for documenting a change in an individual's hearing. The use of distortion product otoacoustic emission (DPOAE) tests may be more sensitive as these tests directly measure outer hair cell function. However, their use for documenting occupational hearing loss is not well accepted and requires further study.

The use of "linear" or "musicians" ear plugs has long been advocated for musicians. These earplugs attenuate all frequencies equally to maintain the balance of harmonics that reach the ear and don't "color" the music. Ear plug should both reduce the perception of the sound levels as being excessive as well as reduce the risk of hearing loss. Unfortunately, few musicians accept their use, citing reasons such as discomfort, feeling of fullness in their ears, and a change of perception of their or their partners instruments' sound.

Acknowledgements

The authors would like to thank Mr. Ian Cowie, Personnel Manager of the *Canadian Opera Company*, who helped organize the measurements. As well, the authors would like to thank all the COC musicians for allowing the investigators to set up the dosimeters just before the performances. Along with the authors, the following members of the Sensory Communication Group at the Institute of Biomaterials and Biomedical Engineering (University of Toronto) helped conduct the measurements: Lisa D'Alessandro, Sheena Luu, Colin Li, Faranak Farzan, Cheng Qian, Kristen Fortney, Andrea Dickinson and Gurjit

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APPENDIX

Table A. Mean L_{eq} for each section across the five operas.

In the section column, the dosimeter location is given in parentheses (See Figure 1 for where these locations are in the pit). For the other columns, the mean L_{eq} are expressed in dBA with the standard deviation in parentheses.

Section (Dosimeter Location)	Traviata	Luisa	Faust	Macbeth	Elektra	Overall
Violin (1)	80.9 (0.7)	81.9 (0.5)	82.9 (0.7)	85.2 (0.6)	86.5 (0.3)	83.5 (2.2)
Viola and Cello (2)	83.3 (3.1)	84.1 (2.7)	85.0 (0.5)	85.8 (0.9)	88.6 (2.9)	85.4 (2.7)
Brass (3)	83.1 (2.1)	86.0 (3.1)	90.0 (2.0)	90.8 (0.8)	92.2 (3.1)	88.4 (4.0)
Woodwind (4)	80.7 (1.4)	81.1 (0.6)	81.2 (4.8)	82.1 (4.9)	88.2 (0.5)	82.7 (4.0)
Brass (5a)	82.8 (0.3)	84.3 (0.9)	-	89.1 (0.6)	92.8 (1.9)	87.3 (4.2)
Double Bass (5b)	-	-	86.6 (1.7)	-	-	86.6 (1.7)
Overall	82.2 (1.9)	83.5 (2.4)	85.1 (3.8)	86.6 (3.7)	89.7 (3.1)	85.4 (4.0)

PERCEPTION OF SYNTHETIC VOWELS BY MONOLINGUAL CANADIAN-ENGLISH, MEXICAN-SPANISH, AND PENINSULAR-SPANISH LISTENERS

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ABSTRACT

Monolingual-Western-Canadian-English listeners, monolingual-Mexican-Spanish listeners, and monolingual-Peninsular-Spanish listeners classified stimuli from a synthetic vowel continuum which allowed for English /ɩ/, /I/, /ɛ/, /E/, and Spanish /ɩ/, /ɛɩ/, and /ɛ/ responses. The continuum varied systematically in initial formant values, vowel inherent spectral change, and vowel duration. The portion of the stimulus space for which the English listeners' modal response was English /ɩ/ was identified as Spanish /ɩ/ by both groups of Spanish listeners. Three quarters of the portion of the stimulus space for which the English listeners' modal response was English /I/ was identified as Spanish /ɩ/ and one-quarter as Spanish νγ4105 /ɛ/ by Mexican-Spanish listeners, but almost all of this portion of the stimulus space was identified as Spanish /ɛ/ by Peninsular-Spanish listeners. Spanish dialect may therefore have a substantial effect on first-language-Spanish listeners' learning of the Western-Canadian-English /ɩ/–/I/ contrast.

RÉSUMÉ

Des auditeurs monolingues de l'anglais canadien de l'ouest, de l'espagnol du Mexique, et de l'espagnol péninsulaire ont identifié des stimuli qui comportaient un continuum de voyelles synthétiques, les choix de réponse étant le /ɩ/, /I/, /ɛ/, /E/ de l'anglais, et le /ɩ/, /ɛɩ/, et /ɛ/ de l'espagnol. Les voyelles sur le continuum variaient quant à leurs valeurs formantiques initiales, au changement spectral intrinsèque à la voyelle ainsi qu'à la durée vocalique. La portion de l'espace de stimuli pour laquelle la réponse la plus fréquente des auditeurs anglophones était le /ɩ/ anglais a été identifiée comme étant le /ɩ/ espagnol par les deux groupes d'auditeurs hispanophones. Les trois-quarts de la portion de l'espace de stimuli identifiés comme étant le /I/ anglais par des auditeurs anglophones ont été identifiés comme étant le /ɩ/ espagnol et l'autre quart comme le /ɛ/ espagnol par des auditeurs hispanophones du Mexique. Cette même portion de l'espace de stimuli a été presque entièrement identifiée comme étant le /ɛ/ espagnol par des auditeurs hispanophones de la Péninsule. Les dialectes de l'espagnol pourraient donc avoir un effet considérable sur l'acquisition du contraste /ɩ/–/I/ de l'anglais canadien de l'ouest par des auditeurs qui ont l'espagnol comme première langue.

1. INTRODUCTION

Spanish speaking learners of English often have problems with the English /ɩ/–/I/ contrast. Álvarez González (1980, ch. 5), Escudero (2005, §1.2.2), Flege (1991), and Møller Glasbrenner (2005) have reported that:

1. First-language Spanish second-language English listeners (L1-Spanish L2-English listeners) misidentify L1-English speakers' productions of English /ɩ/ as English /I/ and vice versa.
2. Monolingual-Spanish listeners assimilate the majority of tokens of English /ɩ/ to the Spanish /ɩ/ category.
3. Monolingual-Spanish listeners assimilate the majority of tokens of English /I/ to the Spanish /ɩ/ category.
4. However, monolingual-Spanish listeners assimilate some tokens of English /I/ to Spanish /ɛ/, and identify some tokens of English /I/ as English /E/.

These results were obtained for Peninsular- and American- Spanish speakers listening to English from South-Eastern England, and for American-Spanish speakers listening to English from the United States; however, there is evidence that the choice of English dialect can affect the extent to which tokens of English /I/ are assimilated to the Spanish /ɩ/ category versus the Spanish /ɛ/ category. Escudero & Boersma (2004) examined Peninsular- and American-Spanish listeners' perception of two dialects of English: Compared to a dialect from the South-East of England, Scottish English has a larger spectral separation and smaller duration separation between /ɩ/ and /I/. Thus L1-Spanish learners of Scottish English were expected to assimilate tokens of English /ɩ/ and /I/ via a two-category assimilation to the Spanish /ɩ/ and /ɛ/ categories respectively, and to have little difficulty perceiving the difference between the two English categories. In contrast learners of the dialect from South-Eastern England were expected to assimilate tokens of English /ι/ and /I/ via a single-category or category-goodness-difference assimilation to the Spanish /ι/, and to have moderate to considerable difficulty perceiving the difference between the two English categories (see Best's, 1995, Perceptual Assimilation Model). The assimilation predictions were confirmed for Peruvian-Spanish listeners (Escudero, 2005, §1.2.2).

There are clearly large differences in vowel pronunciation across English dialects, but Spanish dialects appear to be much more homogeneous in terms of vowel pronunciation (Morrison & Escudero, 2007, failed to find significant formant differences between the vowel systems of Spanish speakers from Madrid and Lima). The present study investigates whether there are differences in vowel perception between monolingual speakers of two Spanish dialects, Mexican Spanish (Mexico City) and Peninsular Spanish (North-Central Spain). Specifically it investigates whether there are perception differences between dialects which could affect learning of the Western-Canadian-English /ι/–/I/ contrast. Monolingual-Western-Canadian-English listeners, monolingual-Mexican-Spanish listeners, and monolingual-Peninsular-Spanish listeners were tested on their perception of a set of synthetic vowels which covered an acoustic space which allowed for the perception of English /ι/, /I/, /ε/, /E/, and Spanish /ι/, /ε/, and /ει/.

The synthetic stimuli in the present study included vowel inherent spectral change (VISC), which has been found to be an important factor in L1-English listeners' vowel perception in Western-Canadian English, as well as other dialects of North-American English (Andruski & Nearey, 1992; Assmann & Katz, 2005; Assmann, Nearey, & Hogan, 1982; Hillenbrand, Clark, & Nearey, 2001; Nearey & Assmann, 1986). This contrasts with earlier synthetic-speech studies and edited-natural-speech studies (Escudero & Boersma, 2004; Flege, Bohn, & Jang, 1997; Morrison, 2002, 2008), in which formant frequencies were fixed over the timecourse of the vowel.

Note that Western-Canadian English /ε/ is produced with diverging VISC (F1 decreases and F2 increases over the timecourse of the vowel), /I/ and /E/ are produced with converging VISC (F1 increases and F2 decreases over the timecourse of the vowel), and /ι/ is produced with negligible formant movement (Andruski & Nearey, 1992; Morrison, 2006b, §3.1; Nearey & Assmann, 1986). In Spanish, /ει/ is produced with diverging VISC, and /ι/ and /ε/ are produced with negligible formant movement (Morrison, 2006b, §3.1).

2. METHODOLOGY

2.1 Listeners

Nineteen monolingual-Western-Canadian-English speakers (eight men and eleven women) were recruited in Edmonton, Alberta, Canada (one was from Saskatchewan and all the others from Alberta). None reported an ability to speak any language other than English. They ranged in age from 18 to 54 with a median of 20.

Twenty monolingual-Mexican-Spanish speakers (ten men and ten women) were recruited in Mexico City, Federal District, Mexico. They were all speakers of Mexico-City Spanish. Thirteen reported a limited ability to speak English or French, but reported being unable to participate in a conversation in these languages. They ranged in age from 18 to 31 with a median of 22.

Seventeen monolingual-Peninsular-Spanish speakers (eight men and nine women) were recruited in Vitoria-Gasteiz, Autonomous Region of the Basque Country, Spain. They were speakers of North-Central Peninsular Spanish (thirteen were from the Basque Country, and one each from Navarre, Burgos, Leon, and Madrid). Seven reported a limited ability to speak one or more of Basque, French, and English, but reported being unable to participate in a conversation in any of these languages. They ranged in age from 25 to 53 with a median of 44.

2.2 Stimuli

A version of the Klatt synthesiser (Klatt & Klatt, 1990) was used to create synthetic /βVπ|/ stimuli, and the results were inserted in to the natural Spanish and English carrier sentences "La pró́xima palabra es __pa" and "The next word is __pa" (both sentences have the same meaning). The final /πα/ used in the English carrier sentence was actually taken from the Spanish carrier sentence. In pilot tests the unstressed utterance final Spanish /α/ was acceptable to L1-English listeners, i.e., it was not perceived as non-English like. In English-listening mode, the author would transcribe the sound as English schwa; its mean F1, F2, and F3 values were 696, 1357, and 2376 Hz. The natural portions of the stimuli were produced by a male bilingual speaker (the author).[1] Care was taken to adjust synthesiser-parameter settings so as to produce synthetic speech which (in the opinion of the author) was a good match for the voice quality of the Spanish natural speech. The speaker's Spanish productions had a greater spectral tilt than his English productions, and the spectral tilt of the English carrier sentence was therefore increased so as to match the voice quality of the Spanish-based synthetic speech.

A large stimulus space (1464 stimuli) was initially constructed, and pilot studies were conducted in order to find a smaller set of stimuli which included stimuli which were acceptable as Spanish /ι/, /ε/, and /ει/ to L1-Spanish listeners, and stimuli which were acceptable as English /ι/, /I/, /ε/, and /E/ to L1-English listeners. Figure 1 provides a plot of the smaller stimulus set. The 90 stimuli selected had ten sets of initial formant values along a diagonal in the F1–F2 vowel space ranging from [F1, F2] of [283 Hz, 2090 Hz] to [580 Hz, 1730 Hz], in equal steps of [+33 Hz, −40 Hz]. At each start-point, stimuli were synthesised with three levels of VISC: F1 and F2 either diverged, did not change (were flat), or converged over the time-course of the vowel. Formant movements [ΔF1, ΔF2] from the beginning to the

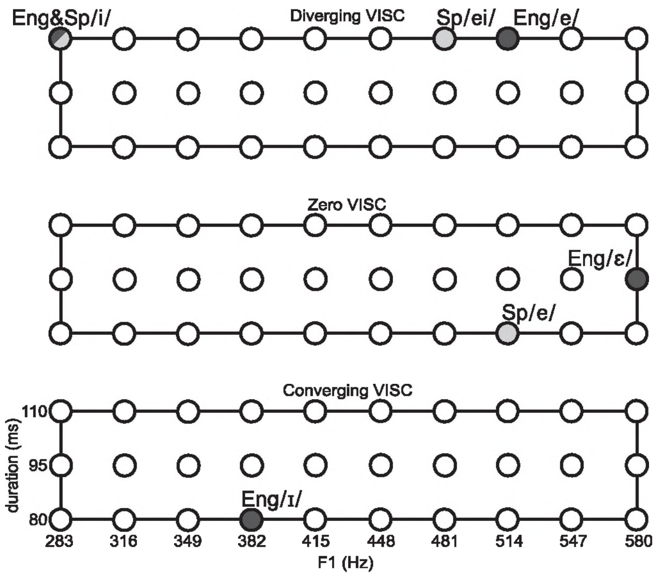

Figure 1. Properties of the synthetic stimuli. Labels are given for the duration of the vowels including consonant transitions. Labels are given for initial F1 values; F1 and F2 covaried, and the corresponding initial F2 values were: 2090, 2050, 2010, 1970, 1930, 1890, 1850, 1810, 1790, 1750, 1730 Hz. The top panel represents stimuli with diverging VISC, the final F1 value was 99 Hz less than the initial F1 value and the final F2 value was 120 Hz more than the initial F2 value. The middle panel represents stimuli with zero VISC, the formant values did not change over the timecourse of the vowel. The bottom panel represents stimuli with converging VISC, the final F1 value was 99 Hz more than the initial F1 value and the final F2 value was 120 Hz less than the initial F2 value. Filled circles represent the stimuli which were selected in pilot studies as the best examples of the four English and three Spanish vowels.

end of the vowel were [−99 Hz, +120 Hz], [0 Hz, 0 Hz], and [+99 Hz, −120 Hz] (minus three, zero, and plus three steps along the F1–F2 diagonal). Following Andruski & Nearey (1992), the formant trajectories described straight lines in a log-hertz F1–F2–F3 space. Following Nearey (1989), third-formant (F3) values were set using a formula based on a linear regression of F1 and F2 values onto F3 values from the model speaker's vowel productions. Equation 1 provides the formula with F1, F2, and F3 values given in hertz.

$$F3 = 4235 - 2.427 \times F1 - 0.272 \times F2. \quad (1)$$

Each of the 30 initial- and final-formant combinations was synthesised at three durations: 55, 70, and 85 ms (for each set of stimuli with the same initial- and final-target combinations, the shorter stimuli had steeper slopes than the longer stimuli). The synthetic stimuli also included a bilabial burst, bilabial onset and offset formant transitions, and a 90 ms long /π/ closure. The consonant transitions added an additional 25 ms to each vowel, resulting in total vowel durations of 80, 95, and 110 ms.

Audio recordings of the carrier sentences and stimuli are available in Morrison (2006b, p. 32).

2.3 Procedures

Listeners were tested one at a time using custom-written software. Monolingual-Western-Canadian-English listeners were tested in the Centre for Comparative Psycholinguistics at the University of Alberta, Monolingual-Mexican-Spanish listeners were tested in the Phonic Studies Laboratory at El Colegio de México in Mexico City, and Monolingual-Peninsular-Spanish listeners were tested in the Phonetics Laboratory at the University of the Basque Country. In Spain and Canada testing took place in a sound booth using a Roland ED UA-30 USB Audio Interface and Sennheiser HMD 280 PRO headphones. In Mexico testing took place in the quietest room available using an Edirol UA-25 Audio Interface and AKG K701 headphones.

Listeners heard a stimulus sentence, and responded by clicking on the response button which corresponded to their identification of the synthetic vowel. A new stimulus was presented 500 ms after a response was given. In the Spanish experiment the response buttons were labelled *BIPA*, *BEIPA*, and *BEPA* representing /βιπα/, /βειπα/, and /βεπα/ respectively, and in the English experiment the response buttons were labelled *BEEPA*, *BIPPA*, *BAYPA*, and *BEPPA* representing /βιπ↔/, /βΙπ↔/, /βεπ↔/, and /βΕπ↔/ respectively. The spelling-to-phoneme relationship is transparent in Spanish, but less clear in English. Prior to the English experiment, listeners were therefore trained on the English spelling-to-phoneme relationship. Listeners saw written sets of real words illustrating the four English vowel categories, and each set was followed by the corresponding response word. Listeners read the real and response words out loud, and the researcher monitored to ensure that they pronounced the same vowel sounds in the response words as in the real words. Any mismatches between the real and response words were corrected by asking the listeners to read the response word with the same vowel as in the appropriate set of real words. The researcher pointed at the written forms of the words but did not pronounce the words or model the vowels in isolation. Training was restricted to making sure that participants produced the same vowel sound in real and response words. The training continued until the researcher was confident that the listeners understood the spelling-to-phoneme relationships. The written sets of real and response words were also visible to the listeners during the experiment.

All 90 stimuli were presented in random order in two blocks, and in each of four subsequent randomised blocks an adaptive procedure selected 45 stimuli for presentation. In each of the last four blocks, category boundaries were estimated on the basis of the responses given in the earlier blocks, and stimuli in the vicinity of the category boundaries had the highest probability of being selected for presentation in the new block. This resulted in a total of 360 trials per listener, with each stimulus identified a minimum of twice and a maximum of six times. The procedure is described in detail in Morrison (2006a). It produces results which do not differ substantially from results obtained using six responses on each stimulus (540 trials), but within a time period which does not lead to listener fatigue.

3. RESULTS & DISCUSSION

3.1 Statistical Modelling Procedures

Perception results were analysed using logistic regression. For an explanation of the type of logistic regression modelling applied here it is highly recommended that the reader refer to Morrison (2007a).

The logistic regression models estimated a set of coefficient values associated with each response category:

bias coefficients:

$\alpha_{/ɩ/}, \alpha_{/I/}, \alpha_{/ɛ/}, \alpha_{/E/}$

initial-formant-tuned coefficients:

$\beta_{/ɩ/intialF}, \beta_{/I/initialF}, \beta_{/ɛ/initialF}, \beta_{/E/initialF}$

duration-tuned coefficients:

$\beta_{/ɩ/dur}, \beta_{/I/dur}, \beta_{/ɛ/dur}, \beta_{/E/dur}$

diverging-VISC-tuned coefficients:

$\beta_{/ɩ/div}, \beta_{/I/div}, \beta_{/ɛ/div}, \beta_{/E/div}$

converging-VISC-tuned coefficients:

$\beta_{/ɩ/conv}, \beta_{/I/conv}, \beta_{/ɛ/conv}, \beta_{/E/conv}$

Initial formant values and duration values were entered as continuous variables in just-noticeable-difference (JND) units. The JND scale for initial formant values was one-dimensional (F1 and F2 were 100% correlated in the synthetic stimuli) with its origin corresponding to the stimuli with the lowest F1 and highest F2 [283 Hz, 2090 Hz]. The JND used was 0.3 Bark (Kewley-Port, 2001). The conversion from hertz to the JND-formant scale (F_{JND}) was performed using Equation 2 (which includes the hertz-to-bark formula from Traunmüller, 1990):

(2)

$$F_{JND} = \sqrt{(\text{Bark}(F1) - \text{Bark}(283))^2 + (\text{Bark}(F2) - \text{Bark}(2090))^2} / 0.3$$

$$\text{Bark}(F) = (26.81F / (1960 + F)) - 0.53$$

The origin of the JND scale for duration corresponded to the stimuli with the shortest duration (80 ms), and the JND used was 5 ms on a base value of 90 ms (Noteboom and Doodeman, 1980, similar to the Weber fraction of 0.05 used by Smits, Sereno, and Jongman, 2006). The conversion from milliseconds to the JND-duration scale (dur_{JND}) was performed using Equation 3:

$$dur_{JND} = \log_{1+(5/90)}(dur/90) - \log_{1+(5/90)}(80/90) \quad (3)$$

Use of JND-scales allows initial-formant and duration results to be compared on an equal footing.

VISC was entered as three discrete levels, resulting in two dummy-coding coefficients [β_{div} β_{conv}]: [0 0] = zero VISC, [0 1] = diverging VISC, [1 0] = converging VISC. This encodes the onset + offset (or the onset + direction) hypothesis for the perceptually relevant aspects of VISC (Gottfried, Miller, & Meyer, 1993; Nearey & Assmann, 1986; Morrison, 2007b; Morrison & Nearey, 2007; Pols, 1977).

3.2 Statistical Modelling Results

Figures 2 through 4 provide population-average territorial maps and probability-surface plots based on logistic regression models fitted to monolingual-Western-Canadian-English listeners' response data, monolingual-Mexican-Spanish listeners' response data, and monolingual-Peninsular-Spanish listeners' response data. Territorial maps indicate which category is the model's predicted modal response in each part of the stimulus space (see Nearey, 1990, 1997). Probability-surface plots indicate the model's predicted probability for each response category in each part of the stimulus space (see Morrison, 2007a, 2008). (Each category is shaded a different colour, the same colours are used in the territorial maps and probability surface plots). The population-average territorial maps and probability-surface plots were created by fitting a logistic regression model to each individual listener's response data, then taking the mean of the logistic regression coefficient estimates across all listeners within each group. These mean coefficient values were then used to calculate the model's predicted probability for each category response at each point in a fine grid of points covering the stimulus space.

Examination of Figure 2 indicates that English /ɛ/ is the modal response in approximately half the diverging-VISC portion of the stimulus space, consistent with its traditional description as a (diverging) phonetic diphthong. Western-Canadian-English /I/ and /E/ are produced with converging VISC, and consistent with this, English /I/ and /E/ were the modal responses in most of the converging-VISC portion of the stimulus space. Western Canadian English /ɩ/ is produced as a monophthong, and consistent with this, English /ɩ/ was the modal response in the low-F1 part of the zero-VISC portion of the stimulus space. Some parts of the stimulus space, e.g., low-F1 converging-VISC, do not correspond to the production values of any English vowel categories, but listeners extrapolated the neighbouring categories and gave responses in these areas. Note that the orientation of the boundary between the modal areas for /ɩ/ and /I/ responses indicates that Western-Canadian-English listeners used a mixture of initial formant values, VISC, and duration to distinguish these two categories.

Examination of Figures 3 and 4 indicates that Spanish /ɛɩ/ is the modal response over about half of the diverging-VISC portion of the stimulus space. This is as expected given that Spanish /ɛɩ/ is a diverging diphthong. The zero-VISC stimulus space is divided between the two Spanish monophthongs /ɩ/ and /ɛ/. This is as expected

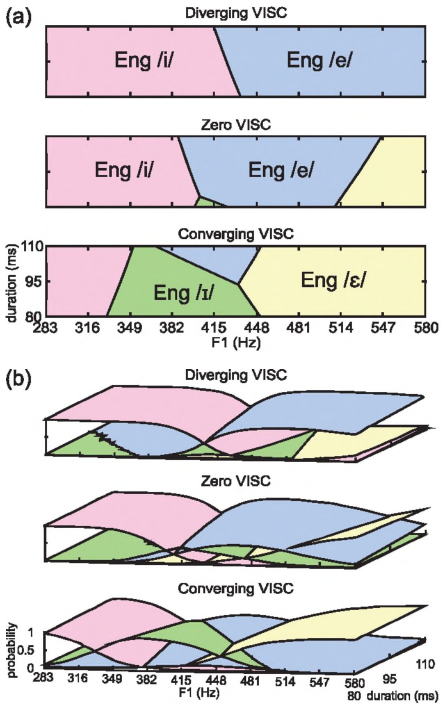

Figure 2. (a) Territorial map based on a logistic regression model fitted to pooled monolingual-Western-Canadian-English listeners' perceptual response data. The territorial map indicates the model's modal predicted response category. (b) Probability-surface plot based on the same data as in (a), the height of a surface indicates the model's predicted probability of a response category.

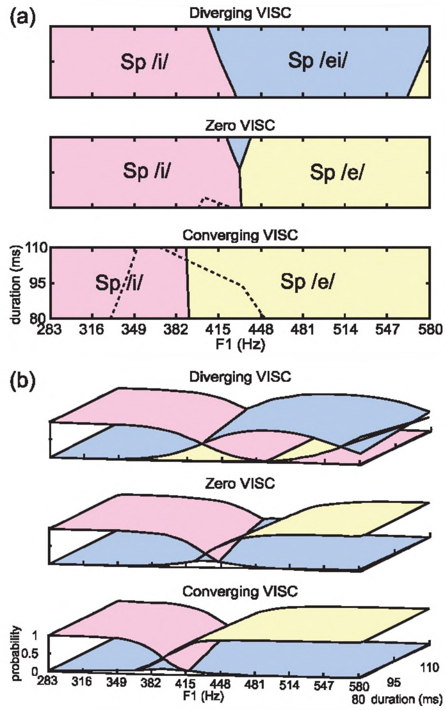

Figure 3. (a) Territorial map based on a logistic regression model fitted to pooled monolingual-Mexican-Spanish listeners' perceptual response data. (b) Probability-surface plot based on the same data as in (a). Dashed lines indicate the area of modal English /I/ responses from Figure 2a.

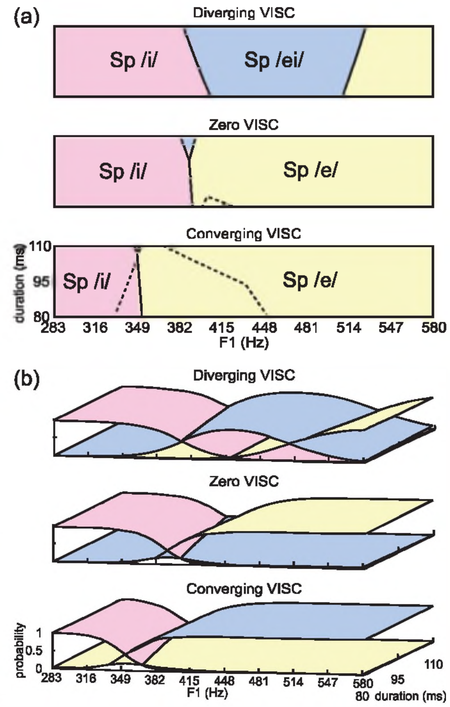

Figure 4. (a) Territorial map based on a logistic regression model fitted to pooled monolingual-Peninsular-Spanish listeners' perceptual response data. (b) Probability-surface plot based on the same data as in (a). Dashed lines indicate the area of modal English /I/ responses from Figure 2a.

assuming that these two vowels are monophthongs. Monolingual-Spanish listeners also had Spanish /i/ and /e/ as the modal response in the converging-VISC portion of the stimulus space. Note that Spanish does not have any vowels with acoustic properties similar to those in the converging-VISC portion of the stimulus space, but the results indicate that the monolingual-Spanish listeners perceived these stimuli as more similar to their Spanish /i/ and /e/ categories than to their Spanish /ei/ category. The boundaries between /i/ and /e/ response categories were relatively close to parallel to the duration axis, suggesting that duration played little part in the monolingual-Spanish listeners' perception of the contrast between these two vowels.

There were differences between Mexican- and Peninsular-Spanish listeners perception of the stimuli: The boundaries between Spanish /ɩ/–/ɛ/ and /ɛɩ/–/ɛ/ have noticeably higher F1 values for Mexican listeners (Figure 3) compared to Peninsular listeners (Figure 4).

3.3 Initial L2-perception predictions based on monolingual perception

Comparing the monolingual-Spanish and monolingual-English models, predictions can be made as to how L1-Spanish speakers just beginning to learn English would perceive the synthetic stimuli in terms of Spanish categories.

The area with English /ɩ/ as the modal response in the monolingual-English listeners' territorial map (Figure 2a), corresponded almost exclusively to areas which had Spanish /ɩ/ as the modal response in the territorial maps of both groups of monolingual-Spanish listeners (Figures 3a and 4a).

Figures 3a and 4a include an overlay of the English /I/ modal response area from Figure 2a.

Approximately two-thirds of the English /I/ modal response area corresponded to the Spanish /ɩ/ modal response area in the monolingual-Mexican listeners' territorial map (Figure 3a). This suggests that L1-Mexican-Spanish listeners will assimilate tokens of Western-Canadian-English /ɩ/ and /I/ primarily via a category-goodness-difference assimilation to Spanish /ɩ/, and may have difficulty distinguishing the two English vowels. The predictions for L1-Mexican-Spanish learners of English are consistent with the results of earlier studies of L1-Spanish listeners' perception of Canadian-English /ɩ/ and /I/, which suggested substantial confusion between /ɩ/ and /I/ (Morrison, 2002, 2008).

In contrast, almost all the English /I/ modal response area corresponded to the Spanish /ɛ/ modal response area in the monolingual-Peninsular listeners' territorial map (Figure 4a), less than one-eighth corresponded to Spanish /ɩ/. This suggests that L1-Peninsular-Spanish listeners will assimilate tokens of Western-Canadian-English /ɩ/ and /I/ primarily via a two-category assimilation to the Spanish /ɩ/ and /ɛ/ categories respectively, and will therefore have little difficulty distinguishing /ɩ/ and /I/.

4. SUMMARY & CONCLUSION

Earlier studies (Escudero, 2005, §1.2.2; Escudero & Boersma, 2004) have shown that L1-Spanish listeners' perception of the English /ɩ/–/I/ contrast is dependent on English dialect. This is not surprising given that across English dialects there can be substantial differences in the phonetic realisation of vowel phonemes. Compared to English there appears to be relatively little difference in vowel realisation across different dialects of Spanish, and several earlier studies (Escudero & Boersma, 2004; Flege, 1991; Flege et al., 1997; Morrison, 2008) have tacitly assumed that Spanish dialect will not have a major impact on the results of studies of L1-Spanish listeners' perception of English /ɩ/ and /I/. The present study tested monolingual-Western-Canadian-English, monolingual-Mexican-Spanish, and monolingual-Peninsular-Spanish listeners' perception of a synthetic vowel continuum which varied systematically in initial formant values, vowel inherent spectral change, and vowel duration. Perception differences were found between Mexican and Peninsular listeners (one would also hypothesise that there are differences in production). In the portion of the stimulus space where Canadian-English listeners' modal response was English /ɩ/, the modal response for both Mexican- and Peninsular-Spanish listeners was Spanish /ɩ/. In the portion of the stimulus space where Canadian-English listeners' modal response was English /I/, the responses for the Mexican-Spanish listeners were approximately two-thirds Spanish /ɩ/ and one-third Spanish /ɛ/, whereas for the Peninsular-Spanish listeners the responses were almost all Spanish /ɛ/. This lead to the prediction that whereas L1-Mexican-Spanish listeners are likely to perceive most tokens of Western-Canadian-English /ɩ/ and /I/ via a category-goodness-difference assimilation to Spanish /ɩ/, and to have difficulty learning the Western-Canadian-English /ɩ/–/I/ contrast, L1-Peninsular-Spanish listeners are likely to perceive most tokens of Western-Canadian-English /ɩ/ and /I/ via a two-category assimilation to Spanish /ɩ/ and /ɛ/, and to have little difficulty learning the Western-Canadian- English /ɩ/–/I/ contrast. L1-Spanish dialect may therefore have a substantial effect on L1-Spanish listeners' ability to learn the English /ɩ/–/I/ contrast.

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NOTE

1. The speaker's first language was English. Although originally from the UK he had lived in Canada for over ten years. In Morrison (2006b, appendix 8) a control experiment was conducted in which a subset of the L1-English listeners also identified stimuli in a carrier sentence produced by a speaker from Edmonton with the synthetic stimulus voice properties matched to that speaker. There were no substantial differences between the listeners' perception of the stimuli. The Speakers' second language was Spanish. He began learning Spanish at age 13, had studied Spanish for many years, had visited Spain many times, had passed the *Diploma Superior de Español como Lengua Extranjera* [Advanced Diploma in Spanish as a Foreign Language], and had lived in Spain for a year. Even after prolonged conversations, Mexicans assumed the was Spanish. The Spanish carrier sentence did not contain any vocabulary or phonemes which would immediately mark the differences between Mexican and Peninsular Spanish.

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A NEW RELATIVISTIC VISION IN SPEAKER DISCRIMINATION

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ABSTRACT

The present paper deals with the task of speaker discrimination using a new relativistic approach. Speaker discrimination has two practical applications: speaker verification and audio document indexing. In such applications, the speaker model is extracted directly from speaker's own speech signal as well as using speaker's own features. However, such a model can be rigid, inaccurate and not appropriate in fluctuating environments where a change in the recording conditions may occur. For instance, during telephone talks, the vocal features for the same speaker may change considerably. And hence, a new relative speaker model is introduced. The new model is based on a relative characterization of the speaker, called Relative Speaker Characteristic (RSC). RSC consists in modeling one speaker relative to another, meaning that each speaker model needs both its speech signal and its competing speech (speech of the speaker to be compared with). This investigation shows that the relative model, used as input at a neural network classifier, optimizes the training of the classifier, speeds up its learning time and also enhances the discrimination accuracy. The experiments of speaker discrimination are done on two different databases: Hub4 Broadcast-News database and a telephonic speech database by using a Multi-Layer Perceptron (MLP) with several input characteristics. Results indicate that the best characteristic is the RSC, when compared to other reduced features evaluated in the same manner.

RÉSUMÉ

Le présent papier s'intéresse à la tâche de discrimination du locuteur en utilisant une nouvelle approche relativiste. La discrimination du locuteur a deux applications pratiques : la vérification du locuteur et l'indexation des documents audio. Dans de telles applications, le modèle du locuteur est extrait directement de son propre signal de parole et en utilisant ses propres caractéristiques. Mais ce type de modèle peut être rigide, imprécis et non approprié dans les environnements fluctuants, où un changement dans les conditions d'enregistrement risque d'arriver. Par exemple, durant les communications téléphoniques, les caractéristiques vocales pour un même locuteur peuvent changer considérablement. Ceci nous a incité à introduire une nouvelle modélisation relative du locuteur. Ce nouveau modèle est basé sur une caractérisation relative du locuteur, appelée Caractéristique Relative du Locuteur (RSC). La RSC consiste à modéliser un locuteur relativement à un autre ; ce qui signifie que pour chaque modèle de locuteur nous avons besoin en même temps de son signal de parole et de son signal dual (signal de parole du locuteur à faire comparer avec). Cette étude montre que le modèle relatif, utilisé comme entrée d'un classifieur connexionniste, permet d'optimiser l'entraînement du classifieur, d'accélérer son temps d'apprentissage et d'améliorer aussi la précision de discrimination. Les expériences de discrimination de locuteur sont effectuées sur deux bases de données : Hub4 Broadcast- News et une base de données d'enregistrements téléphoniques, en employant un Perceptron Multi-couches (MLP) avec plusieurs caractéristiques d'entrée. Les résultats indiquent que la meilleure caractéristique est la RSC, comparativement à d'autres caractéristiques réduites qui sont évaluées de la même manière.

1. INTRODUCTION

Speaker discrimination consists in checking whether two different pronunciations (speech signals) are uttered by the same speaker or by two different speakers (Rose, 2007). This research domain has several applications such as automatic speaker verification, speech segmentation (Meignier, 2006) (Meignier, 2002) or speaker based clustering. All these tasks can be performed either by generative classifiers or by discriminative classifiers, but in practice the second type is simpler and more reliable for short training cases: it consists in a simple comparison between the speech segments.

One method of comparing the speech utterances is to extract the vocal characteristics from each speaker signal, in order to detect the degree of similarity between them.

While fingerprints and retinal scans are more reliable means of authentication, speech can be seen as a non-evasive biometric key that can be collected with or without the person's knowledge or even transmitted over long distances via telephone. Furthermore, a person's voice cannot be stolen, forgotten or lost. Thus, speaker discrimination allows for a secure and efficient method of authenticating speakers. However, existing approaches are not robust enough in noisy environment or for telephonic speech. Any new model must therefore improve the reliability of existing discriminative systems, without altering their architectures.

To address the above issue, a new relativistic characteristic is proposed. The reliability of the new approach is also compared to several other reduced features and thereby show its performance. Experiments show that the use of the new characteristic at the input of a discriminative classifier enhances the discrimination quality. The new approach is called "Relative Speaker Characteristic (RSC)." Basically, the introduction of the relative notion in speaker modelization allows getting a flexible relative speaker template, more suitable for the task of speaker discrimination in difficult environments.

The format of this paper is as follows: In section 2, we give the motivation of this research work and describe some related works. Section 3 introduces the Relativity in speaker discrimination. Section 4 describes the RSC based Neural Network (NN) used for the task of speaker discrimination. Experiments of Speaker Discrimination are presented in section 5 and finally a short conclusion is given.

2. MOTIVATION AND RELATED WORKS

2.1 Speaker recognition, applications and some problems

Speaker recognition is the ability to recognize the speaker, by using the vocal characteristics of his or her speech signal. Speaker recognition is divided into several specialties: speaker identification, speaker verification, speaker indexing and speaker discrimination.

- Speaker identification is the ability to identify the identity of a speaker among others;
- Speaker verification is the process of accepting or rejecting the identity claim of a speaker;
- Speaker indexing consists in segmenting and labeling a multi speaker audio document into homogenous segments containing only one speaker;
- Speaker discrimination is the ability to recognize whether two utterances come from the same or different speakers. This field is an important component of segmenting an audio stream into meaningful subunits, because the location of the speaker changes is crucial for dialogue understanding. Speaker discrimination is also related to speaker verification, but this last process is based on prior knowledge about a limited number of speaker identities, whereas in speaker discrimination, only knowledge about the speech signal is provided.

Speaker recognition has several practical applications in voice dialling, banking transactions by telephone, database access services, voice mail, biometric secure access, and forensic applications.

The problems encountered in speaker recognition are usually due to the intra-speaker variability of the speech, effect of noise and reduction of the spectral bandwidth in telephonic speech: [300-3400Hz]. These problems led to the choice of two types of speech databases during for the experiments, namely Hub4 Broadcast-News for the corrupted speech and telephonic calls for the reduced spectral bandwidth, in order to evaluate the proposed approach.

2.2 Some feature extraction and reduction techniques

Different techniques were developed for the task of features reduction during the last few years. In 1974, Attal (Atal, 1974) used low dimension Auto Regressive coefficients. In 1992, Bennani (Bennani, 1992) investigated the use of mean and eigenvectors of the covariance matrix. Then in 1995, Reynolds proposed the use of the covariance diagonal (Reynolds, 1995) for modeling the Gaussian Mixture Models (GMMs) and in 1995 Bonastre used the sub-bands combination (Bonastre, 1997) in order to select the best spectral bands. Later on, in 2000, Magrin-Chagnolleau conducted an investigation on alternative speech features using Line Spectrum Pairs (LSP), Time- Frequency Principal Components (TFPC) and Discriminant Components of the Spectrum (DCS) for the task of speaker characterization, but his experiments did not succeed in evidencing a benefit of alternate features over classical cepstral coefficients (Magrin, 2000).

Even in the field of speech recognition, Wang indicated in 2003 that although Linear Discriminant Analysis (LDA) and Principal Component Analysis (PCA) are the two most popular independent feature extraction methods, the drawback of independent feature extraction algorithms is that their optimization criteria are different from the classifier's minimum classification error criterion, which may cause inconsistency between feature extraction and the classification stages of a pattern recognizer (Wang, 2003).

Recent works in speaker recognition have demonstrated the advantage of modeling stylistic features in addition to traditional cepstral features (Ferrer, 2006), but the extraction of such features remains difficult in practice.

In 2006, Mami introduced the speaker representation by location in a reference space (Mami, 2006), which is a new technique of speaker recognition and adaptation.

After a thorough investigation on the optimal spectral resolution for speaker characterization Sayoud showed that the spectral parameterization of 37 Mel Frequency Spectral

Coefficients (MFSC) was optimal, implying that high spectral resolutions are interesting in speaker discrimination. (Sayoud, 2000; Sayoud, 2006) However the high dimensionality of the corresponding covariance makes the training step considerably difficult when short speech segments (few training data) were used for the segmentation task. One way to overcome this dimensional issue is to use a reduced and relative characteristic. For this reason, a new relative characteristic called RSC derived from the MFSC coefficients would be used for the task of speaker discrimination.

This relativity approach reduces the features dimension, optimizes the neural network training and tries to improve the speaker discrimination accuracy, without modifying the classifier architecture or without changing the input features.

In fact, the principle is to exploit the usual features and compute the covariance matrix for the whole utterance. We redo the same process for the second utterance to compare. After that, we compute the RSC characteristic (as we will see in section 3), and extract the diagonal vector which will replace the old features at the input of the classifier.

3. RELATIVITY AND DISCRIMINATION

3.1 Introduction

In this research work, we try to introduce a new approach of speaker recognition based on relativist discrimination. This new approach leads to a new way of classification, which can be used in some applications as speaker discrimination, speech recognition, speech segmentation and so on. Instead of drawing the boundaries between the different classes (figure 1-a), the relativity based method consists in analyzing all the possible combinations between all couples of examples and then, keeping only the minimal-distance combinations, which should indicate the examples having a similarity with the corresponding relative reference. All the examples linked to a relative reference are considered having the same type (fig. 1-b).

3.2 Some statistical similarity measures used in Speaker discrimination

A classical discrimination method based on mono-Gaussian models uses some measures of similarity, which are called Second Order Statistical Measures. These measures are used in order to recognize the speaker at each segment of the speech signal.

We recall below the most important properties of this approach (Gish, 1990; Bimbot, 1995; Bonastre, 1997). Let $\{x_t\}_{1\le t\le M}$ be a sequence of M vectors resulting from the P-dimensional acoustic analysis of a speech signal uttered by speaker $\boldsymbol{x}$. These vectors are summarized by the mean vector $\bar{x}$ and the covariance matrix X:

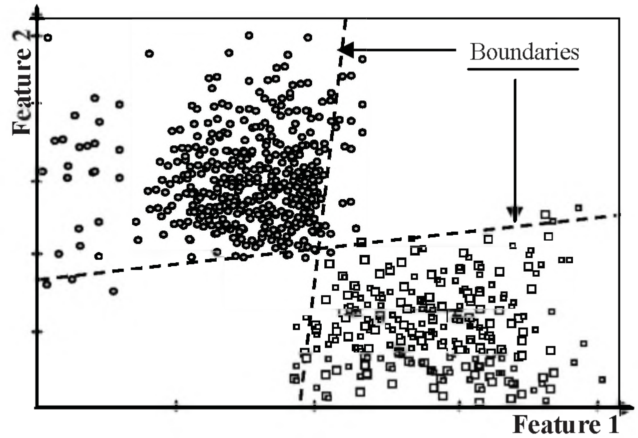

Figure 1-a: Absolute Linear classification:
Absolute boundaries are set between the two classes of examples. Features 1 and 2 represent two pertinent features of the examples.

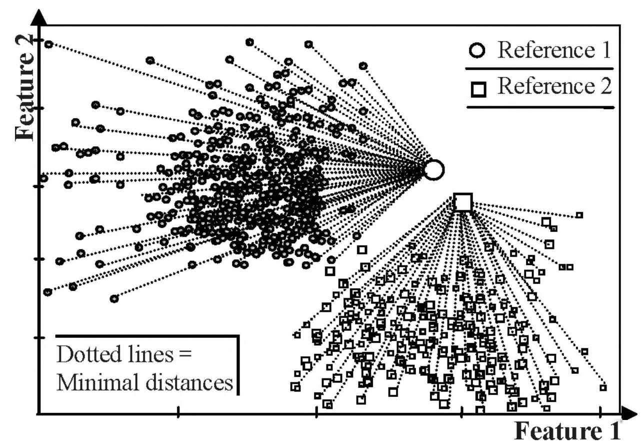

Figure 1-b: Relative Classification:
Relative links are set between the examples and the two references. A relative discrimination is made with respect to the references. No boundaries are set but the examples are relatively classified according to their minimal distances from the two references.

$$\bar{x} = \frac{1}{M}\sum_{t=1}^{M} x_t \qquad (1)$$

and $$X = \frac{1}{M}\sum_{t=1}^{M}(x_t - \bar{x})(x_t - \bar{x})^T \qquad (2)$$

Similarly, for a speech signal uttered by speaker $\boldsymbol{y}$, a sequence of N vectors $\{y_t\}_{1\le t\le N}$ can be extracted. By assuming that all acoustic vectors extracted from the speech signal uttered by speaker $\boldsymbol{x}$ are distributed like a Gaussian function, the likelihood of a single vector y_t uttered by speaker $\boldsymbol{y}$ is

$$G(y_t / \boldsymbol{x}) = \frac{1}{(2\pi)^{p/2}(\det X)^{1/2}} e^{-(1/2)(y_t-\bar{x})^T X^{-1}(y_t-\bar{x})} \qquad (3)$$

If all vectors y_t are assumed to be independent observations, the average log-likelihood of $\{y_t\}_{1 \le t \le N}$ can be written as

$$\overline{L}x(y_1^N) = \frac{1}{N}\log G(y_1 ... y_N | \boldsymbol{x}) = \frac{1}{N}\sum_{t=1}^{N}\log G(y_t | \boldsymbol{x}) \quad (4)$$

We also define the minus-log-likelihood $\psi(\boldsymbol{x}, y_t)$ which is equivalent to similarity measure between vector y_t (uttered by $\boldsymbol{y}$) and the model of speaker $\boldsymbol{x}$, so that

$$\underset{x}{Arg\min}\,\psi(\boldsymbol{x}, y_t) = \underset{x}{Arg\max}\; G(y_t / \boldsymbol{x}) \quad (5)$$

And hence,

$$\psi(\boldsymbol{x}, y_t) = -\log\; G(y_t / \boldsymbol{x}) \quad (6)$$

The similarity measure between test utterance $\{y_t\}_{1 \le t \le N}$ of speaker $\boldsymbol{y}$ and the model of speaker $\boldsymbol{x}$ is then

$$\psi(\boldsymbol{x}, \boldsymbol{y}) = \psi(\boldsymbol{x}, y_1^N) = \tfrac{1}{N}\sum_{t=1}^{N}\psi(\boldsymbol{x}, y_t) \quad (7)$$

$$= -\overline{L}x(y_1^N) \quad (8)$$

After simplifications (Sayoud, 2003b, Bimbot, 1995), we obtain

$$\psi(\boldsymbol{x}, \boldsymbol{y}) = \frac{1}{P}\left[-\log(\frac{\det(Y)}{\det(X)}) + tr(YX^{-1}) + (\overline{y} - \overline{x})^T X^{-1}(\overline{y} - \overline{x})\right] - 1 \quad (9)$$

This measure is equivalent to the standard Gaussian likelihood measure defined in (Bimbot, 1995; Sayoud, 2003). A variant of this measure called μ_{Gc} is deduced from the previous one by neglecting the third term:

$$\mu_{Gc}(\boldsymbol{x}, \boldsymbol{y}) = \psi(\boldsymbol{x}, \boldsymbol{y}) - \frac{1}{P}(\overline{y} - \overline{x})^T X^{-1}(\overline{y} - \overline{x}) \quad (10)$$

3.3 Notion of RSC (Relative Speaker Characteristic)

Natural techniques of discrimination, as those used by human beings, are based on relative assessments or comparisons of something/ somebody with respect to a referential object or person in one's memory. For concreteness, everyone can easily make a discrimination between himself and another person, only by observing his relative height (relative to a model in memory) and deduce if the person near him is an adult or a child (figure 2).

The relative statistics, between the utterances of 2 speakers, represent the statistical features of one speaker relatively to another one considered as a reference speaker. The previous formula 9 gives a similarity measure between a speech signal uttered by a speaker $\boldsymbol{y}$ and the reference model of the speaker $\boldsymbol{x}$:

$$\psi(\boldsymbol{x}, \boldsymbol{y}) = \frac{1}{P}\left[-\log(\frac{\det(Y)}{\det(X)}) + tr(YX^{-1}) + (\overline{y} - \overline{x})^T X^{-1}(\overline{y} - \overline{x})\right] -$$

Due to the fact that the between-variability of the mean vector is low, and is insignificant in noisy or telephonic environment (Sayoud, 2000) we can write:

$\overline{y} \approx \overline{x}$ (i.e. the variability of the mean is negligible).

Moreover, if x and y represent the same speaker, then this approximation is justified. In the other hand, even if the speakers are different, we can make them equal by a special normalization (e.g. normalization by the mean).

So, according to this hypothesis, the approximated similarity measure becomes:

$$\psi^*(\boldsymbol{x}, \boldsymbol{y}) = \frac{1}{P}\left[-\log(\frac{\det(Y)}{\det(X)}) + tr(YX^{-1})\right] - 1 \quad (11)$$

$\frac{\det(Y)}{\det(X)} = \det(Y/X)$, where Y/X represents the expression $Y.X^{-1}$, and hence:

$$\psi^*(\boldsymbol{x}, \boldsymbol{y}) = \frac{1}{P}\left[-\log(\det(Y/X) + tr(Y/X))\right] - 1 \quad (12)$$

And if we denote the ratio Y/X by $\Re(\boldsymbol{x},\boldsymbol{y})$ or simply $\Re$, then

$$\psi^*(\boldsymbol{x}, \boldsymbol{y}) = \frac{1}{P}\left[-\log(\det(\Re) + tr(\Re))\right] - 1 \quad (13)$$

The $\Re$ ratio is **Relative Speaker Characteristic** (RSC)

$$RSC(\boldsymbol{x}, \boldsymbol{y}) = \Re = \frac{Y}{X} = Y * X^{-1} \quad (14)$$

Hence, $\psi^*(\boldsymbol{x}, \boldsymbol{y})$ appears to be a function of the RSC.

3.4 Importance of the diagonal

Let us define a modified similarity measure $\psi^{\#}$ as follows:

$$\psi^{\#}(\boldsymbol{x}, \boldsymbol{y}) = P.(\psi^*(\boldsymbol{x}, \boldsymbol{y}) + 1) \quad (15)$$

After simplification,

$$\psi^{\#}(\boldsymbol{x}, \boldsymbol{y}) = \left[-\log(\det(\Re) + tr(\Re)\right] \quad (16)$$

The two similarity measures $\psi^{\#}$ and ψ^* are proportional and physically equivalent. We will see now the principal components of this modified measure (formula 16). Globally, the value of this measure is closely dependent on the diagonal elements of the $\Re$ matrix. But this dependence is debatable and we can consider four cases.

Case 1: if the two utterances are the same, then the $\Re$ matrix is reduced to the Identity matrix, which confirms the previous statement;

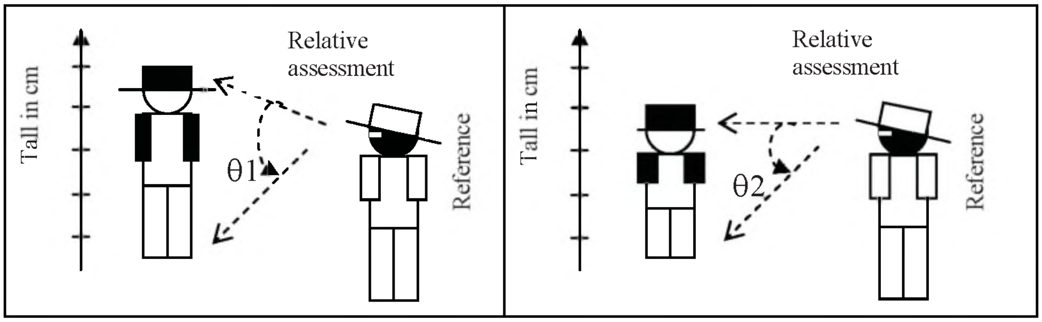

Fig. 2: Relative assessment used in natural human recognition to discriminate between adults and children: in the left side the reference can recognize that the person next to him is an adult; in the right side the reference can recognize that the person next to him is a child. This assessment is made relatively, without using any ruler to measure the person tall.
- θ1 or θ2 is the relative angular tall perceived by the eye -

Case 2: if the two utterances belong to the same speaker, then the $\Re$ matrix is more or less close to the identity matrix even if the non-diagonal elements are non zero. This confirms the previous statement too;

Case 3: if the two utterances belong to different speakers, then the $\Re$ matrix looses the identity form, but if the Speakers' features are not too different, one should retrieve large values on the $\Re$ matrix diagonal (relatively very greater than the non-diagonal elements). The reason is that the two audio signals do have a lot of common acoustic and physiologic characteristics anyway, which are typical to the speech nature of the acoustic signal;

Case 4: if the two audio signals have different types of sources (e.g. one signal is speech and the other is noise or music), then they result in random values in the $\Re$ matrix. The non-diagonal elements of $\Re$ could not be neglected.

Therefore, for the three first cases, more information on the diagonal of the RSC ($\Re$ matrix) is thus obtained. More the similarity between the two signals, the diagonal will be dominant and rich in information. Moreover, if the speech signal is strongly noised or if the two transmission channels are very different we may meet the same problem even if the two speakers are the same.

3.5 RSC pertinence and Symmetry

Let us denote by $\lambda_i|_{i=1..p}$ the eigenvalues of $\Re$ and:

since $\det(\Re)=\prod_i \lambda_i$

and $\mathrm{tr}(\Re)=\sum_i \lambda_i$

we can write :

$$\psi^{\#}(\boldsymbol{x},\boldsymbol{y}) = [-\log(\prod_i \lambda_i) + \sum_i \lambda_i] \quad (17)$$

or $$\psi^{\#}(\boldsymbol{x},\boldsymbol{y}) = \sum_i [\lambda_i - \log(\lambda_i)] \quad (18)$$

if we denote by $\psi_i^{\#}(\boldsymbol{x},\boldsymbol{y})$ the expression $[\lambda_i - \log(\lambda_i)]$ representing the measure part related to the eigenvalues λ_i.

$$\psi_i^{\#}(\boldsymbol{x},\boldsymbol{y})=[\lambda_i - \log(\lambda_i)] \quad (19)$$

Then we can write $$\psi^{\#}(\boldsymbol{x},\boldsymbol{y}) = \sum_i \psi_i^{\#}(\boldsymbol{x},\boldsymbol{y}) \quad (20)$$

The variation of the function $\psi_i^{\#}$ versus λ_i is represented on figure 3. According to figure 3, we can distinguish 2 areas: for $\lambda_i < 1$ (left side) and for $\lambda_i > 1$ (right side). Since the information is focused on the great values of λ_i and since the right side of the figure is more or less linear, it is more accurate to favor the use of eigenvalues greater than 1 resulting in three cases.

Ccase 1: If $\lambda_i > 1 \ \forall$ i,
then we are in the right side of the figure, and the measure is accurate.

Case 2: If the λ_i are > 1 $\forall$ i < ρ,
then we can consider that the dominant information is in the dominant eigenvectors (i < ρ), which leads (with i<ρ) to the same results as for the first case, provided that most of the eigenvalues are superior to 1.

Case 3: If the λ_i are < 1 $\forall$ i,
herein, we are in the left side, and the measure is not linear: varies abruptly with the eigenvalues. This may cause some problems of false rejection.

A new way to unify all these cases, is to consider the two RSC forms: $\Re$ (*x*,*y*) and $\Re$ (*y*,*x*), and integrate them respectively into a new matrix (matrix of matrices).

$$RSC_{Hybrid} = [\ [\Re(x,y)]\ ,\ [\Re(y,x)]\ ] \quad (23)$$

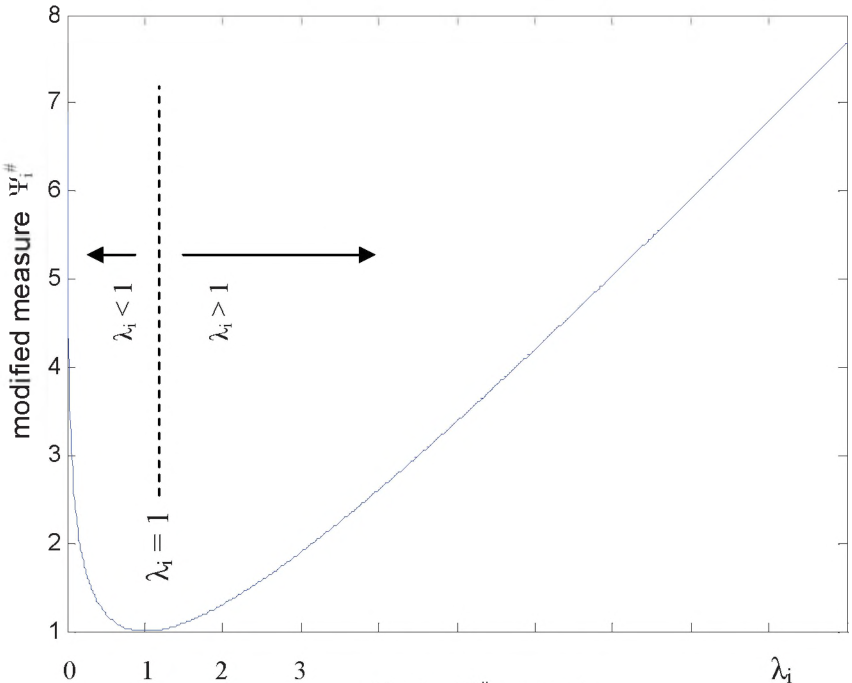

Fig. 3: $\Psi_i^{\#}$ versus λ_i

And since we have shown that the most important information is usually located in the diagonal of the RSC, we propose to use the following relative characteristic, called *symmetric DRSC* ("D" stands for Diagonal):

$$\text{DRSC}\ (\boldsymbol{x},\boldsymbol{y}) = [\ \text{diag}(\Re\ (\boldsymbol{x},\boldsymbol{y})) \cup \text{diag}(\Re\ (\boldsymbol{y},\boldsymbol{x}))\ ] \qquad (24)$$

where $\cup$ denotes the concatenation operator.

The DRSC (Diagonal of the RSC) contains enough information normally able to make a correct discrimination between the speakers ***x*** and ***y***.
Its great interest comes from the low dimension of the DRSC vector which allows minimizing the features size and the processing time in particular when using neural networks. For instance if we use acoustic features of 24 coefficients and their derivatives, we should need 2(48x48) = 4608 components in the covariance matrix to exploit, whereas the DRSC input needs only 2(48) = 96 components and which represents only 96/4608 = 2% of the memory space required for the first case. So the simplification, in term of processing time and training data, will be appreciable.

4. USING THE RSC CHARACTERISTIC IN SPEAKER DISCRIMINATION

Knowing the high discriminative capacities of the NNs (neural networks) (Bennani, 1992; Bennani, 1995), we opted for the use of a Multi-Layer Perceptron using the RSC characteristic as input. Experiments of discrimination are done on audio signals, with a speech duration of four seconds in the first experiment and ten seconds, respectively, in the second experiment.

We use the DRSC characteristic as reduced input vector for the NN, which allows us to improve its performance considerably. Furthermore, by using the Relative Speaker Characteristic, we reduce the size of the NN input and the time of training too.

In fact, the NN must have a number of receptive cells equal to the dimension of the example vector (Sayoud, 2003b). Thus, in case of using an input matrix with *PxQ* coefficients (Lee, 1995; Sayoud, 2003b), the number of input receptive cells is equal to *2PQ*.

An example is shown for concreteness:

- In the case of using acoustic features of P coefficients with RSC reduction, the number of input receptive cells is equal to P if we use non-symmetric DRSC, and it is 2P if we use symmetric DRSC.
- But, in the case of using acoustic features of P coefficients, the resulting covariance matrix will have a size of PxP and then P^2 components are required by the classifier.

So, although P^2 components are needed to exploit the classic parameterization, with RSC parameterization only P (or 2P if symmetric) components are required. Such a strong size reduction is interesting since it simplifies the NN architecture, diminishes the required training data set and reduces the learning time.

Concerning the NN architecture, we used Multi layer Perceptrons with 1 or 2 hidden layers and one output neuron. The training is performed by the back-propagation algorithm. The NN output will give then an indication on the correlation between the two utterances. If $NN_{OUTPUT} = 0$ then the two utterances come from the same speaker. If $NN_{OUTPUT} = 1$ then the two utterances belong to different speakers. Concerning the acoustical-spectral analysis of the signal, a segmentation by windows of 35 ms (ensuring the stationarity of the signal) is used in each segment where a spectral analysis is made, in giving a series of MFSC vectors for each segment (Lee, 1995; Sayoud, 2003a).

This vector set goes through a statistical process, which allows extracting the DRSC components in each couple of segments to compare. The DRSC is directly injected to the NN input which will decide whether the two segments belong to the same speaker or not: see figure 4.

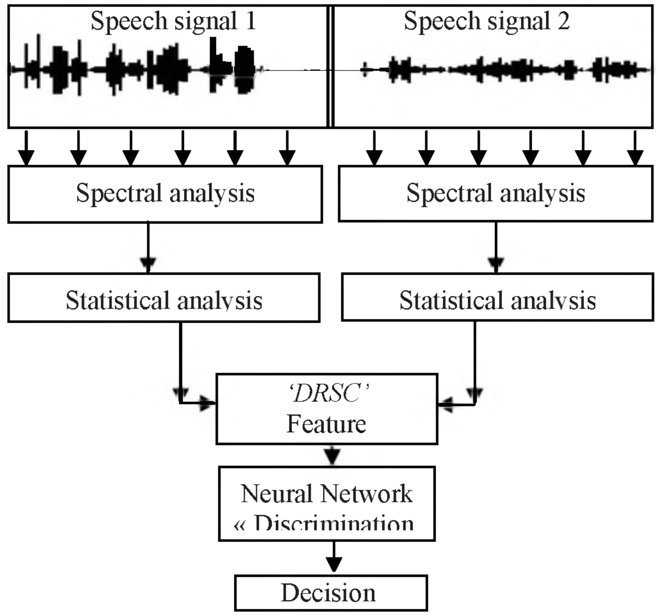

Fig. 4: Relative discrimination between two speech signals.

5. EXPERIMENTS

5.1 Database and experimental protocol

The aim of our experiments is to check the reliability of the new relative characteristic in speaker discrimination. One part of the experiments concerns the comparison between the DRSC and other existing features such as diagonal of the covariance, mean vector and the first two eigenvectors of the covariance. The other part deals with the investigation of a neural classifier using this new speaker characterization in order to assess its discriminative performance compared to a classical statistical classifier. At the end, a fusion attempt between those classifiers is proposed to further enhance the discrimination accuracy.

Experiments of speaker discrimination are conducted on four databases, as described below:

- Two sub-sets (DB1 and DB2) of "Hub4 Broadcast-News 96" database, containing some recordings from the "CNN early edition" and composed of clean speech, music, telephonic calls, noises, etc. The sampling frequency is 16 kHz. The speech signals are extracted and arranged into segments of about 4 seconds each.
- Two other sub-sets (TB1 and TB2) containing some real telephonic recordings with a sampling frequency of 8 kHz. The duration of each speech segment is about 10 seconds.

In all the databases, the testing examples are different from the training ones.

In addition, the experiments are done with two speech types: The first type is extracted from Hub4 Broadcast-News, which has a large bandwidth of [0-8000Hz] with sometimes some sequences of advertisement, music or noise. The second type is collected from real telephonic conversations, which has a reduced bandwidth of [300-3400Hz]. Usually (not always) speaker recognition is more difficult in telephony, due to the limited bandwidth. However, the presence of noise and music in Hub4 Broadcast-News make the discrimination task rather difficult in this case.

The databases are organized into speaker combinations, namely: pairs of two speech segments to discriminate. The sizes of the different databases are indicated below:

-DB1 contains 14 different speakers (most of them journalists, speaking about the news) organized into 259 speaker combinations for the training and 195 speaker combinations for the test.

-DB2 contains 14 different speakers (most of them journalists, speaking about the news) organized into 518 combinations for the training and 390 combinations for the test.

-TB1 contains 24 different speakers: 12 males and 12 females (speaking by telephone about different topics), organized into 670 speaker combinations for the training and 334 speaker combinations for the test.

-TB2 contains 24 different speakers: 12 males and 12 females (speaking by telephone about different topics), organized into 1340 combinations for the training and 668 combinations for the test.

5.2 Performance Comparison between the RSC and other reduced features

In order to evaluate the different speaker characterizations during the different comparative experiments, we use some common error rates for the performance evaluation. Their definitions are given here below:

- False Alarms (FA): represents the errors in case the system decides that the two speech signals (to compare) do not belong to the same speaker, whereas they really come from the same speaker.

- Missed Detections (MD): represents the errors in case the system cannot detect the difference between two speech signals belonging to two different speakers.

- Equal Error Rate (EER) represents the error of speaker discrimination when the FA ratio is equal to the MD ratio. Then the EER is equal to both FA and MD.

Results of experiments are given in figures 5 and 6, and tables 1 and 2.

Table 1 exposes the different Equal Error Rates (EERs) with their corresponding number of iterations required for the NN training.

These EERs are obtained on a sub-set of Hub4 Broadcast-News database: DB1 (section 5.1), with several speaker characterizations, namely: Diagonal of the Relative Speaker Characteristic (DRSC), diagonal of the covariance, mean vector and the first 2 eigenvectors of the covariance. Results show that the NN using the DRSC characteristic as input gives the best performance with an EER of only 7.20% and the lowest number of iterations for the training (between 1000 and 1500), while by using the diagonal of the covariance as input, the NN causes an EER of 13.90% (the double of that obtained by the DRSC). With the mean vector, the EER is 25.19% and with the first 2 eigenvectors of the covariance the EER is 33.67%. This last one represents the worst discrimination score.

The above experiments are repeated with telephonic database (TB1), with a duration of 10 seconds for each speech signal. The results are summarized in Table 1 below.

Table 1: Equal Error Rates obtained, with different features, on DB1.

FEATURE	Approximate number of iterations during the training	EER %
DRSC	between 1000 and 1500	7.20
Diagonal of the covariance	between 3500 and 4000	13.90
Mean vector	between 6500 and 7000	25.19
The first 2 eigenvectors of the covariance	between 2500 and 3000	33.67

Once again, results confirm the good performance of NNs using the RSC characteristic as input, comparatively to the other characteristics tested on the same conditions. This new relative characteristic associated to a 2-hidden layers NN with 10000 iterations gives an EER of 4.65%, while the other characteristics, tested in the same conditions need a much greater number of iterations for the training, as it is in the case of the mean vector: 200000 iterations (20 times of what is required by the DRSC), and for which the EER is 7.01%.

Concerning the diagonal of the covariance, the EER is 10.94%. And for the eigenvectors, we remark that they do not perform well: their EER is 17.5%.

Table 2: Performances obtained with different features, on TB1

FEATURE	Number of iterations during the training	Learning Rate	EER %
DRSC	10000	0.01	4.65
Diagonal of the covariance	20000	0.005	10.94
Mean vector	200000	0.001	7.01
The first 2 eigenvectors of the covariance	100000	0.001	17.5

In order to give a better presentation of the discrimination results provid [illegible] 5 and 6, respectively, display the different Receiver-Operating-Characteristic (ROC) curves of the errors for the different types of features evaluated on DB1 and TB1. It is seen that the NN using the RSC characteristic has got the best performance since it has considerably reduced the EER, followed by the diagonal of the covariance or the mean vector and finally by the first 2 eigenvectors of the covariance which gives the worst results.

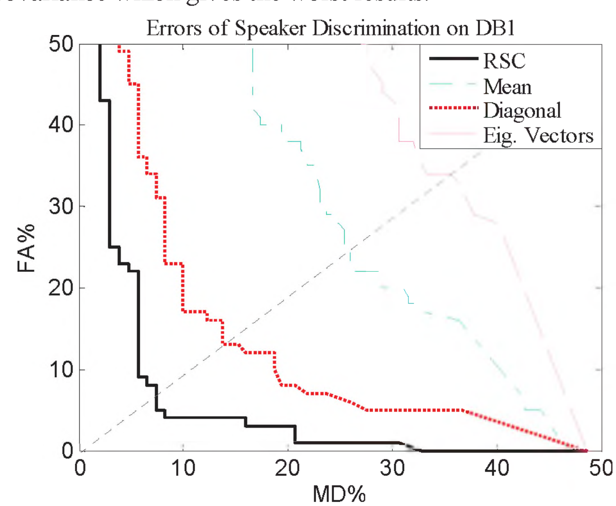

Fig. 5: Errors of speaker discrimination on DB1 - Comparison of different features: RSC, Mean of the covariance, Diagonal of the covariance and the first 2 Eigen-Vectors of the covariance.

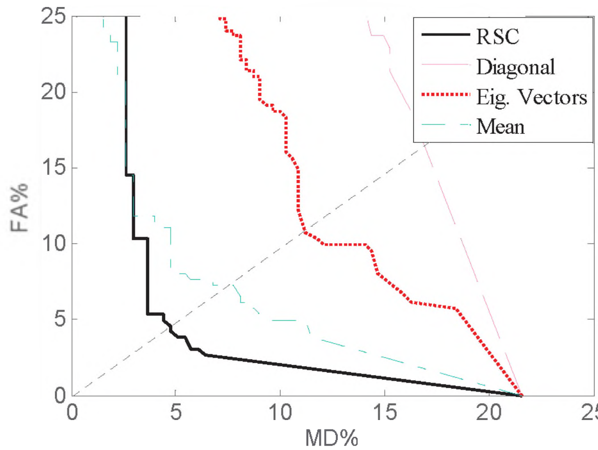

Fig. 6: Errors of speaker discrimination on TB1 - Comparison of different features: RSC, Mean of the covariance, Diagonal of the covariance and the first 2 Eigen-Vectors of the covariance.

5.3 Discriminative performance of the RSC based neural classifier

The second part of the experiment consists in comparing between the MLP-DRSC and the mono-gaussian statistical classifier. Figure 7 and figure 8 represent the ROC curves of the errors for the two different classifiers (MLP and Statistical measure) in Hub4 Broadcast-News and telephonic speech, respectively. For Hub4 Broadcast-News with segments of 4 seconds, we notice that the MLP-DRSC gives an EER of 9.25% while the EER given by the statistical measure is 11.75%. For the telephone speech with segments of 10 seconds, we notice that the MLP-DRSC gives an EER of 3.83% while the EER caused by the statistical measure is 5.74%. Therefore, the MLP-DRSC looks better than the statistical method in the two cases, especially in the medium area of the ROC curve.

Trying to further enhance the discrimination performance, one technique of fusion is proposed between the neural classifier and the statistical classifier, by using a weighted sum of the scores (Kittler, 2005) obtained by each classifier alone.

Table 3: Equal Error Rates obtained, with the different classifiers and the fusion, on different databases DB1, DB2, TB1 and TB2.

CLASSIFIER	EER % in Hub4 Broadcast-News		EER % in real Telephonic talks	
Databases	DB2	DB1	TB2	TB1
Statistical Measure	11.75	11.75	5.74	5.74
NN-DRSC	9.25	7.20	3.83	5.02
Fusion	7.88	6.77	3.65	4.29

Results of that fusion (Verlinde, 1999; Kittler, 2005), on the different databases, are shown in table 3, where it is seen that this last fusion method gives an EER better than the EER obtained by each method alone.

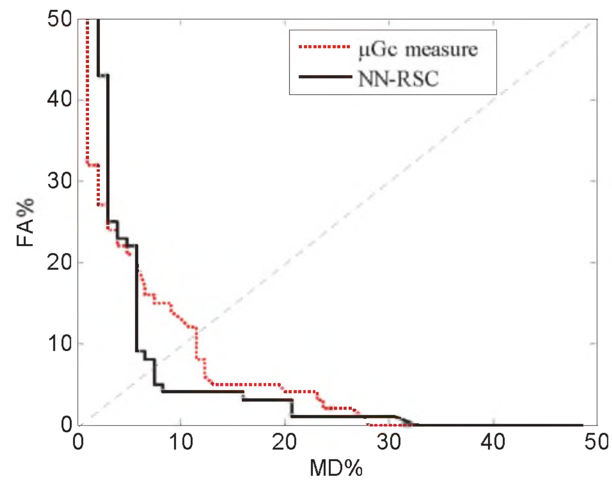

Fig. 7: Errors of speaker discrimination on DB1 (Hub4 Broadcast-News) -Comparison between the MLP-DRSC and the mono-gaussian statistical classifier.

Results presented in table 3, figure 7 and figure 8 show that the neural classifier using the relative characteristic is very interesting in speaker discrimination, on both microphonic and telephonic speech, comparatively to the statistical classifier that is evaluated in the same experimental conditions. Moreover, the fusion technique, between the two classifiers, based on the weighted sum of the scores has further improved the discrimination accuracy, where the EER is reduced in all the databases.

6. DISCUSSION AND CONCLUSION

This research work is a part of an overall project designed for audio documents indexing (Meignier, 2006), and based on speaker discrimination. However, this investigation concerns only the speaker discrimination part (Rose, 2007).

So, the major goal is to improve the discriminative performance of some existing discriminative classifiers, without altering their architecture. For that reason, we have proposed the introduction of the relativity notion in speaker modelization, by the use of a relative reduced characteristic at the input of the discriminative classifiers. We have called it: RSC or Relative Speaker Characteristic. In order to evaluate the pertinence of this new relative characteristic, two experiments were conducted:

- The first experiment was concerned with the comparison between the RSC and other existing features namely: diagonal of the covariance, mean vector and the first 2 eigenvectors of the covariance.

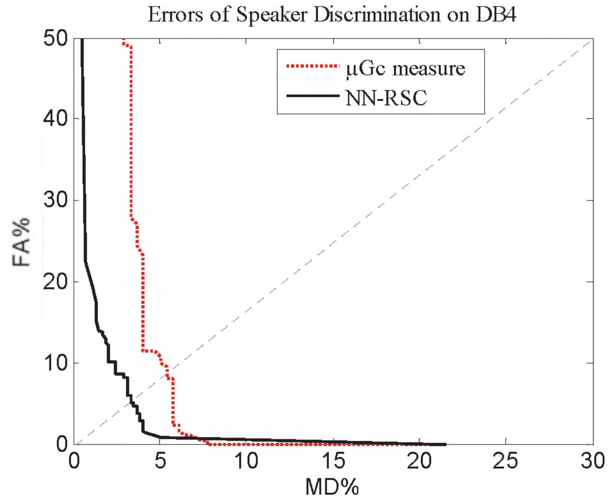

Fig. 8: Errors of speaker discrimination on TB2 (telephonic speech) - the MLP-DRSC and the mono-gaussian statistical classifier.

- The second experiment dealt with the investigation of a neural classifier using this new characteristic, in order to assess its discriminative performance with respect to a classical statistical classifier.

Discrimination experiments are done on different databases (Hub4 Broadcast-News and telephonic talks) and with different speaker modelizations. Results show that the best used modelization is based on the relative speaker characterization. This one, when used at the input of a multi-layer perceptron, provides the best scores comparatively to other types: we get an EER of 7.20% on Hub4 Broadcast-News (with segments of 4 seconds) and an EER of 3.83% on telephonic speech (with segments of 10 seconds). Thereafter, a technique of fusion was applied between the different classifiers, and experiments show that this fusion can further improve the performances.

In addition to the benefit obtained in accuracy, other benefits were noticed by using the relative characterization, such as the reduction of the training set size, reduction of the learning time and optimization of the NN convergence. Furthermore this relativity approach is really interesting due to its simplicity compared to existing techniques like PCA or LDA, and especially because it does not require any preliminary processing for the RSC estimation.

Finally, this research work shows the efficiency of the relativist approach in speaker discrimination. This new characteristic gives to the speaker a flexible model, since it changes every time that the competing speaker model changes. Although classical methods of speaker modelization consider only the speech signal of the speaker alone, the new relative modelization operates differently by using the relative speech features of the two speakers (to compare) at the input of the classifier, which is suitable in the case of speaker discrimination in difficult environments.

ACKNOWLEDGEMENTS

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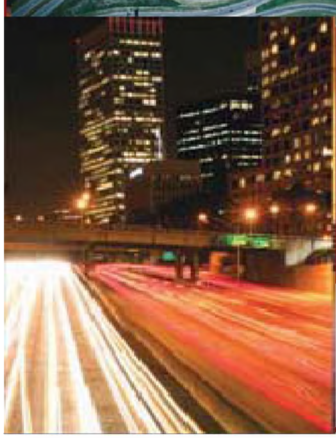

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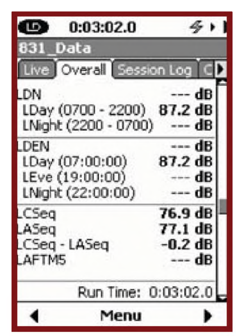

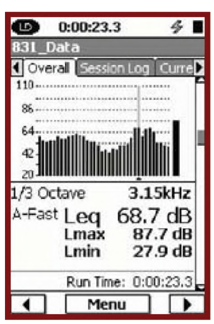

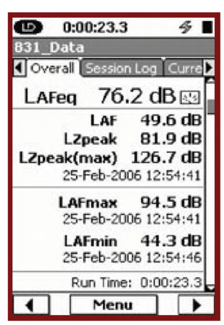

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ACOUSTICS STANDARDS ACTIVITY IN CANADA
2008 UPDATE AND INVITATION TO PARTICIPATE

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ABSTRACT

This article is an update for 2008 of Acoustics Standards activities in Canada, especially those of CSA: the Canadian Standards Association. Canadian acousticians are invited to contact the author to become more involved with the many acoustics standards activities currently underway in Canada and on behalf of Canada around the world. CSA currently has 10 Acoustics Standards and three more with significant acoustics content. Over five times that number of international acoustics standards have been reviewed and endorsed in a new Canadian Standard, Z107.10. This innovative standard streamlines the process whereby CSA endorses standards suitable for use in Canada from other organisations, such as ANSI and ISO.

SOMMAIRE

Cet article est une mise à jour des activités de normalisation en acoustique au Canada pour 2008, spécialement celles de l'ACNOR. Les acousticiens canadiens sont invités à contacter l'auteur pour s'impliquer dans les nombreuses activités en rapport avec les normes acoustiques actuellement en cours au Canada et au nom du Canada partout dans le monde.L'Association canadienne de normalisation (ACNOR) a présentement dix normes acoustiques et 3 autres comportant un contenu acoustique important. Plus de cinq fois ce nombre de normes acoustiques internationales ont été revues et sont endossées dans une nouvelle Norme Canadienne, Z107.10. Cette norme innovatrice améliore le processus par lequel CSA approuve des normes des autres organisations (par exemple ANSI ou ISO) comme étant acceptable pour une utilisation au Canada.

1. INTRODUCTION

The Canadian Standards Association (CSA) Technical Committee Z107 – Acoustics and Noise Control and its subcommittees look after all but one of the 10 Canadian Acoustics Standards (the exception is Z94.2 Hearing Protection Devices, which has its own technical committee). Z107 also coordinates all Canadian acoustics standards activity, with representatives from the Hearing Protection Technical Committee and from Canada's international standards advisory committees providing liaison to their activities. It also reviews international standards and endorses those found relevant and useful for Canada.

One goal of this article is to invite Canadian acousticians who are interested to become more involved with these activities. Participation is one of the best ways to stay in touch with this fast moving field and an excellent way to meet those who are leading it in many fields. Any acoustician interested in becoming involved with Acoustics standards in Canada is invited to contact the author or any of the subcommittee chairs. Most chairs welcome newcomers willing to work and the work need not involve a lot of time.

Specifying or limiting sound levels would become virtually impossible without agreed and recognised ways to measure and describe sound. CSA, ISO, ANSI, IEC and similar bodies' standards define the units we use in Acoustics, the weightings, the instruments. They provide measurement and calculation procedures to allow one practitioner's work to be compared with another.

2. Z107.10 OMNIBUS STANDARD

The most important recent change to Acoustical Standards in Canada is the 2006 publication of Z107.10, Guide for the Use of Acoustical Standards in Canada, a new omnibus standard by Cameron Sherry and his Editorial Subcommittee. The standard summarises all acoustics standards in which Z107 has an interest, including CSA standards, and those ISO, ASTM, ANSI and IEC standards considered of importance to Ca nada. This gives the reader a single source for information relating to Acoustics standards of interest to Canada, including those referred to by regulations and guidelines within Canada. Given the speed with which ISO and other groups are changing standards, this new approach is not only convenient, it is essential, and the intent is to issue revisions annually.

Until now, standards from outside Canada were either endorsed or adopted singly, a time consuming process whereby each standard was reviewed and balloted and in some cases published with small changes required for the Canadian context. The new standard streamlines this process considerably and is the first of its kind in Canada, addressing an important need in allowing Canadian users more ready access to Acoustics standards around the world.

An example will give an idea of what level of detail Z107.10 contains for each standard it lists:

ANSI S12.60-2002

Acoustical Performance Criteria, Design Requirements, and Guidelines for Schools

This Standard provides acoustical performance criteria, design requirements, and design guidelines for new school classrooms and other learning spaces. These criteria, requirements, and guidelines are intended to provide the acoustical qualities needed to achieve a high degree of speech intelligibility in learning spaces. The standard may be applied to the design of new learning spaces, or (in some cases) to the renovation of existing classrooms. Informative annexes provide design guidelines that are intended to aid in conforming to the design requirements. Test procedures for verifying conformance to this standard are also suggested in an annex.
*(Copies of the document may be downloaded (free of charge). The Standard is available through the ASA Standards Store at http://asastore.aip.org/.
This example shows an entry for an ANSI standard proposed for use in Canada. It describes the standard, its results and the relevance in a Canadian context.

3. COMMITTEE ACTIVITIES

3.1 Z107 Acoustics and Noise Control

The Z107 main committee meets once a year, usually during the Canadian Acoustics Week. Its executive, consisting of all the subcommittee chairs and representatives of other committees, meets in the spring, either in person or by teleconference. Most other work is done by e-mail. The main committee reviews progress by each subcommittee and votes on any new work proposals. The main committee is also the last technical hurdle for a standard before CSA editors put it into final form. The steering committee, to which the main committee reports, approves work and reviews completed standards; however they cannot make technical changes.
Most work is done within the Z107 subcommittees, which are responsible for the following standards:

Hearing Measurement, chaired by Alberto Behar, responsible for CAN3-Z107.4-M86 Pure Tone Air Conduction Audiometers for Hearing Conservation and for Screening and CAN/CSA-Z107.6-M90 Pure Tone Air Conduction Threshold Audiometry for Hearing Conservation

Vibration, chaired by Tony Brammer, provides liaison between Z107 and the Technical Advisory Committee of Standards Council on ISO standards on vibration. Tony is active on the ISO group for ISO 2631, the definitive standard on measurement of whole body vibration. Also, Alberto Behar will be joining a new Working Group of ISO/TC108/SC4 to update and enlarge the terminology applicable to human response to vibration.

Occupational Noise, chaired by Stephen Bly, is responsible for the following standards :

- Z107.52-M1983 (R1994) Recommended Practice for the Prediction of Sound Pressure Levels in Large Rooms Containing Sound Sources. This standard is in need of major updating and a chair is being sought to do this work. The intent is to provide guidance to Canadian industry on how to design quiet plants. It is seen as building upon Z107.58, which provides advice on buying quiet equipment.
- A new version of Z107.56-94 Procedures for the Measurement of Occupational Noise Exposure, was published in 2006. It is referenced in Federal and some provincial regulations. Recently, at least in part due to recommendations by Z107, both Manitoba and Ontario adopted a 3 dB exchange rate and dropped impulsive noise limits, leaving Quebec as the only major Canadian province still using the 5 dB exchange rate.

A new appendix to 56 has been written in 2008 by Alberto Behar, Christian Giguere and the author with the active assistance of a dedicated group of Canadian and International acousticians and audiologists. It describes three methods to estimate the noise exposure of those wearing communication headsets, including sound from the headsets and sound coming through the headsets from outside. It is described in more detail in references 5 & 6.

- Z107.58-2002 Noise Emission Declarations for Machinery, is a voluntary guide on noise emission declarations for machinery to be used in Canada and is compatible with European regulations allowing Canadian machinery to be sold into that market. A Noise Emission Declaration is a statement of sound levels produced by equipment,. Measurements are made according to ISO standards and include estimates of the likely variability of the measurements. Z107.58 specifically recommends use of a declaration stating the level and uncertainty as two numbers, rather than adding them together into a single number as is sometimes done elsewhere. This standard is explained and referenced in a recent Health Canada guideline.

Environmental Noise, chaired by Bill Gastmeier has responsibility for environmental noise standards formerly handled by Industrial Noise, Transportation Noise and Powered Machines. These include:

- CAN3-Z107.54-M85 (R1993) Procedure for Measurement of Sound and Vibration Due to Blasting Operations. A working group, chaired by Vic Schroter, is revising this standard.

- CAN/CSA-Z107.9-00: Standard for Certification of Noise Barriers. This standard was written by a group chaired by Soren Pedersen. It provides municipalities, developers, road and highway departments, railways and industry with a standard specification which can be used to define the construction of barriers intended to be durable enough for long term use in Canadian conditions. It has been widely cited in both Canada and the US.
- The US Department of Transportation, Federal Highway Administration, "Highway Noise Barrier Design Handbook" is already harmonized with the CSA standard, as are several Ontario municipalities, the Ministry of Transportation of Ontario, and numerous US state transportation agencies, making this the de-facto standard for barriers across North America.
- ISO 1996 and ISO 9613(2) for assessment and prediction of industrial noise in the community respectively are also reviewed for Z107.10 by this group.
- A new group is being formed to look at construction noise, specifically related to Ontario's construction equipment limits, which are badly out of date.

Wind Turbines – A group chaired by Brian Howe assisted the CSA wind turbine committee with the acoustical aspects of their standards, specifically with adopting the ISO measurement procedures in ISO 61400.

Editorial, chaired by Cameron Sherry, (which reviews all proposed standards) is responsible for reviewing and endorsing ANSI S1.1-1994 Acoustical Terminology. In addition, they have ongoing responsibility for updating the omnibus standard Z107.10 using input from each subcommittee. Cameron is actively looking for new members to assist in this work and can be contacted directly or through the author. It would be a great way to quickly gain an overview on some of the most important acoustics standards in Canada and the world.

Sound Quality is a new group chaired by Colin Novak and concerned with sound quality standards, primarily aimed at the automotive industry but becoming increasingly useful in other areas.

Z107 also has subcommittees providing liaison with International Standards activities, specifically steering committees in Building Acoustics, Instrumentation, Acoustics and Noise. These Steering committees are run by the Standards Council of Canada and are harmonised with the Z107 committee to which they report regularly on progress and upcoming issues. Draft international standards are provided on a private website to which steering committee members have access in order to review them and recommend Canada's position.

- Building Acoustics, chaired by David Quirt, does not have its own CSA standards, but reviews other standards from a Canadian viewpoint, mostly those from ASTM and ISO. David Quirt is chair (and Z107 liaison) of the Standards Council of Canada Steering Committee for ISO TC 43 SC2, Building Acoustics. Members of this group are active on many ASTM and ISO building acoustics groups. Their main issue in the next few years will be the balance between the technically superior ISO standards and the ASTM standards which are important for North American trade. They also recommend Canadian endorsed standards on building acoustics (a large part of the current Z107.10 list) and prepare appropriate entries.

- Instrumentation and Calibration: Leo Wu, is the chairman (and the CSA liaison) for the Standards Council of Canada Canadian Subcommittee of IEC/TC 29: Electroacoustics, seconding for George Wong. This group deals with all instrumentation pertaining to acoustical measurements, such as WG 4: Sound level meters; WG 5: Microphones; WG 10: Audiometers; WG 13: Hearing aids; WG 17: Sound calibrators; WG 21: Ear simulators; and maintenance teams (MT) MT19: Filters; and MT20: Hearing aids induction loops. All of the above international Working Groups have Canadian members.

- The Canadian Steering Committee for ISO TC43 (Acoustics) and TC43(1)(Noise) is chaired by Stephen Keith, who provides Canadian comments, votes on ISO standards and coordinates the work of Canadian representatives on several ISO working groups. This group deals with ISO Standards on measurement and assessment of sound and hearing, such as WG 17: Hearing protectors WG28: Machinery noise emission standards (referenced in CSA Z107.58) WG 40: Impulsive sound propagation for environmental noise assessment, WG 45: Acquisition of data pertinent to land use, and WG 53: Occupational Noise Exposure. All of the above international Working Groups have Canadian members.

All these groups are always interested in new members willing to work.

Z94 – Hearing Protection

The other CSA Acoustics Standards Committee, the Hearing Protection Technical Committee is responsible for the Z94.2-02 Standard: Hearing Protection Devices – Performance, Selection Care and Use , widely referred to in Canadian occupational noise regulations. They major new version of this standard was issued in January 2002 that includes changes to the ANSI hearing protector standards and procedures. They also liaise with the ANSI groups currently reforming the NRR information found on all Hearing Protector packaging in North America (and most of the world).

Canadian Acoustics Standards

Table 1 shows all the Canadian Standards currently in force and also lists three standards with significant acoustical content. This table may also be found at the CAA website and

will be kept up to date there. In addition, the list can be found at
http://www.csa-intl.org/onlinestore/GetCatalogDrillDown.asp?Parent=430

Table 1- CSA Acoustics Standards

CAN3-Z107.4-M86 Pure Tone Air Conduction Audiometers for Hearing Conservation and for Screening / Audiomètres tonals à conduction aérienne pour la préservation de l'ouïe et pour le dépistage

CAN/CSA-Z107.6-M90 Pure Tone Air Conduction Threshold Audiometry for Hearing Conservation

CAN/CSA-Z107.9-00: Standard for Certification of Noise Barriers

Z107.10 Guide for the Use of Acoustical Standards in Canada,

Z107.52-M1983 (R1994) Recommended Practice for the Prediction of Sound Pressure Levels in Large Rooms Containing Sound Sources .

CAN3-Z107.54-M85 (R1993) Procedure for Measurement of Sound and Vibration Due to Blasting Operations / Méthode de mesure du niveau sonore et des vibrations émanant des opérations de dynamitage

Z107.56-06 Procedures for the Measurement of Occupational Noise Exposure / Méthode de mesure de l'exposition au bruit en milieux de travail

Z107.58-2002 Noise Emission Declarations for Machinery

Z94.2-02 • Hearing Protection Devices - Performance, Selection, Care, and Use / Protecteurs auditifs

Standards with Acoustics Component:

Z62.1-95 Chain Saws

CAN/CSA-Z412-M00 Office Ergonomics / L'ergonomie au bureau

CAN/CSA-M5131-97 (R2002)Acoustics - Tractors and Machinery for Agriculture and Forestry - Measurement of Noise at the Operator's Position - Survey Method (Adopted ISO 5131:1996)

Endorsed Standards (Over 50 standards listed in Z107.10)

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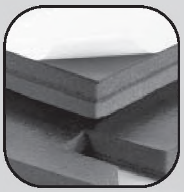


Blachford

ON THE PHONETICS OF SCHWA IN SLIAMMON (M. COMOX SALISH): IMPLICATIONS FOR THE REPRESENTATIONS OF SALISH VOWELS

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1. INTRODUCTION[1]

This paper presents the results of an acoustic study of schwa ([ə]) in Mainland Comox (Homalco/Klahoose/ Sliammon). We investigated [ə] as compared to the other, 'full' vowels ('V's) in the language, in stressed and unstressed position. Vs in unstressed position are typically called 'reduced', given the crosslinguistically common finding that Vs are shorter, quieter, and more central in quality in unstressed than in stressed position [2, 3]. Previous work has shown that reduced Vs are often [ə], or [ə]-like, in quality [2]. Our aim is to determine the distinction, if any, between [ə] and the reduced variants of the full Vs in Sliammon. In this language, [ə] behaves very differently from the full Vs: e.g., it lacks prosodic 'weight', whereas the full Vs are weight-bearing [1], a pan-Salish distinction [4, 5]. We thus set out to discover if the weight distinction is altered under V reduction.

2. LANGUAGE

M.Comox (Homalco/Klahoose/Sliammon) is the northernmost of the Central (Coast) Salishan languages and is currently spoken in an area ranging from Campbell River on Vancouver Island to Cortes Island, and southeastward to Sliammon on the Malapina Penninsula. The language is critically endangered.

The Sliammon V inventory, typically Salish, is shown in (1) [1, 5, 6].

(1) i a u ə

The distribution of [ə] is predictable and therefore [ə] is argued to be epenthetic [1]. It is inserted to satisfy morpho-phonological requirements, e.g., that a prosodic foot must be properly headed, that consonants are syllabified, and that roots meet prosodic minimality requirements [1]. The full Vs and [ə] have a range of surface variants triggered by adjacent consonants and Vs [1, 6]. The language also has an 'excrescent' [ə] ([^{ə}]), i.e., a very brief transitional [ə]-like vocoid that speakers produce with some variability. This is also a typical Salish phenomenon [5].

3. METHOD

3.1 Data

The acoustic data were produced by a female native speaker, aged 68 years, Sliammon Elder MH. Recording took place at Anywhere Studios in Campbell River, BC. The V data were produced in the carrier forms in (2). MH was asked to produce each word six times in isolation, and six times in the context of the phrase in (3) with each word from (2) inserted in the position of the underscore.[2] Our elicited dataset comprised 12 tokens each of the underlined Vs in (2). The analyzed Vs are the same per carrier word; in (2a) they are both /i/ [ɛ], in (2b) they are both /a/, in (2c) they are both /u/ [o], and in (2d) they are both [ə]. The first V in each word bears primary stress whereas the V to its right occurs in unstressed post-tonic position. Our dataset thus comprised, for each V, 12 tokens in stressed position, and 12 tokens in unstressed position. A total of 95 V tokens were analyzed.[3]

(2) carrier form		analyzed V
a. ʔɛ́ɬʔɛɬtən	'eating'	i
b. p'áʔp'aʔač	'nets'	a
c. t'^{θ}ót'^{θ}osos	'getting dark'	u
d. qə́k'^{w}qək'^{w}ƛ'actən	'aprons'	ə

(3) čenuxw čehots kw ____. ('He said ____ six times.')

3.2 Acoustic analysis procedure

Recording used a professional unidirectional microphone. The data were digitally captured at 44.1 kHz sampling rate, using *Pro Tools*. Acoustical analysis used *Multi-Speech 3700*. Segmentation was based on waveform and wideband spectrogram displays, checked with audio playback of the waveform. Vs were measured for quality: F_1 and F_2. Formant centre frequency was taken as the average of the formant centre frequency values obtained from wideband and narrowband spectrogram displays per V, using the formant readings provided by *Multi-Speech 3700* with visual placement of the cursor on the estimated formant centre. Formant measurements were at V midpoint. Vs were also measured for duration, with the beginning of the V identified as the beginning of its first glottal pulse and the end as the end of its last glottal pulse. They were also measured for amplitude, based on the values provided by *Multi-Speech* with visual placement of cursor on the amplitude peak. Amplitude values are reported as duration of unstressed tokens relative to duration of stressed tokens per V.

4. RESULTS

4.1 Quality

A F_1, F_2 plot of the Vs is presented in Fig. 1. All tokens are shown. Ellipses are centered around the mean F_1, F_2 values per V, with the length of the *x* and *y* axes equal to the

[1] 'Sliammon' is used here as a cover term for the Central (Coast) Salishan language spoken by the Homalco, Klahoose and Sliammon people. As Elders explain, they were one people with one language [1].

[2] The forms in (2) and (3) are presented in broad phonetic transcription using the Northwest Phonetic Alphabet.

[3] MH inadvertently produced only five tokens of (2b) in phrasal context.

F_2 and F_1 standard deviations (SDs), respectively. The solid shapes plot tokens in stressed position; the hollow shapes plot tokens in unstressed position. Each V symbol associates with the set of tokens (stressed or unstressed) nearest to it. Fig. 1 shows that all Vs are backed when unstressed; [i] and [a] are also centralized. The data indicate that the reduced V inventory involves no neutralization in quality: there is no collapsing of the reduced Vs with each other, unlike in other languages, like English, in which the reduced variants of a range of Vs are all [ə].

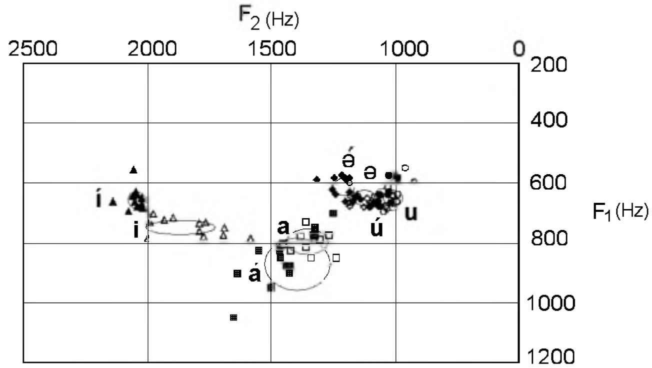

Fig.1. F_1, F_2 plot of Sliammon Vs tokens. Solid shapes = tokens in stressed position. Hollow shapes = tokens in unstressed position. Ellipses centered around means per V.

4.2 Duration

Fig. 2 shows the duration of the Vs, in stressed and unstressed position. The dots plot mean values. SD per V is shown by the length of the vertical lines, with ½SD above the dot and ½SD below it. For each V, the tokens in unstressed position are shorter than those in stressed position. Unstressed [ə] is shorter than unstressed [i] and unstressed [u]. It is 39% shorter than unstressed [i], and 47% shorter than unstressed [u]. It is not shorter than unstressed [a] in our data. Our data included tokens of the excrescent V, which is always unstressed: in 10 of the 12 tokens of *ʔɛ́ɬʔɛɬtən*, the speaker produced *ʔɛ́ɬᵊʔɛɬtən*. Duration data for excrescent [ᵊ] are included in Fig. 2. The mean duration of the excrescent schwa tokens is 39 msec.

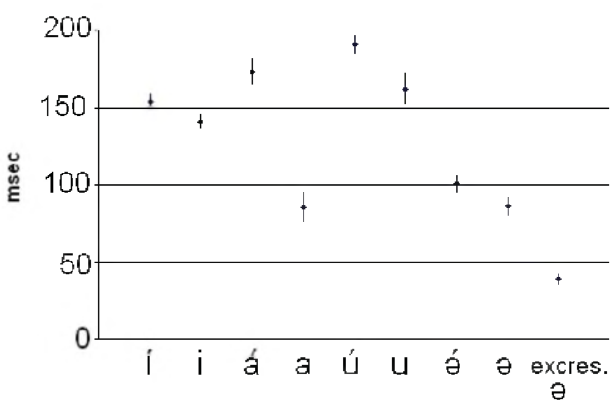

Fig.2. Duration of Sliammon Vs tokens. Dots plot means. Vertical bars show SDs.

4.3 Amplitude

Figure 3 presents the difference in amplitude between the unstressed vs. stressed tokens per V. Unstressed [i] is 8% quieter than stressed [í]; unstressed [a] is 8% quieter than stressed [á]; unstressed [u] is 13% quieter than stressed [ú]; and unstressed [ə] is 5% quieter than stressed [ə́].

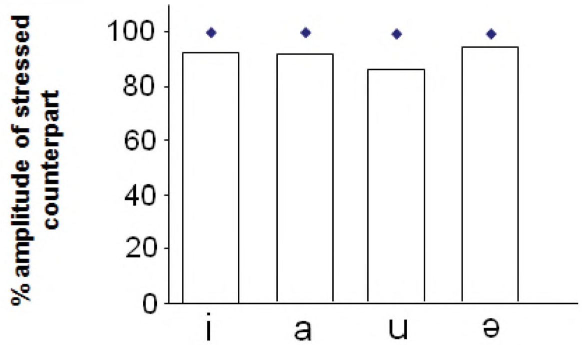

Fig.3. Relative amplitude of unstressed vs. stressed V tokens

5. DISCUSSION

Our results support previous crosslinguistic findings that Vs are shorter and quieter when reduced, but show that V reduction does not always involve neutralization of quality contrast. Sliammon has no such neutralization. This indicates a functional limitation on V reduction, that it is blocked if the language has a very small V inventory and so must preserve phonemic contrasts between Vs. Our study found that reduced [ə] is distinct from the reduced full Vs in quality, and distinct from two of them in duration. Its short duration when unreduced supports analysis of unreduced [ə] as prosodically weightless, i.e, lacking a mora (μ). The shortening of the full Vs when reduced indicates that they are weight-bearing, i.e., moraic, when unreduced and weightless (non-moraic)–like [ə]–when reduced. This supports the representations in (4) [1]. In (4), angle brackets around μ represent μ loss; 'F' represents feature structure. We suggest that (4) applies to Salish languages in general, although future acoustic study should test this hypothesis.

(4)

full Vs	reduced full Vs	ə	reduced ə
μ | [F]	<μ> | [F]	⋮ [F]	⋮ [F]

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AN ACOUSTIC STUDY OF STRESS IN L2 PRODUCTION OF GERMAN AND SPANISH

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1. INTRODUCTION

Stress is a multi-faceted construct and its correlates may differ in different languages. Among the physical dimensions perceived as stress are higher pitch and longer vowel duration. The phonetic realization of stress may be subject to interference from the learner's L1, and may be interpreted by a native speaker (NS) as a phonological problem (stress misplacement) [7]; we therefore set out to compare the correlates of stress in vowels produced by American English speakers learning German or Spanish in a classroom setting.

1.1 Acoustic correlates of stress in German and English

In German, the experimentally established acoustic cues of word stress include vowel duration, pitch and intensity changes, as well as laryngeal features [2, 6]. Studies have confirmed that vowel duration is regarded as the primary cue to German word stress and that the phonetic realization of word stress also involves an increase in F0 [6]. The intensity (loudness) of a stressed vowel is higher than that of an unstressed vowel in German, but the contrast is weaker than for the other cues [6]. This has also been confirmed for English [4], namely that the intensity correlates of stress are weaker than the duration and pitch changes.

In stressed syllables, only tense vowels are lengthened, whereas in unstressed position the quantity contrast is neutralized [8].

1.2 Acoustic correlates of stress in Spanish

Pitch, duration, and intensity are the main correlates of stress in Spanish [9, p. 400 and literature cited therein]. Quilis and Esgueva [10] also maintain that there is no significant correlation between the vowels' spectral quality and stress. They do find that stressed vowels are significantly longer than unstressed ones.

1.3 L2 production of stress

A number of studies have addressed how L2 learners master the stress patterns of the language they are learning, particularly the placement of primary word stress [1]. There are not many that have investigated the acoustic correlates of stress among L2 learners. An exception is [3] where both stress placement and the phonetic realization of English stress by Spanish learners of English were studied. They found that the magnitude of vowel duration differences between stressed and unstressed syllables were greater in the English NSs' speech than in the L2 Spanish learners' speech.

Some common errors in L2 German mentioned in [5] are related to reduction and stress and attributed to interference from L1: among others, English NSs reduce unstressed syllables too drastically, Spanish NSs learning German do not produce the contrast between stressed and unstressed syllables correctly, and mark accent predominantly by intensity.

2. METHOD

2.1 Vowels in Standard German

The vowel inventory of Standard German contains 7 pairs of tense and lax vowels /i–ɪ, y–ʏ, e–ɛ, ø–œ, aː–a, u–ʊ, o–ɔ/. Words containing these vowels were embedded in a carrier sentence *Sag das Wort X noch einmal* ('Say the word X again'). In this pilot study, three NSs of German, five American students in an advanced German language class, and five American students in a beginner class read these sentences.

Both tense and lax vowels in German may occur in stressed and unstressed syllables. In order to determine the acoustic correlates of stress, measurements of F0, F1, F2, and F3, along with measurements of vowel duration and intensity were taken. Since the front rounded vowels (*Umlaute*) are notoriously difficult for English-speaking L2 learners, we are not including them in this pilot study.

2.2 Vowels in Spanish

The vowel inventory of Spanish contains 5 vowels /i, e, a, o, u/. Words containing these vowels were embedded in a carrier sentence *Dime la palabra X otra vez* ('Say the word X again'). Three NSs of Spanish (two Mexican and one Peninsular), five American students in an advanced Spanish language class, and five in a beginner class read these sentences.

All Spanish vowels were recorded in open stressed and unstressed syllables in word pairs of the type *p*[í]*pa* – *p*[i]*sar*. In order to determine the acoustic correlates of stress, measurements of F0, F1, F2, and F3, along with measurements of vowel duration and intensity were taken.

3. RESULTS

3.1 Results for the German vowels can be seen in Figure 1-2. In the analysis of the German vowels, the stressed tense (ST T) vowels were distinguished from the unstressed tense vowels (UN T), as were the stressed lax (ST L) and the unstressed lax (UN L) vowels.

Figure 1. Duration of German vowels (ms)

	ST T	UN T	ST L	UN L
NS	140.7	87.6	72.0	69.9
L2-adv	107.2	82.3	90.7	73.3
L2-beg	111.1	87.3	99.5	76.3

Figure 2. F0 (Pitch) of German vowels (Hz)

	ST T	UN T	ST L	UN L
NS	160.7	138.9	165.7	141.1
L2-adv	137.6	127.2	144.3	123.8
L2-beg	162.9	147.3	153.5	146.0

German NSs use longer duration and higher pitch on stressed than unstressed vowels, with a considerable difference in duration between tense and lax vowels (and very little variation in intensity): (1) Unstressed tense vowels are 62% as long as stressed tense vowels; (2) Unstressed lax vowels are 97% as long as stressed lax vowels; (3) Unstressed tense and lax vowels are 86% and 85% as high in pitch as stressed tense and lax vowels, respectively.

Both the upper division (L2 advanced) and the lower division (L2 beginning) students manipulate duration, pitch (and intensity) to signal stress, but to lesser degrees than NSs: (1) Unstressed tense vowels are 77% (L2 adv) and 79% (L2 beg) as long as stressed tense vowels; (2) Unstressed lax vowels are 81% (L2 adv) and 77% (L2 beg) as high in pitch as stressed lax vowels.

3.2

Results for the Spanish vowels can be seen in Figure 3-4.

Figure 3. Duration of Spanish vowels (ms)

	ST	UN	%
NS	125.6	98.9	78
L2-adv	92.2	87.5	94
L2-beg	95.5	90.1	94

Figure 4. F0 (Pitch) of Spanish vowels (Hz)

	ST	UN	%
NS	162.0	135.0	83
L2-adv	206.5	184.3	89
L2-beg	213.9	209.0	98

Spanish NSs clearly manipulate duration and pitch as correlates of stress [9]: unstressed vowels are only 78% as long as stressed ones (as in [10]), and their pitch is 83% lower than stressed counterparts. So do L2 learners, but to a considerably lesser extent. Differences in intensity among groups are too slight to evaluate (unlike in [5]).

4. DISCUSSION

As [8] reports for German NSs, our NS data also show that in stressed syllables, only tense vowels are lengthened, whereas in unstressed position the quantity contrast is neutralized.

In addition, as [3] reports for L2 Spanish speakers learning English, our data for L2 German and Spanish learners also reveal that the magnitude of vowel duration differences between stressed and unstressed syllables was greater in the native speakers' speech than in the L2 learners' speech, though learners do use both duration and pitch to signal stress. Our L2 German and Spanish advanced learners show greater differences in intensity than NSs do, but use intensity in general much less than duration or pitch to signal stress.

Contrary to expectation [9, 10] our data for Spanish show that NSs tend to reduce (centralize) unstressed vowels, and that beginners do not implement this tendency with any consistency, whereas advanced learners approximate the NSs' vowel systems. Our German data on the other hand do not consistently show centralization in any group.

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A Perfectly Matched Layer Technique for Lattice Boltzmann Method

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1. INTRODUCTION

In recent years, the Lattice Boltzmann Method (LBM) has emerged as a promising computational technique in fluid dynamics. LBM has some intrinsic advantages over conventional Navier-Stokes schemes [1] such as ease of parallel implementation.

The main difference between LBM and conventional Navier-Stokes schemes is that, Navier-Stokes equations are derived explicitly for the macroscopic properties of the fluid, while LBM's involve the solution of lattice-Boltzmann equation (LBE) by explicitly tracking the development of particle distribution functions either at the mesoscopic or the microscopic scale. Using the Chapman-Enskog expansion, the compressible Navier-Stokes equations can be recovered from the LBE at the hydrodynamic limit.

Recently, the LBM has been evaluated and utilized for some aeroacoustics applications. However, robust nonreflective boundary conditions are still needed for LBM. As underlined in one recent study [2], little work has been reported on this topic.

In the present study, a boundary condition was developed based on the perfectly matched layer (PML) concept introduced by Berenger for numerical simulations of electro-magnetic fields [22]. The most significant feature of the PML technique is the fact that it creates absorbing layers that are theoretically non-reflective for any angle and frequency of incident wave. Moreover, the intrinsic linearity and computational scheme robustness of LBE prevent instabilities and complexities associated with nonlinear convection terms which are present in Euler and Navier-Stokes equations.

2. A PML FORMULATION FOR LATTICE BOLTZMANN METHODS

The lattice Boltzmann equation is one discrete form of the continuous Boltzmann equation:

$$\frac{\partial f}{\partial t} + \left(\vec{\xi} \cdot \vec{\nabla}\right) f = \Omega \,, \qquad (1)$$

where Ω is the inter-molecular collision operator. In order to facilitate solution of the Boltzmann equation, the collision operator is usually simplified using the Bhatnagar-Gross-Krook (BGK) approximation:

$$\Omega = -\frac{f - f_{eq}}{\tau}, \qquad (2)$$

where τ is the relaxation time and f_{eq} is the local equilibrium Maxwell-Boltzmann distribution. The hydrodynamics properties such as density, momentum, kinetic energy, and others can be obtained by different moments of the equilibrium distribution function in the phase space. To enable numerical integration of these moments, the distribution function is obtained only for certain velocity directions which are the abscissas of a Gaussian-type quadrature. These velocity directions form a D*n*Q*m* lattice, where *n* is the number of dimensions of the flow field and *m* is the number of velocity directions within the lattice. A D2Q9 lattice which is commonly used in 2D simulations is shown in Figure 1.

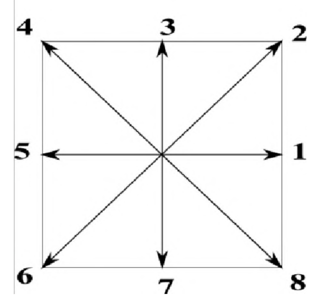


Figure 1. A D2Q9 lattice used in 2D simulations.

The decomposition of the equilibrium distribution function into the sum of a mean component, which corresponds to the hydrodynamic field, and a perturbation component, which corresponds to the acoustic perturbation, yields a set of equations consistent with the Boltzmann equation at the interface between the absorbing zone and the interior domain (see Figure 2).

The following formulation is proposed for the absorbing zone in a lattice Boltzmann simulation:

$$\frac{\partial f}{\partial t} + \left(\vec{\xi} \cdot \vec{\nabla}\right) f = \Omega - \Omega^{\mathrm{PML}}, \qquad (3)$$

where

$$\Omega^{\mathrm{PML}} = \sigma\left(\vec{\xi} \cdot \vec{\nabla}\right) \mathrm{Q} + 2\,\sigma\left(f_{eq} - \overline{f_{eq}}\right) + \sigma^2 \mathrm{Q}\,,$$

and

$$\frac{\partial Q}{\partial t} = f_{eq} - \overline{f_{eq}} \, .$$

The details of the derivation are presented in Ref [4]. It is notable that the PML role is encapsulated in only one single additional term to the collision operator. The damping coefficient σ controls the decay rate of the waves entering the PML zone. Eq. (3) can then be made discrete in the same manner as the classical lattice Boltzmann method. The damping coefficient is predefined by the user at the beginning of the simulation considering the thickness of the PML region.

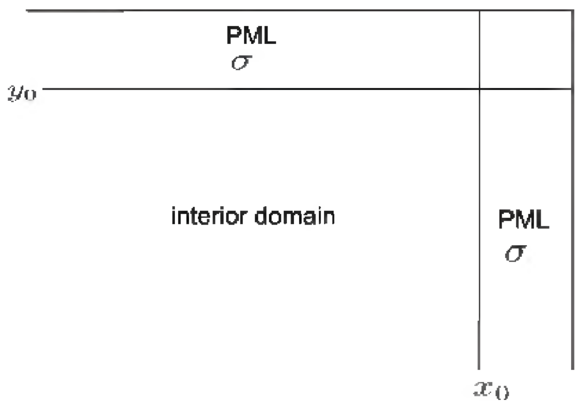


Figure 2. PML setup in a 2D simulation.

4. Numerical Examples and Discussion

4.1. Propagation of a Gaussian Acoustic Pulse

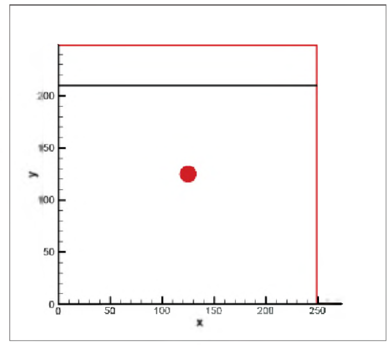
One classical problem to assess the performance of numerical boundary conditions is the propagation of a Gaussian pulse. The following initial conditions were imposed in this case:

$$\rho = 1 + 0.0001 \exp\left(-\ln 2 \frac{x^2 + y^2}{9}\right)$$

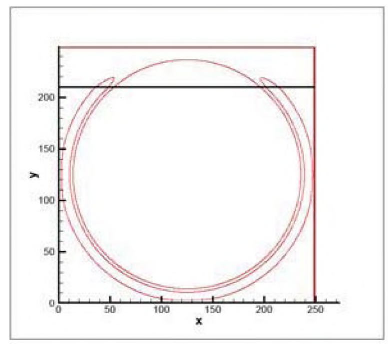
$$u = 0$$

$$v = 0$$

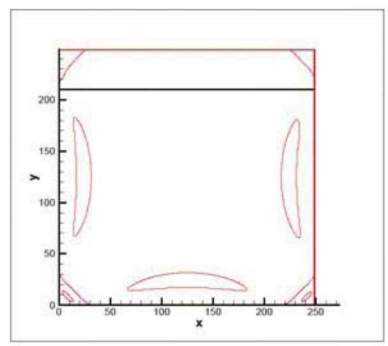
All quantities are made non-dimensional using the grid spacing and mean density. The pulse was initially located at the center of a 256 by 256 nodes grid. A 40-lattice wide PML was created between the interior domain and the northern boundary while conventional outlet (zero normal gradients) BCs were chosen for all other boundaries. A damping coefficient of 0.03 was chosen for the PML. The attenuation of the wave in the PML is demonstrated in Fig 3. Almost no reflection from the northern boundary was observed. Similar simulations have also been performed with PML boundary conditions on all boundaries, and in situations where the Gaussian pulse exits the boundary in presence of a mean flow with arbitrary direction. Excellent results were obtained for all cases.



(a)



(b)



(c)

Figure 3. Gaussian pulse propagation; (a) t = 0; (b) t = 200; (c) t = 280; The PML is located on the north boundary. All dimensions are normalized by lattice units.

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ACOUSTIC TESTING FOR PHONOLOGIZATION

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1. INTRODUCTION

Phonologization [1, 2] occurs when some variation in production occurs with frequency and is stabilized as a new pattern [1, 3]. The Optimality Theory grammar of a language is its constraint ranking. Phonologization occurs when categorical, non-numeric versions of numerically weighted phonetic constraints [4] enter the strict dominance relations of the grammar. This paper examines how this shift arises from the acoustic signal, focusing on gradience [5] in postvelar phenomena in Salish and Arabic.

2. PHONETIC TO PHONOLOGICAL OPTIMIZATION

Flemming [4] proposes that phonetic properties can be understood as the effect of the interaction of weighted constraints. He explains it as follows. In CV sequences, e.g., F_2 of the C and V are co-determined by a constraint against deviation from C and V F_2 targets and a constraint against quick articulator movement. Achieving both targets could mean quick speech, and slow movement could mean achieving neither target. The actual production is an optimization of this conflict. The constraint weighting is such that both targets are undershot. Degree of undershoot depends on exact weighting. In this model, the weightings figure into a mathematical cost function which determines the optimization, e.g.:

(1) Flemming's cost function for F2 in CV [4]

$$c = w_c(F2_C - F2_L)^2 + w_v(F2_V - F2_T)^2 + w_e(F2_C - F2_V)^2$$

where $F2_C$ is F_2 of the C, $F2_V$ is F_2 of the V, $F2_L$ is fixed target F_2 of the C, $F2_T$ is fixed target F_2 of the V, and w_c, w_v and w_e are positive weights.

The first two terms express 'Don't deviate from targets' separately for C and V. If the differences are minimal, cost on contrast will be minimal. The overall cost also includes cost on effort. This is that incurred by the difference between $F2_C$ and $F2_V$, as specified by the last term of the function, which expresses 'Don't move quickly'. If the difference is small, the articulators move quickly. As stated by Flemming, weighted constraints compute costs in real numbers. They reflect the scalar nature of phonetic factors and their additive effects.

This differs from the phonological grammar, as illustrated in (2). ALIGN-TR, with phonetic basis in $w_e(F2_C - F2_V)^2$, requires [TR], the phonological feature implemented as tongue root articulation, to be aligned with the word edges. IDENT, with phonetic basis in $w_c(F2_C - F2_L)^2 + w_v(F2_V - F2_T)^2$, requires that there be no feature change between input and output. In (2), the input is between slashes; competing outputs are between square brackets. Output candidate b is optimal because it best satisfies the two discrete constraints, given their ranking: it satisfies the higher ranked ALIGN-TR whereas candidate a violates it ('*'), fatally so ('!').

As phonetic properties are gradient but phonological properties are not, a key trigger for the shift between the phonetics and phonology is degree of gradience.

(2)

/t̲a/	ALIGN-TR	IDENT
a. [t̲a]	*!	
☞ b. [t̲a̲]		*

3. ACOUSTIC STUDY

3.1 Method and procedure

St'át'imcets Salish words were produced by an adult male native speaker, aged 68 years. Palestinian Arabic words were produced by an adult male native speaker, aged 45. See the Appendix. For St'át'imcets, 60 V tokens and 72 C tokens were analyzed. For Palestinian, 120 V tokens were analyzed. Recording used a Marantz P420 tape recorder. Digitization was at 22.05 kHz sampling rate. Analysis used *Multi-Speech 3700*. F_1 and F_2 of Vs and approximants were measured. The resonance in the area of F_2 was measured for fricatives, and stops (in the release burst). Measurements were at durational midpoint. Formant ('F') centre frequency was taken as the average of values obtained from wide and narrowband spectrograms using the values provided by *Multi-Speech 3700* with placement of the cursor on the estimated F centre.

3.2 Results: St'át'imcets Salish

Figs. 1-3 present data from St'át'imcets relevant to uvularization spread, lowering of [ə] before [ʔ], and lowering of labialized uvulars. F means (in Hz) and standard deviations (SDs) are shown. SD is used here to determine if a property is gradient, as phonetic properties vary more than phonological ones [5]. Fig. 1 shows that F_2 is dropped for [a] preceding and following a uvularized C ('C̱'). F_1 is raised in both cases. The effects are greater preceding. The SDs provide no evidence for identifying the greater F effects preceding the C̱ as phonological: F_2 SD in that case is even greater than F_2 SD for [a] following a C̱ (86 vs. 46). This counters usual assumption that the leftward coarticulation is phonological in this language. Fig. 2 shows that [ə] is lowered preceding [ʔ], as F_1 is raised in that context. The F_1 SD is lower preceding [ʔ] than preceding C (61 vs. 71). This indicates that the [ə] lowering, considered phonetic in this language, is perhaps becoming phonologized. For Fig. 3 we focus on F_2, the one resonance measurable for all C types. The labialized uvulars, including [x̱ʷ] ([χʷ]) and [ḵ(')ʷ] ([q(')ʷ]), show a drop in 'F_2', as expected. F_2 SD is lower for [ʁ(')ʷ] than for [ʁ(')] (31 vs. 69), indicating that the lowered F_2 for [ʁ(')ʷ] phonological. The [ʁ(')ʷ] is produced with auditorily perceptible pharyngeal articulation, and is [ʕ(')ʷ]. The lower F_2 of pharyngeal compared to uvular articulation enhances the lower F_2 of the labialization. For [x̱ʷ] and [ḵ(')ʷ] the variation in F_2 is greater than for their plain variants, indicating that their F_2 drop with labialization is phonetic. The [x̱ʷ] and [ḵ(')ʷ] are not perceptibly pharyngeal, i.e., they are not [ħʷ] and [ʡ(')ʷ].

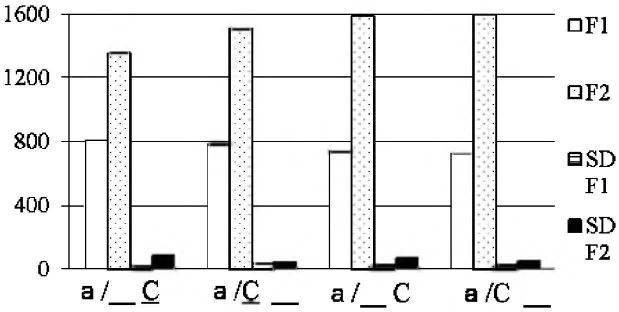

Fig. 1. F_1 and F_2 of St'át'imcets Vs in C-V/V-C sequences

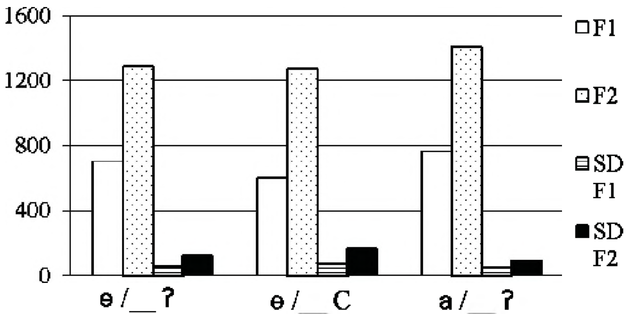

Fig. 2. F_1 and F_2 of St'át'imcets [ə] and [a] before [ʔ]

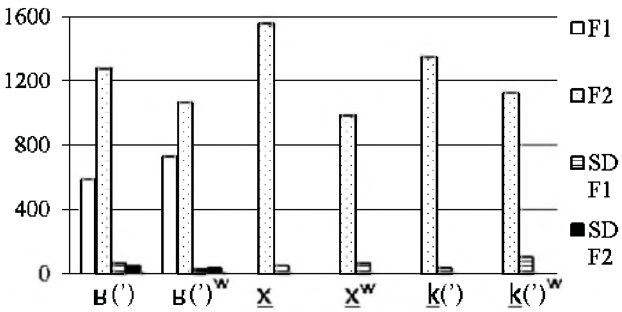

Fig. 3. Resonances of non-labialized and labialized St'át'imcets uvulars

3.3 Results: Palestinian Arabic

Fig.4 presents data from Palestinian relevant to uvularization of the low V ('A'), opacity to uvularization spread by the high front V ('I'), and lack of pharyngealization for a stem-final V, which was 'U' in the carrier word [6]. We take 40 as normal SD for Fs of a distinct sample [7]. SDs of 19.2 (F_1) and 29.8 (F_2) for uvularized A indicate that its coarticulation is phonological. SDs of 13.7 (F_1) and 31.7 (F_2) for I adjacent to C̲ indicate phonological lack of coarticulation for that V. In this language, Vs in closed syllables are pharyngealized (i.e., become rtr) except when stem-final. SDs of 30.2 (F_1) and 52.7 (F_2) for closed-syllable, stem-final U indicate that that rtr quality for stem-final Vs is perhaps becoming phonologized.[1]

4. CONCLUSION

This work illustrates acoustic testing for phonologization. Gradience was examined and found to underlie phonologized patterns, and to indicate that certain patterns previously considered phonological are perhaps phonetic.

[1] Other SDs from the data are: 13.2 (F_1), 15.9 (F_2) for nonuvularized A; 8.4 (F_1), 27.8 (F_2) for I not adjacent to C̲; 9.1 (F_1), 17.8 (F_2) for closed syllable, non-stem-final U.

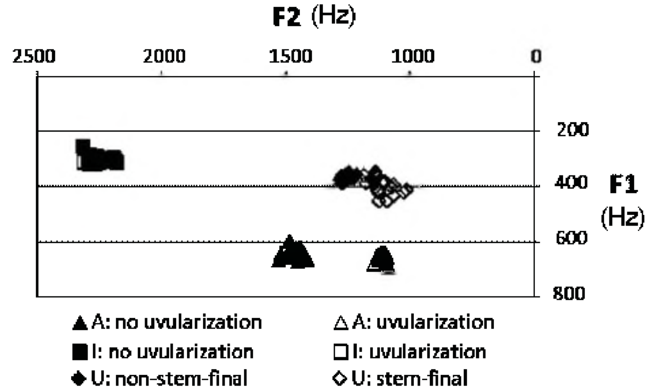

Fig. 4. F_1, F_2 plot of Palestinian Vs in postvelar contexts

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APPENDIX

For each word, the number of tokens recorded is given in parentheses.*

A. St'át'imcets words recorded for the acoustic study

a. ʔaχʷxal 'dig' (6) b. xʷəʔaz 'no, not' (2)
c. maqaʔ 'snow' (6) d. mɛχaɬ 'black bear' (6)
e. qəʔəz'ʔul 'tired out' (2) f. qəʔamaj'ɬ 'breastfeed' (2)
g. məʔəʁ' 'dawn' (4) h. pəʔəʁ' 'pale, faded' (2)
i. təwæn 'salmon berry' (2) j. təqiw 'horse' (2)
k. zəhakaʔ 'right hand' (2) l. zəwatən 'know' (2)
m. wənaxʷ t͡ɬ'uʔ 'true' (2) n. χʷumqaʔ 'salmon head' (6)
o. q'ʷijʃqin 'axe' (2) p. ts'uqʷaz' 'small fish' (6)
q. χʷaʔʃ 'sockeye' (6) r. χaχtʃaʔ (name of Band) (6)
s. wəʁən 'sort s.t.' (2) t. k'iʔiʁ'ʷ 'feel run down' (2)
u. ʁawən 'gather things' (2) v. ɬəʁʷilx 'jump' (2)
w. kanɬiʁʷa 'swallow s.t. wrong' (2) x. q'ʷəʁʷp 'slide down' (4)
y. q'ʷəʁʷpalwaʃ 'pants falling down' (4) z. ləʁʷən 'hide' (2)
a'. məluχʷakaʔ 'sprain one's hand' (2) b'. ziʔzəʁ t͡ɬ'uʔ 'always' (2)
c'. kanɬiʁʷkana 'I swallowed s.t. wrong' (2) d'. ʁʷuj't 'sleep' (2)
e'. ʔəʔχaʔ 'sacred, supernatural talented' (2)

B. Palestinian words recorded for the acoustic study

a. kəsæːt 'cups' (20) b. bəs̲ːɑːt 'busses (20)
c. tiːn 'fig' (20) d. t̲iːn 'mud' (20)
e. fulːə (type of doll) (20) f. bɪsəkfu-lnæːʃ 'they don't clap for us' (20)

* IPA is used. Underlining denotes uvularization. The hyphen in B(f) indicates that the [u] in that word is at a right stem edge.

ADDRESSING THE EFFECTS OF OVERTOPPING VEGETATION ON THE PERFORMANCE OF HIGHWAY NOISE BARRIERS

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1. INTRODUCTION

The reflection and scattering of mid and high-frequency sound by vegetation may be observed in a number of familiar situations. For example, the reflection of tire noise when driving an open car beneath the overhanging branches of broad-leafed trees or the echoing of shouts or gunshots from the edge of a forest. Generally these phenomena have little broader relevance. However, where vegetation is close to and overtops a highway noise barrier, it will tend to scatter sound down behind the barrier thereby reducing its insertion loss, particularly at higher frequencies. Not only is the A-weighted insertion loss of the barrier reduced, but on its "shielded" side, traffic noise no longer sounds "muffled" because its high-frequency content has not been sufficiently attenuated. Therefore, while the barrier may still be providing a worthwhile reduction in the A-weighted sound level, the listener's impression may to be that the barrier is having little or no effect. This phenomenon may have significant implications for the success of highway noise mitigation programs, particularly where the source-receiver geometry makes it challenging to achieve substantial noise reductions and when it is necessary to confirm the barrier's performance (insertion loss) through post-project field measurements.

Drawing on the very limited quantitative research that appears to have been done on this subject, this paper will assess the effects of sound scattering by overtopping vegetation on highway noise barrier performance and discuss ways in which they might be addressed, either physically or administratively. The interaction between pavement design (e.g. quiet pavement) and vegetation scattering effects is also explored.

2. M.I.T. SCALE MODELING STUDY

The only previous investigation found to have focused specifically on the effects of overtopping vegetation on the insertion loss of noise barriers was based on scale model studies [1] conducted by Christopher N. Blair at M.I.T. Key results of this work were summarized in a 1977 paper by Richard H. Lyon, Blair, and Richard G. DeJong [2]. The scattering effects of scale model broad-leafed trees, placed to one side of, and then directly above a noise barrier, were measured in a 1:20 scale model facility using an electric spark discharge as the sound source.

These scale-model results have been used herein to estimate the potential effects of overtopping vegetation on highway noise barriers which, in the absence of such vegetation, would provide insertion losses ranging from 5 to 15 dBA.

Figure 1, from Lyon, shows the generalized effects of vegetation scattering on sound levels both with and without a noise barrier present.

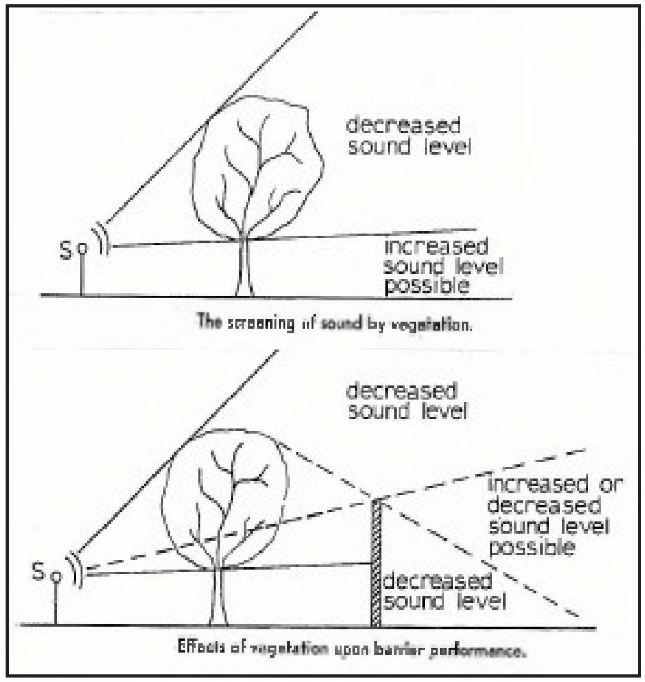
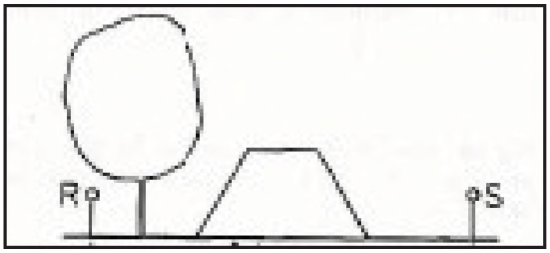


Figure 1; Generalized Effects of Vegetation Scattering

It is seen that vegetation, particularly broad-leafed trees, can either reduce or increase sound levels at a distance from a broad-band source depending on the location of the receiver relative to the vegetation (e.g., crowns of trees), the ground (assumed acoustically soft) and the barrier if present.

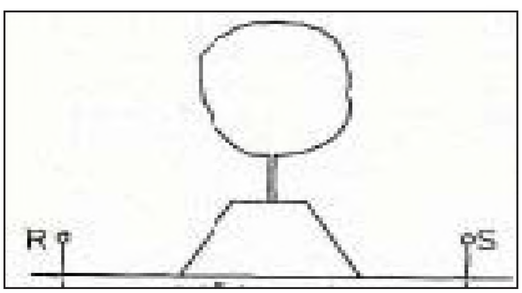
Figure 2 shows the scale-model configuration with 9 m maple trees located to one side of an approximately 3.5 m high earth berm. The sound receiver is located beneath the tree while the source is on the far side of the berm. The accompanying graph shows the measured attenuations (insertion losses) in one-third octave bands both with and without trees present. It is seem that the effects of tree scattering ranged from 2 to 7 dB at mid frequencies (630 to 1,250 Hz.) and reached 12 dB at 4,000 Hz.



630 Hz.	800 Hz.	1.0 kHz.	1.25 kHz.	1.6 kHz.	2.0 kHz.	2.5 kHz.	3.15 kHz.	4.0 kHz.
11	14	21	23	24	19	24	24	30
9	8	16	16	15	12	17	15	18
Δ =2	6	5	7	9	7	7	9	12

Figure 2; Attenuation of Sound by Barrier Without (upper row) and With (middle row) Broad-Leafed Trees along One Side. Difference (bottom row).

Figure 3 shows the modeled configuration with 9 m maple trees located directly on top of the earth berm with the sound source and receiver located on opposite sides of the berm. The accompanying graph shows the measured attenuations both with and without trees present. It is seen that the effects of tree scattering can reach 10 to 14 dB at mid frequencies and exceed 20 dB at 4,000 Hz.



630 Hz.	800 Hz.	1.0 kHz.	1.25 kHz.	1.6 kHz.	2.0 kHz.	2.5 kHz.	3.15 kHz.	4.0 kHz.
11	14	21	23	24	19	24	24	30
1	3	9	8.5	8.5	3	9	7	9
Δ=10	11	12	14.5	15.5	16	15	17	21

Figure 3; Attenuation of Sound by Barrier Without (upper row) and With (middle row) Broad-Leafed Trees on Top. Difference (bottom row).

3. APPLICATION OF SCALE MODELING RESULTS TO HIGHWAY NOISE

3.1 Traffic Noise Spectra

To explore the effects of tree scattering on highway noise specifically, a noise spectrum measured beside Highway 19 in Nanaimo, B.C. was used. At the time (1995) this highway featured somewhat worn, standard hot-mix asphalt pavement and carried roughly 2,500 vehicles per hour (with 5% heavy vehicles) at an average vehicle speed of 75 kmph. This traffic flow generated an equivalent sound level of L_{eq} 75.5 dBA at a distance of 15 m from the centre of the near lanes while its spectrum peaked at 1,000 Hz. This section of highway was later paved with open-graded asphalt (OGA) as part of a "Quiet Pavement" assessment. The traffic noise generated with OGA pavement contains less energy at middle and high frequencies so that it less susceptible to scattering by vegetation.

3.2 Vegetation Scattering Effects with Standard Asphalt

To estimate the effects of vegetation scattering on barrier performance against traffic noise generated on standard asphalt, the scale-modeled barrier attenuations from Figures 2 and 3 (with and without trees) were applied to the highway noise spectrum described above and the overall A-weighted insertion losses calculated. In the absence of trees, the scale model earth berm was able to reduce the traffic noise generated on standard asphalt pavement by 15.5 dBA. With 9 m maple trees located to one side of the berm and above the receiver position (Figure 2), the earth berm's performance was reduced by about 2 dBA to 13.4 dBA. However, with trees located directly on top of the berm (Figure 3), its insertion loss was reduced by 8.5 dBA, from 15.5 to 7.0 dBA.

At 15.5 dBA, the scale model earth berm's highway noise insertion loss in the absence of trees is near the upper end of the range typically observed in the field - the berm's effectiveness being enhanced by its nearness to both noise source and receiver. It is of interest to examine the effects of vegetation scattering on noise barriers having more typical capabilities – i.e., those providing insertion losses of between 5 and 10 dBA in the absence of vegetation. It was assumed that the sound intensity at the receiver location behind the barrier due to scattering alone would be the same for all cases. The level of scattered sound behind the barrier was then estimated from the insertion loss-degradation effect caused by the maple trees located directly on top of the scale model earth berm. The procedure was as follows.

Arbitrarily assume that the traffic noise level at the receiver with neither barrier nor trees present is 70 dBA. Therefore when a nominal "15 dBA" noise barrier is inserted, the receiver level will drop by 15 dBA to 55 dBA with this residual sound level being attributable to the diffracted sound field behind the barrier. Since it was found above that tree scattering reduced the insertion loss of the scale model earth berm by about 8 dBA, when such trees are placed above our nominal "15 dBA" barrier, its insertion loss will be reduced from 15 to 7 dBA. The noise level at the receiver in the presence of such trees would then become 70 – 7 = 63 dBA. The level of scattered sound behind the barrier can therefore be estimated as the logarithmic difference between the receiver level with and without trees, that is 63 minus 55 dBA, or 62.3 dBA. It was then assumed that this same level of scattered sound would

From Acoustics Week in Canada 2008/De l'acte semaine candienne d'acoustique 2008

VIBRATIONAL CHARACTERISTICS OF HARP SOUNDBOARDS

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1. INTRODUCTION

A concert harp (Fig. 1) is basically a triangular structure, formed of the post or (fore)pillar, the neck, and a soundboard mounted on a soundbox. The strings are attached at one end to tuning pegs and bridge-pins mounted in the neck, and at the other end to the soundboard. The structure has to be made strong enough to withstand a total string tension of about 12-20kN. The soundboard (Fig. 2) is approximately trapezoidal in shape, around 1.4m in length, 0.5m wide at the base, 0.1m at the top, and of thickness varying from 11-12mm at the bottom (bass) end to 2-2.5mm at the top (treble). It is made of strips of spruce (Sitka or Engelmann) between 3 to 8 cm wide bonded together, and covered with a thin veneer, typically also of spruce. [1].

Fig. 1. The configuration of a modern 47-string concert harp, a Salvi Aurora (author photo).

The soundbox is semi-conical in shape, and is built up by bonding hardwood veneer (e.g. beech) around a mold. There are four or five soundholes in the back of the soundbox and one in the base. The primary function of these holes is to gain access to mount or replace strings, although they have important acoustical effects. Inside the back of the soundbox are strong U-shaped ribs (beech, aluminum, or steel) which prevent the box from undergoing too much flexure under the string tension.

A modern concert harp has 46 or 47 strings, running from C1 or D1 to G7. The lowest strings are mounted a few cm from the base of the soundboard, the highest strings a few cm from the top. The lower strings of concert harps are made of copper-wrapped steel, those in the mid-range are gut, and the upper strings are nylon.

2. SOUND PRODUCTION

Harp soundboxes, like those of all string instruments, are wooden shells with hole(s). This configuration, when properly optimized, ensures a wide frequency band with good radiativity and no frequencies where the radiativity is zero. The band stretches between two vibration modes, known as the "air" resonance and the "wood" resonance, often called A0 and T1 respectively. This phenomenon is well described in a classic work by Gabriel Weinreich [2]. A similar mechanism has been shown to operate in the harp at low frequencies [3].

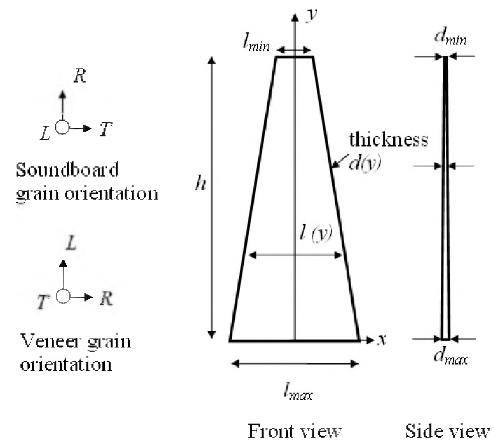

Fig. 2. Layout of harp soundboard, showing the x-y coordinate system used in this paper, and the orientation of the wood grain for the soundboard base and veneer. The longitudinal (L), transverse (T) and radial (R) directions refer to the natural cylindrical coordinate system of a tree limb.

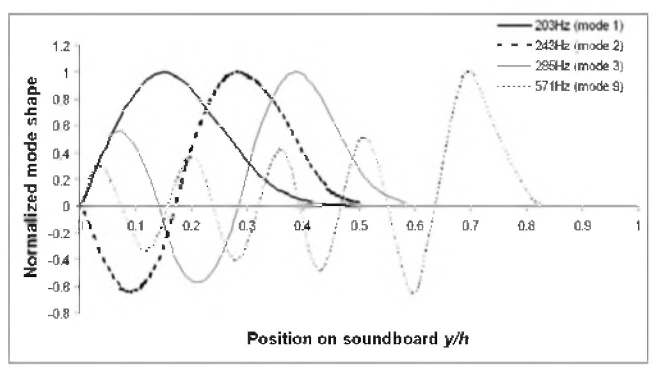

Fig. 3 Finite-element model predictions for the modal shapes for the first three modes of a trapezoidal spruce soundboard, clamped at all edges. The modal shapes are normalized such that the primary antinodes have unit amplitude.

The analysis in terms of A0 and T1 resonances only considers the lowest frequency behaviour of the soundboard. This is appropriate to the violin, whose strings excite the soundboard at the same point (via the bridge) where these modes are most prominent. In the case of the harp, the strings are attached all the way up the soundboard, and beyond the half-way mark, modes higher than the fundamental become dominant for sound production. The progression of modes of a bare soundboard, as calculated with finite-element techniques, is shown in Fig. 3.

3. MEASUREMENTS AND ANALYSIS

First, the soundboard was scanned by measuring the driving-point admittance at many points along the axis of symmetry, i.e. where the strings are attached. We make the assumption that the strings will primarily excite the symmetrical modes, ignoring for now second-order effects where non-planar string motion excites twisting modes. The admittance was measured using a small, light (0.2g) accelerometer and an impact hammer.

The results for the admittance of the soundboard are shown in a contour plot (Fig. 4) in which the frequency is plotted against vertical position on the soundboard, and the shading represents the admittance (darker means higher). The progression in modal shapes is very plain, and the regions of highest admittance move steadily up the soundboard as the frequency increases. Some splitting is observed, particularly in mode 4 (~500Hz). Plotting the string pitch versus the attachment positions produces a "string trajectory" on the plot (marked by the points) which runs on the right side of the primary antinodes (except for the fundamental antinode - it runs past the left of that). Ref.[1] shows how important is the relationship between soundboard modes and the string frequencies at the string attachment positions.

Second, the admittance measurements were repeated with the accelerometer replaced by a microphone at the lowest sound hole on the back of the instrument. These results are plotted in Fig. 5 in the same manner as the admittances.

A comparison of Figs. 4 and 5 is striking. Where the progression of modes appear predominantly at single frequencies in the admittance plot, the sound pressure plot shows double resonances. This is particularly noticeable in the structures around 500 and 700 Hz. A comparison with the low frequency work of Le Carrou [3] on a Camac Atlantide harp suggests that the two peaks near 200 Hz at the 400 mm position can be identified with the T1 and A0 resonances. At present this association is somewhat speculative as the Atlantide and Aurora harps do not have precisely the same specifications. However, if true, it is also likely that the other pairs of resonances have a similar phase relationship.

With a single microphone it was not possible unambiguously to show the phase relationships between all the pairs of peaks. These measurements need to be repeated with a velocity probe.

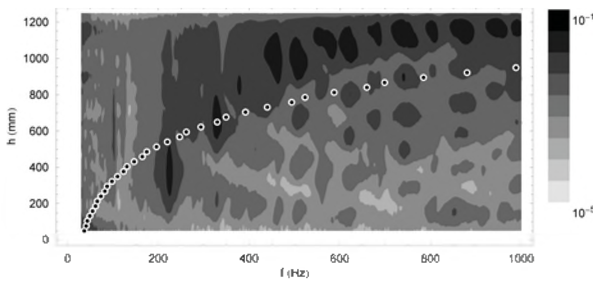

Fig. 4. Driving-point admittance data for the central string bar of a Salvi Aurora soundboard. The frequency is plotted against vertical position h on the soundboard, and the shading represents the admittance Y (s/kg). The points show the position and fundamental frequencies of the harp strings.

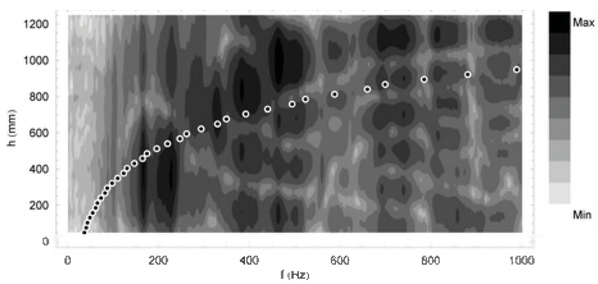

Fig. 5. Sound pressure at the lowest sound hole at the back of a Salvi Aurora, normalized to the force of an impact hammer striking position h along the central string bar on the soundboard.

4. CONCLUSION

We are within striking distance of a fairly complete understanding of the vibro-acoustic behaviour of a modern harp soundbox. In the near future we hope to extend the work to earlier forms of the harp which had very different structures and distinctive voices.

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ACKNOWLEDGMENTS

We thank Domenic DiTomaso and David Axen for technical assistance, and the University of British Columbia School of Music and Elizabeth Volpé-Bligh for making the Salvi Aurora concert harp available.

CANADA WIDE SCIENCE FAIR

From File Reports

Devon Sawatzky is the winner of this year's Special Award from the Canadian Acoustics Association for his project "Sense What You Can't Hear."

Devon Sawatzky is a grade eight student from Winnipeg. His interests include electronics, reading, composing electronic music, working on his computer and making movies with his friends. In the summer he enjoys camping, biking, canoeing and traveling with his family. Over the past several years, Devon has spent Saturday mornings building robots with a group at a local community college. He is also quite involved with the youth group in his church. Devon hopes to study engineering, electronics or computer science at university in the future.

Devon Sawatzky's full article is reproduced below.

SENSE WHAT YOU CAN'T HEAR*

Devon Sawatzky
Acadia Junior High School, Winnipeg, Manitoba, Canada, Canada

Editor's Note: The submission by Devon Sawatzky was reformatted and edited to fit in to the Journal format.

Abstract

In this project a device was constructed that could help deaf people by vibrating when it detects sudden noises that may indicate impending danger. The device was tested to determine how well it would respond to different frequencies. The test revealed that the device responded to mid frequencies the best, and that overall it worked well.

1 INTRODUCTION

By some estimates, approximately 2.8 million Canadians suffer from hearing loss, about 310,000 of them profoundly deaf (Canadian Association of the Deaf, 2007). There are three common types of deafness: conductive hearing loss, which is basically mechanical damage to the mechanisms in the ear, sensorineural hearing loss, which is damage to the hair cells in the ear, or the auditory nerves. Mixed hearing loss is a combination of both of these types. When someone loses their hearing, they need to adapt. Many aspects of life become harder, including sensing many common events indicated by a sound, such as a ringing phone, doorbells, car horns, smoke alarms, and more. (American Speech-Language-Hearing Association, 1997-2008). There are many assistive devices out there that connect to sound sources such as phones or smoke alarms, but they don't actually sense the sounds, but just connect to the source, rendering them useless for detecting unpredictable sounds such as shouting and car horns. Almost all assistive devices available work by this principle.

The objective of this project is to make a device that will be able to sense sudden sounds, and warn the user of these sounds in the form of vibration, and warn the user of sounds such as car horns, shouting, and other sounds that warn of impending danger.

2 THE DEVICE

The device consists of 5 main parts: the battery, the regulator circuit, the microphone, the sound detector board, and the PICAXE microcontroller board. The microphone converts sound waves into a small AC current, which is then amplified and smoothed into a DC voltage relative to the sound level in the sound detector board. In the PICAXE microcontroller, the built - in Analog to Digital Converter (ADC) takes the voltage from the sound detector board and converts it into a

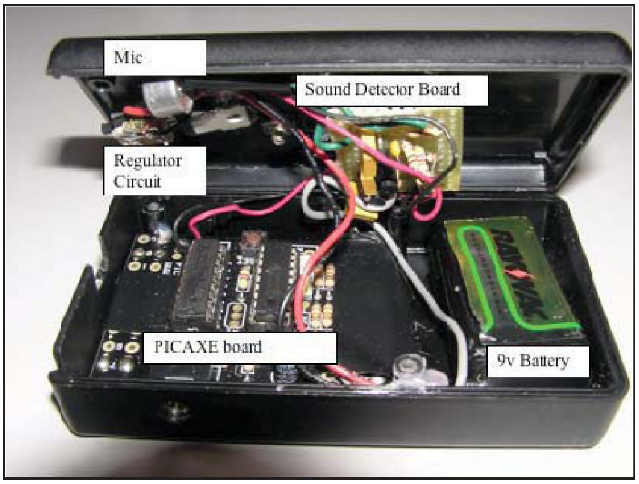

Figure 1: Inside view of the device

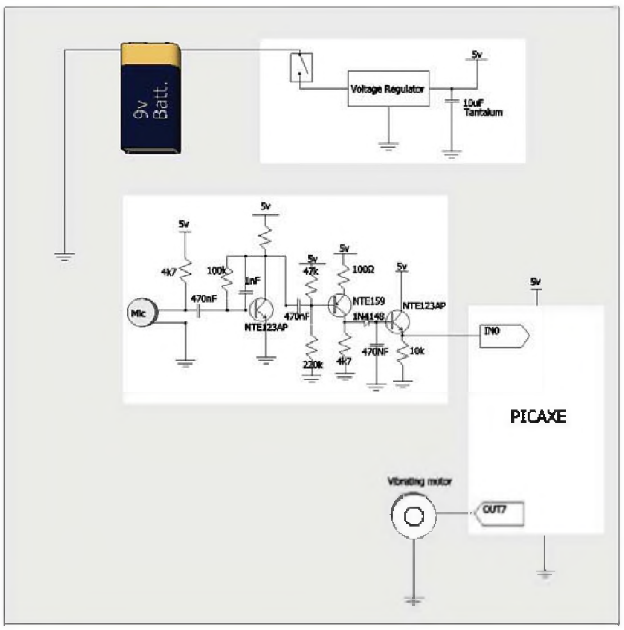

Figure 2: Main Schematic of the device

digital signal that is read by the PICAXE microcontroller. A 9V battery powers the entire system through regulator, which supplies a constant voltage to the system.

The microcontroller executes a program, which consists of two main stages. When the user turns on the device, it first vibrates briefly to notify the user that they have activated it. Then there is a 5 second pause for the user to clip the device to their belt, before it takes 5 samples of the sound levels around it, each spaced 1 second apart. The microcontroller then averages these samples. This value is called the ambient level. It then adds a predetermined amount to the ambient level, and defines this as the alert threshold. The entire stage takes about 10 seconds. Then the program enters the sensing stage, where it will remain in this stage for the rest of the time the device is on. Here, the microcontroller constantly takes samples from the sound detector board, and whenever the sound level goes above the alert threshold, the microcontroller alerts the user by activating the vibrator motor. After that, the device pauses for half a second to allow the supply voltage to stabilize before returning to the sensing stage. This is because the vibrator motor draws enough current to throw off the reading, despite the voltage regulator's attempts to stabilize it. It continues doing this until the voltage supply is cut off using the power switch or until the battery power has diminished.

3 PROCEDURE

After constructing the device, it was tested using the following method:

After building the device, I tested it by using the software NCH Tone Generator to play 16 sounds of different frequency, from 60 Hz to 960 Hz. The sounds were played through a Logitech X-240 speaker set. Set up 2 meters away from the speakers was the device and a decibel meter, placed as close together as possible. Each tone was played, and the volume slowly increased until the device vibrated. The value displayed on the decibel meter when the device started vibrating was written down. The entire test was repeated 3 times to ensure accuracy.

4. DISCUSSION

The device responded better to some sound frequencies than others. Figure 3 shows that the device seems to respond best to the mid frequencies, and not as well to the upper and lower. Another point about the data is the two spikes in the threshold around 360 and 760 Hz. They are almost like two "blind spots", but they are still below 90 decibels.

I had some interesting observations about the data while performing the test. My original plan had been to do a basic test with 5 different tones, but after noting the lower threshold in the mid frequencies, I decided I should do a more extensive test, as described in the procedure. Also, I had originally used the handheld volume control on the speakers, but it wasn't accurate enough. It would have the occasional random jump of about 5 decibels, and would even react to the pressure of my hand slightly. A slight problem with the

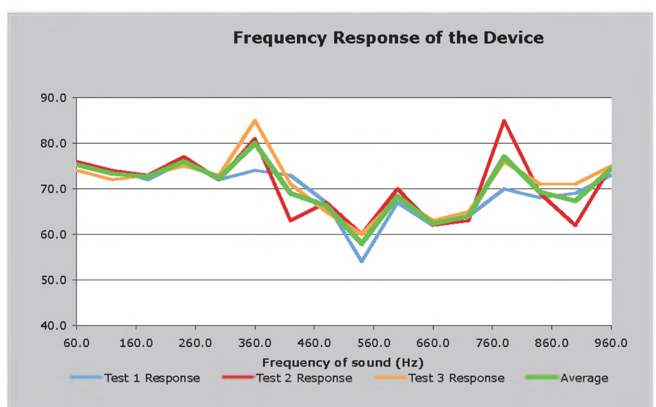

Figure 3: Frequency Response of the Device

device is that occasionally it will calibrate to a much lower level than the ambient level, causing false alarms. This isn't nearly as serious as the alternative, of not sensing sounds, which did not occur after perfecting the code.

4. CONCLUSIONS

In conclusion, the device I have constructed meets the purpose of this project. It is able to detect sudden sounds reasonably well, and the variations in sensitivity are not exceptionally major. It is still not perfect. Occasionally, the 5 samples in the calibration stage will not accurately represent the actual sound levels. This phenomenon does not occur during the sensing stage. My theory is that one of the samples in the calibration stage occasionally occurs at the low point of the sound wave, or during a quiet moment. The capacitors in the sound detector board are incorporated to smooth that out, but voltage smoothing systems are not perfect. This phenomenon will have no effect on the sensing stage, because samples are constantly being taken. That would also explain why lower frequencies have this problem more than upper frequencies, because the signals are better smoothed out in the upper frequencies.

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Fundamentals of Acoustics - 4th Edition
by L.E. Kinsler, A. R. Frey, A.B. Coppens and J.V. Sanders
John Wiley and Sons 2000
List price: $110 USD (Hardcover)
548 pp., ISBN: 978-0-471-84789-2

One of the classical text books on acoustics has always been Fundamentals of Acoustics by Kinsler and Frey. The first edition appeared in 1950 (nearly sixty years ago). The current reviewer learnt all his acoustic basics from the 2nd edition that was released in 1962 nearly 40 years ago and it is a pleasure to review the current edition. By the time the fourth edition was released in the year 2000, both Mr. Kinsler and Mr. Frey have passed away.

Fundamental of Acoustics is divided into seventeen chapters and twelve appendices as well as a list of answers to odd-numbered problems. The seventeen chapters are: 1) Fundamentals of vibration; 2) The transverse motion: the vibrating string; 3) Vibrations of bars; 4) The two-dimensional wave equation: vibrations of membranes and plates; 5) The acoustic wave equation and simple solutions; 6) Reflection and transmission; 7) Radiation and reception of acoustic waves; 8) absorption and attenuation of sound; 9) cavities and waveguides; 10) Pipes, resonators and filters; 11) Noise signal detections, hearing and speech; 12) Architectural acoustics; 13) Environmental acoustics; 14) Transduction; 15) Underwater acoustics; 16) Selected non-linear acoustics; and 17) Shock waves and explosions. The twelve appendices are: A1) Conversion factors and physical constants; A2) Complex numbers; A3) Circular and hyperbolic functions; A4) Some mathematical functions; A5) Bessel functions: tables, graphs, zeros, and extrema; A6) Table of directivities; A7) Vector operators; A8) Gauss's theorem and Green's theorem; A9) A little thermodynamic and the perfect gas; A10) Tables of physical properties of matter; A11) Elasticity and viscosity; and A12) The Greek alphabet.

It is natural that the current review will focus on a comparison between the two editions. By now, I am sure that most of our readers will be very familiar with the original Kinsler and Frey classical treatment of the fundamental principles. Since modern day textbooks on acoustics do not rely on vibrational principles to begin the acoustical treatment, this review looks at materials from Chapter 5 onwards.

Chapter 5 deals with the basic derivation of the wave equation and its simple solutions. The first 12 sections are very similar to the ones treated in the second edition even though these 12 sections have been somewhat reformatted. Chapter 5, however, includes four new sections dealing with cylindrical waves, Rays and waves, Inhomogeneous wave equation and Point source. These new sections are welcome addition to the structure of Chapter 5. Each of these additional sections provide basic introduction to the topics and some of them have been developed further in later chapters. For example, the section on Ray acoustics introduces the reader the fundamental eikonal and eikonal wave equation for Ray propagation so that the users of the auditorium acoustics softwares such as Raynoise and CATT Acoustics would have a better appreciation of the complexity of these application programs.

Each chapter that was covered in old editions has been revised with new materials and has been rearranged so that any application would have all the basic information covered appropriately. For example Chapter 7 discusses radiation and reception of acoustic waves. Even though there is a separate chapter on transduction (Chapter 14), the fundamental principles of reception are covered in Chapter 7 itself, preparing the readers for in-depth treatment in Chapter 14. Chapter 7 also describes a linear array of receptors, once again preparing the reader to become familiar with state-of-the-art measurement techniques such as Beam-Forming methods. Chapter 9, a new chapter in the fourth edition, combines cavities and waveguides and discusses the behavior of sound in cavities. The normal mode behavior in many different kinds of cavities is discussed in Chapter 9. Rectangular, cylindrical and spherical cavities and acoustic modal behavior in these cavities are discussed in this chapter. Propagation in layered waveguides is also treated in Chapter 9 and provides a brief introduction to channels as wave-guides. The above is a required material for detailed analysis of underwater acoustics.

Three new chapters are added to the fourth edition when compared to the second edition. These welcome additions are: Chapters 13, 16 and 17. Chapter 13 is on environmental acoustics and describes the basic concepts of acoustic descriptors, rating curves, and community noise. Statistical aspects of community noise are introduced due to the variable nature of community noise. Criteria for community noise as they apply highway noise and aircraft nosie as well as community response and its regulatory aspects are described. In addition, brief introduction to sound transmission class is presented through single and double leaf partitions.

Chapters 16 and 17 deal with non-linear acoustics and shock waves. Only brief treatments (less than 30 pages) are provided in these two chapters and the readers are referred to detailed descriptions in other texts. A simple non-linear wave equation is derived and two parameters – discontinuity distance and Goldberg number – are used to characterize the degree of non-linearity. Perturbation methods are used to solve the acoustical equation. Chapter 17 is an extension of Chapter 16, where discontinuous behavior in total pressure, density and particle speed are treated. After describing the basic characteristics of shock waves and the controlling equations, examples such as blasts, chemical explosion and nuclear explosions that produce shock waves are highlighted in Chapter 17.

The fourth edition has kept the original flavor and methodology of the earlier editions. The number of homework problems has been more than doubled in the later versions, thus keeping the original spirit of a text book intact. Even the appendices have been updated to include more information. For example, Appendix A4 presents basic information on Gamma function, Bessel function, Spherical Bessel functions and Legendre functions. In addiiton, detailed information on Bessel functions and Spherical Bessel functions such as tables of values, graphs, zeros, extrema values are provided in Appendix A5.

The fourth edition is thus a valued text book for teaching senior level introductory course in acoustics.

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The Department of Mechnical Engineering of the Katholieke Univeristry in Leuven, Belgium organized the 2008 ISMA conference on Noise and Vibration Engineering.

The conference was held between 15th and 17th September 2008 in Leuven, Belgium. Approximately 550 people attended the conference. 350 papers abstracts were submitted to the conference.

The conference programme included 2 keynote lectures, 330 papers presented in eight parallell sessions and three plenary poster sessions.

The two key note speakers were -1) T. Abe of Ford Motor Company (NVH Engineering) and 2) A. Preumont of University of Brussles (Adaptive Structures).

The main sessions were: a) Active noise control; b) Active vibration control and smart structures; c) Aeroacoustics and flow noise; d) Civil applications; e) Condition monitoring; f) Damping; g) Durability testing; h) Dynamics of rotating machinery; i) EUREKA project; j) Rotor noise and vibration; k) Instrumentation; l) Medium and high-frequency techniques; m) Modal testing; n) Modal updating; o) Monitoring and diagnostics; p) Multi-body dynamics; q) MYMOSA; r) Noise Control; s) Non-linearities; t) Operational modal analysis; u) Parameter estimation; v) Railway dynamics; w) Self-excited vibrations; x) Signal processing; y) Sound quality; z) Source localization; aa) Structural damage detection; ab) Structural dynamics; ac) Substructure and coupling; ad) Transfer path analysis; ae) Uncertainiites in vibration and acoustics; af) Underwater and ship acoustics; and ag) Vibro-acoustic modelling.

The conference proceedings are available now. Contact for information: Mrs. L . Notre at Leuven, Belgium. Her e-mail address is: lieve.notre@mech.kuleuven.be

Canadian Acoustical Association

Minutes of the Board of Directors Meeting
5 October 2008
Vancouver, BC

Present: Christian Giguère (chair), David Quirt, Alberto Behar, Rich Peppin, Stan Dosso, Tim Kelsall, Ramani Ramakrishnan, Frank Russo, Jérémie Voix, Clair Wakefield

Regrets: Vijay Parsa, Nicole Collison, Dalila Giusti

The meeting was called to order at 4:35 p.m. Minutes of the Board of Directors meeting of 26 April 2008 were approved as published in Canadian Acoustics (June 2008 issue). *(Moved A. Behar, second R. Peppin, carried).*

President's Report

Christian Giguère reported that there have been no major problems in the affairs of the Association, in the sense that everything is proceeding normally. He emphasized that the current priority is to update the website by adding online capabilities to support the Treasurer and Secretary.

Secretary's Report

David Quirt reported that routine processes of the Association are proceeding with few problems. With respect to routine CAA communications:

- Forms for annual filing with Corporations Canada have been acknowledged.
- Invoice from I-INCE and ICA received and transferred to Treasurer for payment.

Secretarial operating costs for the fiscal year ended in August totaled $1444 (~20% above last year), mainly for mailing costs and postal box rentals. A budget of $1500 is proposed for next fiscal year.

Issues of Noise News International were mailed to 42 members who requested this option, and are now arriving from the publisher in the USA shortly after the cover date. Cost of mailing was nearly double the amount collected from participating members. After brief discussion, it was decided to increase the fee from $5 to $10

David reported that memberships have risen. Last year the total was 370 on 4 October, and this year's paid-up total on that date is 407. Renewals are essentially unchanged from last year, but many new members were enrolled at the Montreal conference.

Mailing list (26 Sept.)	**Canada**	**USA**	**Other**	**Change**
Member	227	21	9	**+20**
Student	73	1	5	**+20**
Sustaining	39	3	1	**– 2**
Direct	3	1	–	**– 1**
Indirect	11	8	4	**–**
	Total = 407			**+37**

As usual, this report prompted some discussion of possible changes in membership categories and promoting increased membership. The category of Direct Subscriber has dwindled, and it was confirmed that this option will be eliminated at the end of this year, before implementation of online processing. It was agreed that accepting early renewal payment at the prevailing rate (e.g.- with conference registration or 2 years at once) is acceptable. Rich has submitted a proposal for handling some new options such as Life Members. However, extended discussion of this issue was deferred to the next meeting.

(Approval of report moved by A. Behar, seconded R. Ramakrishnan, carried)

Treasurer's Report

The Treasurer, Dalila Giusti, submitted a report including a preliminary financial statement for the fiscal year. Most expenses were essentially as budgeted, except the journal ($3k under). It was noted that no student travel expenses were identified; Frank will consult with organizers and supervisors to check that no requests have been ignored. The proposed budget for 2008-2009 was also discussed, and several changes were agreed (increase the budget for office expenses from $1000 to $1500 and for BoD meeting expenses from $1200 to $1500) as well as the change noted under Awards.

A change of financial year-end to 30 June was proposed, to permit completion of the annual audit before the fall meeting. Dalila will submit a request to Industry Canada, and Members will be notified of the proposed change by these minutes and by announcements at the AGM and in the December journal, in case it must be treated as a bylaw change. *(Moved R. Peppin, second R. Ramakrishnan, carried)*

Dalila has proceeded with adjustment of CAA investments, as requested in April, to ensure more yield on capital funds. $225,705 is now invested in GIC's; interest will almost cover the maximum $8950 per annum for prizes.

The backlog of invoicing for advertising in Canadian Acoustics was nearly eliminated, but many payments are still outstanding. Ramani agreed to coordinate the process.

A fee increase at the October AGM was suggested (See AGM minutes).

The Treasurer's report was accepted. *(Moved R. Ramakrishnan, seconded A. Behar, carried)*

Editor's Report

The Editor, Ramani Ramakrishnan, submitted a brief report on issues related to Canadian Acoustics. Some issues:

- A special issue was published in March 2008, which featured papers from a workshop. This large issue had high costs, but a financial contribution offset these.
- The implementation of online publication of the journal has not advanced significantly.
- There was extended discussion of revamping the News section of the journal, with less content on international conferences (identifying other sources for such lists would be adequate), but adding information about regulations, standards, technical news, and other related societies pertinent to Canadian acousticians.

The Board made a unanimous vote of thanks to Ramani for his continuing contributions.

CAA Conferences – Past, Present & Future

2007 (Montreal): A final report has been received from Rama Bhat for the conference in Montreal, with the final $2500 transfer of funds.

2008 (Vancouver): Murray Hodgson reported on budget and the final program details, which include 3 plenary lectures, 115 papers in 3 parallel sessions, 23 exhibits on the 2^{nd} day, and expected attendance of 178 registrants and 45 exhibitors.

2009 (Niagara-on-the Lake): Organization of the conference is on schedule, with Moustafa Osman and Ramani Ramakrishanan leading the team. The meeting will be at the Pillar and Post Inn on October 14-16. See the announcements in this and subsequent issues of *Canadian Acoustics*.

Subsequent meetings: Sites for later meetings were discussed. Desirable options for 2010 included Calgary and Québec, if teams can be established.

Awards

Frank Russo presented a report summarizing decisions by the coordinators for all CAA awards. There were applications for all awards except the Shaw Prize, and the winners have been selected. Winners were announced on 7 October at the banquet, and in this issue of *Canadian Acoustics*.

Some changes to the awards were proposed:

- Rules for the Shaw Prize were changed to permit students to take up their PDF at the same school as their Ph.D. *(Moved S. Dosso, seconded A. Behar, carried)*
- For Canada-Wide Science Fair, offer award at senior level (Grade 11/12) at $2000 prize cost. *(Moved F. Russo, second S. Dosso, carried)*
- It was decided to seek industry sponsors for Student Presentation Awards *(Moved F. Russo, second R. Peppin, carried)*

For preparation of award certificates, Frank was requested permission to proceed with acquiring an embossing device; this was approved.

CAA Website

Christian led discussion on the CAA website. Geoff Morrison has resigned from Webmaster position.

There was broad agreement that CAA should proceed with acquiring a complete website package. Several suppliers have website packages suitable for a small association; key features include online integration of membership list, event management system for conference administration, tools for website page development and credit card payment capabilities. After discussion of costs and risks, the Board authorized funding of up to $7000 plus $2000/year to proceed with a system. *(Moved R. Peppin, second T. Kelsall, carried)*

Other Business

Stan led the discussion on nominations for the election at the Annual General Meeting (See AGM minutes for details).

Adjournment

Meeting adjourned at 9:46 p.m. *(Moved R. Ramakrishnan, seconded F. Russo, carried)*

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inter-noise 2009
innovations in practical noise control
2009 August 23-26 — Ottawa, Canada

Invitation and call for papers

Dear Colleagues,

The Organizing Committee of the 38th International Congress and Exposition on Noise Control Engineering (INTER-NOISE 2009) extends a warm welcome and invitation to participate fully in what promises to be the premier noise control engineering conference of 2009. The INTER-NOISE 2009 Congress, sponsored by the International Institute of Noise Control Engineering and co-organized by the Canadian Acoustical Association and the Institute of Noise Control Engineering-USA, will be held in Ottawa, from 23–26 August 2009.

The Congress will feature a broad range of high-level research papers from around the world, as well as an extensive exhibition of noise and vibration control and measurement equipment and systems. Distinguished speakers will provide additional stimulation for our technical sessions and discussions with a focus on our theme of “Innovations in Practical Noise Control.”

The 2009 International Symposium on Active Control of Sound and Vibration (ACTIVE 2009) will be held 20-22 August, immediately before the INTER-NOISE 2009 congress.

The INTER-NOISE 2009, and ACTIVE2009, will be held at the Westin Ottawa Hotel, which is located in the heart of Canada’s Nation’s capital close to all major attractions, Parliament Buildings, National Gallery, Royal Mint, and many museums.

Both INTER-NOISE and ACTIVE symposium will have the same schedule for abstract and paper submission:

Abstracts Due: 23 January 2009
Notification of Acceptance: 20 March 2009
Papers Due: 22 May 2009

The congress website provides complete information on the congress including, instructions on paper and abstract submission, planned technical sessions, distinguished lectures, exposition, registration, and social events, so please visit internoise2009.com often.

It is our pleasure to welcome you to INTER-NOISE 2009 and ACTIVE 2009 in Ottawa.

Trevor Nightingale and Joe Cuschieri,
Co-Presidents
&
Brad Gover and Stuart Bolton,
Technical Co-Chair

Canadian Acoustical Association

Minutes of Annual General Meeting

Vancouver, BC
7 October 2008

Call to Order

President Christian Giguère called the meeting to order at 5:00 p.m. with 21 members present.

Minutes of the previous Annual General Meeting on 11 October 2007 in Montreal were approved as printed in the December 2007 issue of Canadian Acoustics. *(Moved by R. Peppin, second R. Ramakrishnan, carried)*

President's Report

Christian Giguère briefly summarized his report to the Board meeting on 5 October. He emphasized that the society is in good condition, and he thanked all those who have made contributions to our activities. The key business of the coming year is shifting our operations to a new web-based system to facilitate routine financial and membership transactions.

Secretary's Report

David Quirt gave an overview of membership and operational activity.

- CAA membership and subscriptions have risen 10%, from 370 to 407. Renewals are essentially unchanged from last year, but many new members were enrolled at the Montreal conference.
- An itemized account of the administrative budget of $1444 (mainly mailing expenses) was presented to the Board of Directors.
- The major tasks in the coming year are shifting the membership database and annual renewal process to the website, and promoting a shift towards more email and online transactions, to handle membership and the annual conference with less volunteer effort.

(Acceptance of the report moved by R. Ramakrishnan, seconded T. Kelsall, carried.)

Treasurer's Report

In the absence of the Treasurer, Dalila Giusti, Christian Giguère presented an overview of her report on CAA finances. CAA is in good financial shape, with total assets of $276,473 at fiscal year end (before audit). Total assets rose marginally, despite awarding almost all prizes in a year when interest on our capital investments and other revenue were low (due to delays in re-investing and in collecting advertising revenue). Re-investment in new GIC's has now been done, and these will cover the cost of awards for the next two fiscal years.

A change of financial year-end to 30 June is proposed, as discussed in Board minutes. This will be debated and finalized at next AGM, following our standard procedure for bylaw changes.

This year, a budget deficit is predicted due to increased website and service costs as we implement online payment, plus small increases in other parts of the budget. These increases should be partly offset by collecting overdue invoices for advertising.

Therefore proposed a $5 increase in 2009 fees for Students (to $30) and for Members and Subscribers (to $70), with other rates remaining unchanged. *(Acceptance of proposed fee structure moved by Rich Peppin, second Bill Gastmeier, carried.)*

(Acceptance of the report moved by Brian Howe, seconded R. Ramakrishnan, carried.)

Editor's Report

Ramani Ramakrishnan gave the Editor's report. *Canadian Acoustics* production has proceeded smoothly throughout the year. A proceedings issue, in March 2008, featured papers from a workshop on marine mammals. This large issue had high costs, but a financial contribution offset these, so annual costs were about $3k below budget.

There has been limited progress on the project to establish online publication of *Canadian Acoustics* (See Board minutes of October-07).

Award Coordinator's Report

Frank Russo acknowledged the continuing hard work of CAA awards coordinators, and reported the awards to be presented this year. This year CAA is awarding all prizes except the Shaw Postdoctoral Prize. In addition, there are three student paper awards for presentations at the conference. (See separate announcement in this issue for names of recipients.)

Several changes in the prizes have been authorized by the Board:

- For the Shaw Prize, rules were changed to permit students to take up their postdoctoral fellowship at the same school as their Ph.D.
- For Canada-Wide Science Fair, CAA will offer award at "senior" level (Grade 11/12), which costs $2000.
- For the Student Presentation Awards, the Coordinator will seek industry sponsors.

Past and Future Meetings

Reports were presented on the past, present and future annual meetings:

2007 (Montreal): Final report has been received for the conference in Montreal in May, and final balance of $2500 has been transferred to CAA.

2008 (Vancouver): The meeting is proceeding smoothly, with a high number of registrants and exhibitors. The organisers were thanked, and many positive features of this meeting were lauded.

2009 (Niagara-on-the-Lake): The meeting will be at the Pillar and Post Inn on October 14-16. Ramani Ramakrishanan reported organization is proceeding well, and that optional extensions for a wine tour and/or attendance at the Shaw Festival are planned. See announcements in this issue and subsequent issues of *Canadian Acoustics*.

Subsequent meetings: Proposed sites for the annual conference in 2010 include Calgary and Québec; Christian will seek local organizers.

CAA Website

Christian Giguère reported that Geoff Morrison has resigned as Webmaster, and that a new volunteer is needed. This is critical, to implement plans for improvements, such an online payment capability for membership and other transactions, and online access to *Canadian Acoustics*.

Nominations and Election

CAA corporate bylaws require that we elect the Executive and Directors each year. This year, Dave Quirt chose not to seek re-election after six years as Secretary, and two Directors completed their terms on the Board - Nicole Collison and Alberto Behar.

The Past President, Stan Dosso, presented the nominations and managed the election process. In each case, he read the name of the nominee, and then asked if there were other nominees from the floor.

- Christian Giguère for President
- Dalila Giusti for Treasurer
- Ramani Ramakrishnan for Editor
- Finally, Stan presented names of proposed continuing Directors (Rich Peppin, Vijay Parsa, Tim Kelsall, Clair Wakefield, Frank Russo and Jérémie Voix) and new Directors (Sean Pecknold and Roberto Racca).

In each case, there were no other nominations from the floor, so these nominees were declared elected by acclamation. After completion of the election process, Stan Dosso expressed thanks for the contributions by the outgoing Directors and for David's 6 years as Secretary. There was enthusiastic applause.

Adjournment

Adjournment was proposed by Rich Peppin and seconded by Stan Dosso. Carried. Meeting adjourned at 6:10 p.m.

Canadian Acoustical Association
Association canadienne d'acoustique

2008 PRIZE WINNERS / RÉCIPIENDAIRES 2008

SHAW POSTDOCTORAL PRIZE IN ACOUSTICS /
PRIX POST-DOCTORAL SHAW EN ACOUSTIQUE

-

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

Donald Derrick, University of British Columbia
"*Kinematics, Strategy-shift and Planning in English Flap Sequences*"

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

Dag Tollefsen, University of Victoria

ECKEL GRADUATE STUDENT PRIZE IN NOISE CONTROL /
PRIX ÉTUDIANT ECKEL EN CONTRÔLE DU BRUIT

Musarrat Nahid, University of British Columbia
" Prediction of Speech Transmission Index in Eating Establishments"

RAYMOND HÉTU UNDERGRADUATE PRIZE IN ACOUSTICS /
PRIX ÉTUDIANT RAYMOND HÉTU EN ACOUSTIQUE

Marianne Pelletier, Marco Coletta, and Renée Giroux, University of Toronto
"Effects of Acoustic Distortion and Semantic Context on Lexical Access: a Replication and Expansion

Canada-Wide Science Fair Award / Prix Expo-sciences pancanadienne

Devon Sawatzky, Acadia Junior High, Winnipeg Manitoba

"Sense What You Cannot Hear"

Directors' Awards / Prix des Directeurs

Individual Member / Membre Individuel:

G. Robert Arrabito, DRDC, Toronto

"Methods For Mitigating The Vigilance Decrement In An Auditory Sonar Monitoring Task: A Research Synthesis"

Canadian Acoustics 35(4): 15-23

Student / Étudiante:

Shazia Ahmed, Sina Fallah, Brenda Garrido, Andrew Gross, Matthew King, Timothy Morrish, Desiree Pereira, Shaun Sharma & Ewelina Zaszewska, University of Toronto (Mississauga)

"Use Of Portable Audio Devices By University Students"

Canadian Acoustics 35(1): 35-52

Student Presentation Awards / Prix pour Communications Étudiantes
Concordia University, Montréal (QC), October 9-12, 2007

Kate Dupuis, University of Toronto

"Effects of emotional content and emotional voice on speech intelligibility in younger and older adults"

Payam Ezzatian, University of Toronto

""The effect of informational masking and word position on sentence recall"

Omar Falou, Ryerson University

"Modelling high frequency acoustic backscatter response from non-nucleated biological specimens"

CONGRATULATIONS / FÉLICITATIONS

The Canadian Acoustical Association
L'Association Canadienne d'Acoustique

PRIZE ANNOUNCEMENT • ANNONCE DE PRIX

A number of prizes and subsidies are offered annually by The Canadian Acoustical Association. Applicants can obtain full eligibility conditions, deadlines, application forms, past recipients, and the names of the individual prize coordinators on the CAA Website (http://www.caa-aca.ca). • Plusieurs prix et subventions sont décernés à chaque année par l'Association Canadienne d'Acoustique. Les candidats peuvent se procurer de plus amples renseignements sur les conditions d'éligibilités, les échéances, les formulaires de demande, les récipiendaires des années passées ainsi que le nom des coordonnateurs des prix en consultant le site Internet de l'ACA (http://www.caa-aca.ca).

Deadline for Underwater Acoustic and Signal Processing Student Travel Subsidy: **31 March 2008**
Échéance Subvention de Voyage pour Étudiants en Acoustique Sous-marine ou Traitement du Signal: **31 Mars 2008**

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

$3,000 for full-time postdoctoral research training in an established setting other than the one in which the Ph.D. was earned. The research topic must be related to some area of acoustics, psychoacoustics, speech communication or noise. • $3,000 pour une formation recherche à temps complet au niveau postdoctoral dans un établissement reconnu autre que celui où le candidat a reçu son doctorat. Le thème de recherche doit être relié à un domaine de l'acoustique, de la psycho-acoustique, de la communication verbale ou du bruit.

ALEXANDER GRAHAM BELL GRADUATE STUDENT PRIZE IN SPEECH COMMUNICATION AND HEARING • PRIX ÉTUDIANT ALEXANDRE GRAHAM BELL EN COMMUNICATION VERBALE ET AUDITION

$800 for a graduate student enrolled at a Canadian academic institution and conducting research in the field of speech communication or behavioural acoustics. • $800 à un(e) étudiant(e) inscrit(e) au 2e ou 3e cycle dans une institution académique canadienne et menant un projet de recherche en communication verbale ou acoustique comportementale.

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

$500 for a graduate student enrolled at a Canadian academic institution and conducting research in underwater acoustics or in a branch of science closely connected to underwater acoustics. • $500 à un(e) étudiant(e) inscrit(e) au 2e ou 3e cycle dans une institution académique canadienne et menant un projet de recherche en acoustique sous-marine ou dans une discipline reliée à l'acoustique sous-marine.

ECKEL GRADUATE STUDENT PRIZE IN NOISE CONTROL • PRIX ÉTUDIANT ECKEL EN CONTRÔLE DU BRUIT

$500 for a graduate student enrolled at a Canadian academic institution and conducting research related to the advancement of the practice of noise control. • $500 à un(e) étudiant(e) inscrit(e) au 2e ou 3e cycle dans une institution académique canadienne et menant un projet de recherche relié à l'avancement de la pratique du contrôle du bruit.

RAYMOND HÉTU UNDERGRADUATE PRIZE IN ACOUSTICS • PRIX ÉTUDIANT RAYMOND HÉTU EN ACOUSTIQUE

One book in acoustics of a maximum value of $150 and a one-year subscription to *Canadian Acoustics* for an undergraduate student enrolled at a Canadian academic institution and having completed, during the year of application, a project in any field of acoustics or vibration. • Un livre sur l'acoustique et un abonnement d'un an à la revue *Acoustique Canadienne* à un(e) étudiant(e) inscrit(e) dans un programme de 1er cycle dans une institution académique canadienne et qui a réalisé, durant l'année de la demande, un projet dans le domaine de l'acoustique ou des vibrations.

CANADA-WIDE SCIENCE FAIR AWARD • PRIX EXPO-SCIENCES PANCANADIENNE

$500 and a one-year subscription to *Canadian Acoustics* for the best project related to acoustics at the Fair by a high-school student • $500 et un abonnement d'un an à la revue *Acoustique Canadienne* pour le meilleur projet relié à l'acoustique à l'Expo-sciences par un(e) étudiant(e) du secondaire.

DIRECTORS' AWARDS • PRIX DES DIRECTEURS

One $500 award for the best refereed research, review or tutorial paper published in *Canadian Acoustics* by a student member and one $500 award for the best paper by an individual member • $500 pour le meilleur article de recherche, de recensement des travaux ou d'exposé didactique arbitré publié dans l'*Acoustique Canadienne* par un membre étudiant et $500 pour le meilleur article par un membre individuel.

STUDENT PRESENTATION AWARDS • PRIX POUR COMMUNICATIONS ÉTUDIANTES

Three $500 awards for the best student oral presentations at the Annual Symposium of The Canadian Acoustical Association. • Trois prix de $500 pour les meilleures communications orales étudiant(e)s au Symposium Annuel de l'Association Canadienne d'Acoustique.

STUDENT TRAVEL SUBSIDIES • SUBVENTIONS POUR FRAIS DE DÉPLACEMENT POUR ÉTUDIANTS

Travel subsidies are available to assist student members who are presenting a paper during the Annual Symposium of The Canadian Acoustical Association if they live at least 150 km from the conference venue. • Des subventions pour frais de déplacement sont disponibles pour aider les membres étudiants à venir présenter leurs travaux lors du Symposium Annuel de l'Association Canadienne d'Acoustique, s'ils demeurent à au moins 150 km du lieu du congrès.

UNDERWATER ACOUSTICS AND SIGNAL PROCESSING STUDENT TRAVEL SUBSIDIES • SUBVENTIONS POUR FRAIS DE DÉPLACEMENT POUR ÉTUDIANTS EN ACOUSTIQUE SOUS-MARINE ET TRAITEMENT DU SIGNAL

One $500 or two $250 awards to assist students traveling to national or international conferences to give oral or poster presentations on underwater acoustics and/or signal processing. • Une bourse de $500 ou deux de $250 pour aider les étudiant(e)s à se rendre à un congrès national ou international pour y présenter une communication orale ou une affiche dans le domaine de l'acoustique sous-marine ou du traitement du signal.


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--- FIRST ANNOUNCEMENT ---

ACOUSTICS WEEK IN CANADA

Niagara-on-the-Lake, 14 - 16 October 2009

Acoustics Week in Canada 2009, the annual conference of the Canadian Acoustical Association, will be held in Niagara-on-the-Lake, Ontario from 14 to 16 October 2009. This is the premier Canadian acoustical event of the year, and is being held in beautiful, quaint Niagara-on-the-Lake village, making it an event that you do not want to miss. The conference will include three days of plenary lectures, technical sessions on a wide range of areas of acoustics, the CAA Annual General Meeting, an equipment exhibition, and the conference banquet and other social events.

Venue and Accommodation – The conference will be held at the Pillar & Post Inn, Niagara-on-the-Lake, Ontario [http://www.coasthotels.com/hotels/canada/bc/vancouver/coast_plaza/overview]. Pillar and Post is located in a quiet residential area, surrounded by a wonder of gardens and only a five minute walk from Niagara-on-the-Lake's main street. Originally built in the late 1800s, it was used as a canning factory in the midst of Niagara's wine and fruit region. Since 1970 it has been gradually transformed into a luxurious country inn with 122 newly redesigned guestrooms, plus ample meeting space with the latest business amenities. Participants registering with the hotel before 5 September 2009 will receive the reduced room rate of $179/night (single or double). Stay at the conference hotel to be near all activities and your colleagues, and to help make the conference a financial success, to the benefit of all CAA members.

Plenary Lectures – Plenary lectures will be presented in the areas of Architecture & Acoustics, Psychological Acoustics and Bio Acoustics.

Special Sessions – Special sessions consisting of invited and contributed papers are currently being organized on the following topics:

- Architectural and Classroom Acoustics
- Acoustic Ecology and Soundscape
- Sound Absorbing Materials
- Biomedical Acoustics
- Speech Production, Speech Perception and Speech Disorders
- Noise Control
- Aeroacoustics
- Acoustical Consulting—Challenges and Opportunities
- Occupational Noise Standards
- Psychological Acoustics
- Vibroacoustics

If you would like to propose and/or organize a special session in your technical area, please contact the Conference Chair or Technical Co-Chair as soon as possible.

Equipment Exhibition – The conference will include either one or two one-day exhibitions of acoustical equipment and products on Thursday and/or Friday, 15 and 16 October 2009. If you are an equipment supplier interested in participating in the exhibition, please contact the Exhibition Coordinator as soon as possible.

Social Events – The conference will begin on Wednesday morning with an opening ceremony and welcome by Prof. Kendra Schank Smith, Chair, Architectural Science Department, Ryerson University. On Wednesday evening, a reception will be held for all delegates, followed by a potential Soundscape Walk along the village's main street as well as a musical listening experience, "EMOTICHAIR."

Courses / Seminars – If you would like to propose to offer a course / seminar in association with Acoustics Week in Canada, please contact the Conference Chair. Assistance can be provided in accommodating such a course / seminar, but it must be financially independent of the conference.

Student Participation – The participation of students is strongly encouraged. Travel subsidies and reduced registration fees will be available. A hotel room-sharing program will be available to reduce costs. Student presenters are eligible to win prizes for the best presentations at the conference.

Paper Submission – Following are the deadlines for submission of abstracts, and of two-page summaries for publication in the proceedings issue of *Canadian Acoustics*: submission of abstracts: 1 June 2008; submission of two-page summaries: 15 July 2008.

Registration – details of registration fees and the registration form will be made available on the conference website. Early registration at a reduced fee is available until 5 September 2009.

Local Organizing Committee

- *Conference Chair: Ramani Ramakrishnan [rramakri@ryerson.ca]*
- *Technical Co-Chair: Frank Russo [russo@ryerson.ca]*
- *Technical Committee: Ben Dyson [bdyson@ryerson.ca]*
- *Local Co-Chair: Moustafa Osman [moustafa.osman@sympatico.ca]*
- *Treasurer: Dalila Guisti [dalila@jadeacoustics.com]*
- *Equipment Exhibition: Rich Peppin [RPeppin@aol.com]*
- *Registration: Mandy Chan [machan@hgcengineering.com]*
- *Registration: Megan Munro [mmunro@hgcengineering.com]*
- *Registration: Payam Ezzatian [payam.ezzatian@gmail.com]*
- *Website: Payam Ashtiani [pashtiani@aercoustics.com]*
- *Translations: Inna Petrennic [inna@echologics.com]*

Conference Website at http://www.caa-aca.ca/

--- PRÉMIÈRE ANNONCE---

SEMAINE CANADIENNE D'ACOUSTIQUE

Niagara-sur-le-Lac, 14-16 octobre 2009

la conférence annuelle de l'Association Canadienne d'Acoustique se tiendra à Niagara-sur-le-Lac en Ontario du 14 au 16 octobre 2009. Il s'agit de plus important événement canadien de l'acoustique de l'année que vous ne voulez pas manquer, car il aura lieu à Niagara-sur-le-Lac, un bel et pittoresque village. Trois jours de sessions plénières, ainsi que des sessions techniques seront présentées, couvrant un large éventail du domaine de l'acoustique. La conférence comprendra aussi la réunion annuelle générale de l'ACA, l'exposition de divers équipements acoustique, un banquet et autres événements sociaux.

Lieu du congrès et hébergement – La conférence se tiendra au Pillar & Post Inn à Niagara-sur-le-Lac en Ontario [http://www.vintage-hotels.com/niagara-on-the-lake/hotels/pillar-and-post.php] dans la zone résidentielle tranquille, entourée des jardins étonnants à seulement cinque minutes de marche à pied de la rue principale de Niagara-sur-le-Lac. Construit au départ à la fin des années 1800, ce bâtiment a été conçu comme une conserverie au millieu de la région de vin et fruit de Niagara. Depuis 1970 on le transforme graduellement dans une auberge de luxe aux 122 chambres récemment renouvellées, ainsi qu'au ample espace pour des réunions avec les derniers outils de bureatique. Les délégués qui résevront leur chambre avant le cinque septembre 2009 bénéficieront d'un tarif préférentiel de 179 $/nuit (occupation simple et double). Choisissez cet hôtel pour participer pleinement au congrès, à proximité de toutes les activités et de vos collegues, et pour assurer le succès de la confèrence pour le bénéfice de tous les membres de l'ACA.

Sessions plénières – Les sessions plénières séront présentées dans les domaines de l'architecture and l'acoustique, la psychoacoustique et la bioacoustique.

Sessions spéciales – Des sessions présentées par des conférenciers invités ou par des communications soumises par les délégués sont actuellement organisées autour de divers sujets, tels que:

- Acoustique architecturale et de salles de classe
- Ecoacoustique et Soundscape
- Matériaux absorbants
- Acoustique biomédicale
- Production, perception et troubles de langage
- Contrôle de bruit
- Aéroacoustique
- Consultation en acoustique – les difficultés et les opportunités
- Normes du bruits au travail
- Psychoacoustique
- Vibroacoustique

Si vous désirez suggérer un sujet de session spéciale et/ou organiser une de ces sessions, veuillez communiquer avec le président du congrès ou le directeur scientifique.

Exposition technique – La Conférence comprendra deux expositions d'équipement et de produits de l'acoustique, qui auront lieu jeudi et vendredi, le 15 et le 16 octobre 2009. Si vous êtes un fournisseur d'équipement intéressé de participer, veuillez contacter la personne en charge de la coordination de l'exhibition le plus vite possible.

Activités – La conférence débutera le mercredi matin avec une cérémonie d'ouverture et un discours de bienvenue par Kendra Schank Smith, professeur et directeur du Département d'architecture à l'Université Ryerson. Mercredi soir, une réception est prévue pour tous les délégués, suivie par une marche Soundscape le long de la rue principale du village, ainsi qu'un concert musical "EMOTICHAIR".

Cours / Séminaires – AFin de présenter un cours/séminaire en association avec la semaine canadienne d'acoustique, veuillez contacter le président du comité d'organisation. Sous condition d'une indépendance financière, l'accommodation d'une cours/séminaire pourra être appuyée.

Participation étudiante – La participation d'étudiants au congrès est vivement encouragée. Des aides financières pour le déplacement et une réduction pour l'inscription seront mises à disposition. Un programme pour faciliter le partage des chambres sera mis sur pied pour réduire les dépenses. Les étudiants présentant leurs travaux seront éligibles pour les prix des meilleurs présentations au congrès.

Soumission des présentations – Les dates limites pour soumission pour la publication dans l'issue en cours de "L'Acoustique Canadienne" sont le 1 juin 2009 pour les résumés at le 15 juillet 2009 pour les sommaires de deux pages.

Inscription – Les détails ainsi que le formulaire d'inscription seront mis en ligne sur le site Web de la conférence. Une réduction sera effective pour tout inscription avant le cinque septembre 2009.

Comité d'organisation

- *Président: Ramani Ramkrishnan [rramakr@ryerson.ca]*
- *Directeur scientifique: Frank Russo [russo@ryerson.ca]*
- *Comité scientifique: Ben Dyson [bdyson@ryerson.ca]*
- *Directeur: Moustafa Osman [moustafa.osma@sympatico.ca]*
- *Trésorier: Dalila Guisti [dalila@jadeacoustics.com]*
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- *Inscription: Mandy Chan [machan@hgcengineering.com]*
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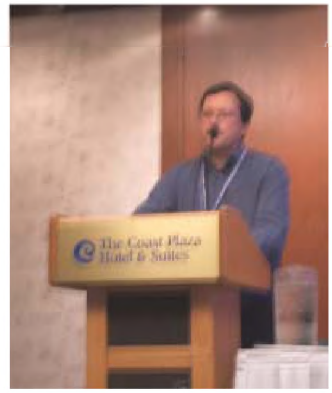
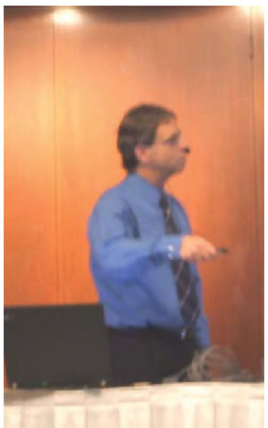
Site Web de la conférence à http://www.caa-aca.ca/

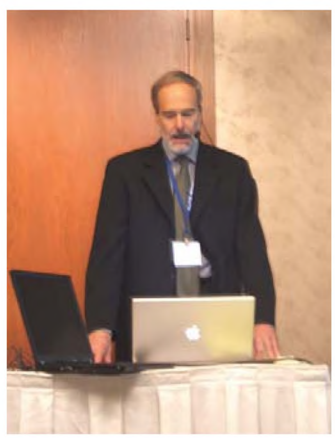
Acoustics Week in Canada / Semaine canadienne d'acoustique
Vancouver, 6-8 October/octobre 2008
--- Photo Report / Rapport en photos ---
by/par Murray Hodgson

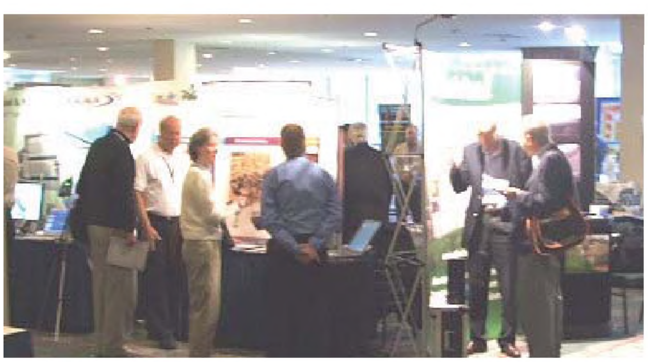


Conference words of welcome /
Mots de bienvenue au congrès



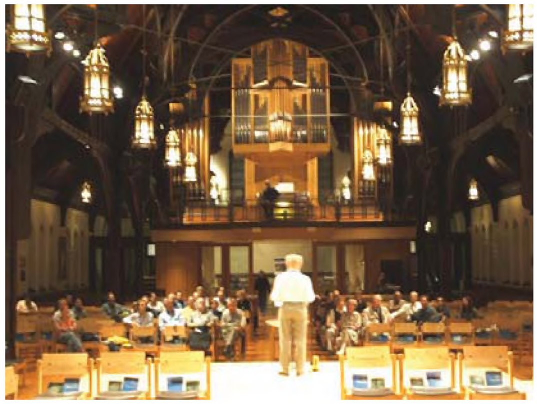
Plenary lectures / Sessions plénières

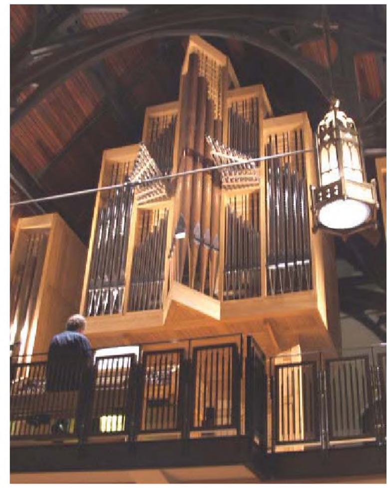




Exhibition Exposition

Visit to / Visite à Christ Church Cathedral





Banquet with performance by AUGUST /
Banquet avec concert par AUGUST

Student awards / Prix étudiant(e)

Local organizing committee

Mark Bliss
Kimary Shahin
Christine Harrison
Hind Sbihi

Comité organisateur

Murray Hodgson
Mark Cheng
Bernadette Duffy
Linda Rammage

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Le nombre juxtaposé à chaque inscription réfère aux champs d'intérêt tels que condifés ci-dessous

Areas of interest		Champs d'intérêt
Architectural Acoustics	1	Acoustique architecturale
Engineering Acoustics / Noise Control	2	Génie acoustique / Contrôle du bruit
Physical Acoustics / Ultrasonics	3	Acoustique physique / Ultrasons
Musical Acoustics / Electro-acoustics	4	Acoustique musicale / Electroacoustique
Psycho- and Physio-acoustics	5	Psycho- et physio-acoustique
Shock and Vibration	6	Chocs et vibrations
Hearing Sciences	7	Audition
Speech Sciences	8	Parole
Underwater Acoustics	9	Acoustique sous-marine
Signal Processing / Numerical Methods	10	Traitement des signaux / Méthodes numériques
Other	11	Autre

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General Presentation: Papers should be submitted in camera-ready format. Paper size 8.5" x 11". If you have access to a word processor, copy as closely as possible the format of the articles in Canadian Acoustics 18(4) 1990. All text in Times-Roman 10 pt font, with single (12 pt) spacing. Main body of text in two columns separated by 0.25". One line space between paragraphs.

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