

# RESEARCH AT MARCS AUDITORY LABORATORIES, UNIVERSITY OF WESTERN SYDNEY

Denis Burnham, Kate Stevens, Bruno DiBiase, Jörg Buchholz, Christine Kitamura,  
Stephen Malloch, Mark Wiggins

MARCS Auditory Laboratories,  
University of Western Sydney, Sydney, NSW 1797  
marcs@uws.edu.au

**ABSTRACT:** MARCS Auditory Laboratories is a University Research Centre at the University of Western Sydney. MARCS specialises in research on speech, music, and auditory processes. This paper elaborates particular research strands in MARCS – Auditory Processes and Speech Technology, the Baby Lab, Communicative Musicality, Human Factors and Performance, Music Cognition, Second Language Acquisition, and Speech and Language, and describe current projects in each of these strands. This is followed by a brief history of the Centre and its role at UWS.

## 1. MARCS AUDITORY LABORATORIES

MARCS is a research centre for basic and applied research on auditory perception and cognition, with particular focus on the significant domains of speech and music. Since the inception of MARCS in 1999 it has developed a dynamic and vibrant research culture that has attracted researchers with common interests in auditory research. Our members' backgrounds vary - experimental psychology, various branches of linguistics, music, electrical engineering, and we work with people from a range of disciplines, including music, linguistics, phonetics, computer science, human performance, and engineering, using our skills in cognitive science, research design, statistical analysis, and computer programming. So, while MARCS is a broad church, it has a particular methodological leaning (laboratory-based experimental psychology and related approaches) and subject matter (auditory research) which direct our enterprise.

In this paper, we first discuss various representative research projects at MARCS, and follow this with some background information regarding the University of Western Sydney, and MARCS.

## 2. REPRESENTATIVE RESEARCH AT MARCS

A range of research is conducted at MARCS, and the breadth of work is conveniently collected under our 7 labs, the Auditory Processes and Speech Technology, the Baby Lab, Communicative Musicality, Human Factors and Performance, Music Cognition, Second Language Acquisition, and Speech and Language. Examples of recent research projects in these labs are provided in the following sections.

### **Auditory Processes and Speech Technology Lab**

*Lab Leader: Dr Jörg Buchholz*

#### ***Modeling the auditory signal processing of reverberant sounds***

The well-known cocktail party effect shows that we humans monitor various concurrent sounds in our environment, and parse their spatial and information content. For machines and in mathematical modelling, cocktail-party processors are often applied to separate the superimposed signals. Although such techniques show promising results in simple scenarios, they usually fail in realistic – especially reverberant – environments. However, the human listener is able to perform this complex signal separation task, by applying sophisticated monaural and binaural signal processing. Hence, it is very important to understand and to model these auditory processes in order to employ them in modern cocktail-party processors.

In this regard, the phenomenon of room reflection masking has been investigated in our lab and a model describing the underlying auditory processes has been proposed. The proposed model is composed of four main stages: (a) bandpass filterbank stage, (b) Signal Dependent Compression (SDC) stage, (c) Equalization-Cancellation (EC) stage, and, (d) decision device stage. According to this model-structure, the SDC stage represents the important monaural mechanisms, and the EC stage the important binaural mechanisms. The model has been adjusted to simulate known psychoacoustic data on a test reflection being masked by a direct sound as well as being masked by the direct sound plus an additional reflection.

With reference to the first masking condition, it was found that an auditory model, which is solely based on monaural processes, could successfully describe the involved auditory processes. With reference to the second condition, it was found



The MARCS artificial head "Gustav" listening to a performance in the Sydney Opera House.

that binaural processes also need to be considered, processes that seem to be successfully described by the employed EC-approach. Furthermore, the proposed auditory model has been employed to predict the masking effect of a complete room impulse response, revealing that monaural processes play an important role in such complicated conditions.

#### **Baby Lab**

*Lab Leader: Dr Christine Kitamura*

#### **Reorganisation of speech perception in infancy**

Young infants understand aspects of speech well before they can speak themselves. Newborns perceive a wide variety of speech sounds but then between 6 and 9 months they begin to focus especially on the sounds that are used in their own language and disregard those used in other languages. This has been found for consonants and vowels, but the development of the perception of tone in infancy has been relatively neglected. Tone, the use of pitch movements and associated cues to convey meaning at the lexical level, is used in Asian tone languages such as Cantonese, Mandarin and Thai, various West African register languages, and pitch-accent languages such as Japanese and Swedish, languages spoken by over half the world's population. Now PhD student, Karen Mattock, using a reinforced head-turn procedure, has established that Chinese babies continue to focus on tone variations in words, as they get older, while Australian English babies (for whom lexical tone is phonologically irrelevant) reduce their attention to tones between 6 and 9 months. However, when the same tones are presented as musical pitches, Australian English infants' attention remains unchanged between 6 and 9 months. Further studies will be conducted on infants' use of tone information to learn new words. The results have implications for second language learning, identifying language deficits, designing appropriate interventions, and for machine recognition and synthesis of Chinese.

#### **Communicative Musicality Lab**

*Lab Leader: Dr Stephen Malloch*

#### **Communication and education: the case of Teacherese**

A major factor in children's early development is the nature of the interactions with those who feature significantly in their lives – primary care givers, peers and mentors. Recognition of the inter-connectedness of a child's cognitive, social and emotional development highlights the interpersonal or intersubjective nature of communication and education. What encourages a person to engage with another? Certainly the content of the exchange will be important, but what of the underlying dynamics of the interchange?

We investigated the relationship between rated degree of engagement between primary-school classes and their teachers and timing characteristics of the verbal exchanges in these classes. This research comes out of previous work suggesting that communication between a parent and a young infant takes place through the intentions (underlying impulses for action) and affect carried by the 'music-like' qualities of their joint vocalisations in combination with the joint 'dance-like' gestures of their bodies and facial movements within a shared sense of time – communicative behaviour called communicative musicality. Stephen Malloch and Rudi Crncec from the Communicative Musicality Lab teamed up with Catherine Scott from the School of Education at the University of New England. Using the model of *communicative musicality* as a theoretical framework, the aim was to investigate the hypothesis that the more engaged the students are with the teacher, the more 'harmonious' the classroom interaction. A more harmonious interaction was defined as one with fewer interruptions and overlapping turns and fewer instances of student-to-student talking while the teacher was talking. Video recordings were collected of three teachers from three schools instructing 7/8 year olds. Extracts from these video recordings were rated for class engagement by seven expert raters. Measurements were made of timing categories in the vocal interactions between teacher and students, and ratings and measures were statistically compared. Significant correlations were found between ratings and those vocal timing categories related to teacher-student interaction. As the communicative musicality model would predict, ratings of low engagement were associated with vocal timing that suggested a more disrupted classroom interaction style, and ratings of high engagement were associated with vocal timing that suggested a more 'harmonious' interaction style.

#### **Human Factors and Performance Lab**

*Lab Leader: Dr Mark Wiggins*

#### **Information acquisition, expertise, and decision-making in advanced technology environments**

There is considerable evidence to suggest that human operators rely on a series of visual, auditory, and/or tactile cues as the basis for their decisions. These cues are extracted from a complex array of stimuli within the operational environment and their significance is usually determined by previous experience. Although the importance of cues has been recognised for some time, the acquisition of cues and the way in which cues interact to impact performance has been

difficult to establish. Our present research involves the development and evaluation of a theoretical model of cue acquisition and integration as the basis for improving human performance within applied industrial environments such as aviation. In our most recent study, 50 pilots were asked to conduct a simulated in-flight diversion, the information pertaining to which was presented in one of three formats. These formats were based on three different types of decision heuristics (rules of thumb). The results indicated that the successful integration of cue-based information was dependent upon a number of factors, including the proximity and perceived relationship between different forms of cue-based information. We also observed differences between experienced and inexperienced pilots in terms of the ease with which they perceived the task. Specifically, experienced pilots preferred an environment in which task-related information could be acquired quickly and efficiently, whereas inexperienced pilots preferred an approach in which they could plan the sequence with which information would be presented. While the latter was more time-consuming, it resulted in more accurate results than might otherwise have been the case. Overall, the results suggest that the process of information acquisition is mediated, in part, by previous experience in the domain. This has important implications for the future development of decision support systems.

#### **Music Cognition Lab**

*Lab Leader: Dr Kate Stevens*

#### *Using novel and familiar melodies to investigate episodic memory for music*

The Music Cognition Lab applies methods from experimental psychology to investigate perception, cognition, and production of music. Western tonal music is an effective stimulus and tool to examine general auditory perceptual and cognitive processes as it is highly structured, gives rise to learned expectancies, and can be either novel or familiar. Research topics covered by our six postgraduate research students include pitch and time perception, synchrony and additivity of visual and auditory cues in marimba performance, attentional capture for expressive movement, the role of contour in recognition of speech and music, and development of a psychometric scale for measuring psychological responses to dance and music.

A recently published experiment used novel and familiar melodies to investigate episodic memory for music. Melodies were presented either once or three times, either on Day 1 or Day 2, and participants made judgments about the recency and frequency of presentation of the melodies. Differences emerged between accuracy of judgments of recency and frequency, and this interacted with whether melodies were novel or familiar. More specifically, the results indicated that episodic recognition of novel melodies is based more on a generalized "feeling of familiarity" than a specific episodic memory. Frequency information contributes more strongly to this generalized memory than recency information, and formation of an episodic memory for a melody depends either on the overall familiarity of the stimulus or the availability of a verbal label.

Other developments in the Music Cognition Lab include the validation of the Audience Response Tool (ART) developed by PhD student Ms Renee Glass. The ART records open-ended and rating scale responses to live performance of dance or music. Responses include cognitive, interpretative, aesthetic, and affective responses. The ART is now also available on hand-held computers and, as well as recording questionnaire data *after* a performance, real-time continuous measures can be made as a performance unfolds. The computerised version of the ART and continuous recording devices were trialed during a performance of Sue Healey's *Fine Line Terrain* at the Sydney Opera House on July 2, 2004.

#### **Second Language Acquisition Lab**

*Lab Leader: Mr Bruno Di Biase*

#### *Italian L2 learning programs in primary schools*

The Second Language Acquisition Laboratory conducts investigations in two broad areas: acquisition of second language (L2) in instructional environments, and bilingual first language acquisition. Both strongly relate to the multilingual nature of Australian (particularly urban) environments and have implications for the success of language instruction and learning in educational settings (especially with the increasing presence of overseas students), as well as for the maintenance of languages in bilingual families and community environments. The Lab is currently investigating acquisition of Chinese-English (Ruying Qi), Japanese L2 (Satomi Kawaguchi), Japanese-English (Yuki Itani-Adams), Arabic L2 (Stuart Campbell) Italian L2 and Spanish L2 (Di Biase), and English L2 (Campbell, Di Biase, Kawaguchi). The Lab's theoretical orientation is mainly based on Processability Theory (PT) devised by Piensman and others. This provides a cross-linguistic instrument for measuring language development as well as a common point of reference for language processing in both corpus-based approaches and on-line experimentation.

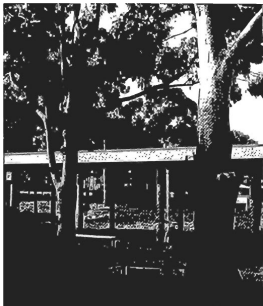
A large project, recently completed with ARC support, by Bruno Di Biase and Patrizia Berti along with other researchers and teachers involved a classroom-based longitudinal study of Italian L2 learning programs in three primary schools. The effectiveness of form-focusing techniques in instructed language development was assessed via videorecordings taken over an 18-month period, using metrics provided by PT. It was found that L2 programs in schools provide considerable lexical support but little, if any, grammatical development. This may be partly accounted for by the decidedly limited exposure children may have to the L2 in the school environment. However, on the other hand, the project shows that even moderate doses of (developmentally moderated) form-focused instruction appear to bootstrap grammatical development in the learners.

#### **Speech and Language Lab**

*Lab Leader: Prof Denis Burnham*

#### *Seeing is Hearing*

Optical information from facial movements of a talker contributes to speech perception not only when acoustic information is degraded or when the listener is hearing-



The delightfully rural campus of the University of Western Sydney in Bankstown.

impaired, but also when the acoustic information is clearly audible. This is most clearly shown in the classic McGurk effect, in which dubbing the auditory speech syllable [ba] onto the lip movements for [ga] results in the emergent perception of "da" or "tha". Intuitively one would assume that there is little or no visual speech information for the pitch variations associated with lexical tone in languages such as Cantonese and Thai. However, recently at MARCS labs we have found that Cantonese perceivers identify better than chance the Cantonese word being said from visual information alone, when given 6 alternatives with identical phonetic, but differing tonetic information. Additionally, visual speech information augments auditory discrimination for pairs of Cantonese words differing only in tone for Cantonese perceivers, for tone language perceivers unfamiliar with Cantonese tones (Thais), and even for non-tone language (Australian English) perceivers! Currently we are, with our collaborators at ATR labs in Japan, conducting speech production studies using a combination of signal processing, biological, and behavioural techniques (including OPTOTRAK to track the movement of the face during speech) to identify the essential characteristics of tone, affect, and identity and develop a comprehensive model of auditory-visual speech processing and communication. This research will have implications for understanding of the basis of auditory-visual perception and production in tonal languages and in affective communication, facilitate links between neurophysiological processes and auditory-visual speech processing; and contribute to applications in automatic person recognition, automatic speech recognition, text-to-speech systems, and talking head aids for the hearing impaired.

### 3. BACKGROUND

#### The University of Western Sydney

Established in 1989, the University of Western Sydney (UWS) early on realised that research concentrations in niche areas were both in line with emerging Department of Education, Science and Technology, and Australian Research Council (ARC) policy, and an effective way to realise this goal in a new university. UWS provides internal funding to its research centres, and encourages both internal grant applications through, and higher degree research places at these centres. By such means UWS has facilitated the development of a small number of research centres of excellence, and MARCS Labs is one of these.

#### MARCS Auditory Laboratories

UWS is situated on six campuses, and MARCS is situated on the Bankstown campus. MARCS has significant affiliations and collaborations with other UWS groups – the School of Psychology, the School of Languages and Linguistics, the Centre for Advanced Systems Engineering, and the Precision Robotics Research Group.

MARCS Auditory Laboratories grew out of the Macarthur Auditory Cognition Laboratory (MACL), which was formed in 1996 under the direction of Dr Kate Stevens. Identifying a niche in Australian research, Dr Stevens applied for University funding for MACL in 1997, obtained funding in 1998 and attracted Denis Burnham from the University of NSW as inaugural director. In 1999 MARCS began life as a Research Centre at the then University of Western Sydney, Macarthur, and continued as such until in 2001 when the three members of UWS amalgamated and MARCS became a University Research Centre at the new unified University of Western Sydney.

Support from the University of Western Sydney, and the College of Arts, Education and Social Sciences, and hard work by our collaborators and a dedicated bunch of academic, research and support staff in MARCS has allowed MARCS to grow and augment their external funding, increase PhD and Research Masters student load and timely completions, and build our equipment and lab infrastructure.

MARCS now consists of around 60 members, the Director, Professor Denis Burnham, and Deputy Director, Dr. Kate Stevens, the newly appointed Professor Cathi Best, 5 members from the School of Psychology and the School of Languages and Linguistics, 2 Research Fellows, 3 Postdoctoral Fellows, 1 Honorary Adjunct Professor, 3 Honorary Adjunct Fellows, 20 Higher Degree (PhD or Masters) Students, in any year around 10 Honours or Graduate Diploma Students, affiliates from the Precision Robotics Research Group, and the Centre for Advanced Systems Engineering, 6 Research Assistants, a Business Manager, a Technical Services Team Leader, 2 Software Engineers, and an Administrative Assistant. There are 15 testing laboratories and accompanying office space and recent university grants of space and funds have enabled the initiation of a building program (due for completion in September, 2004) which will double lab and office space. Facilities consist of sound proof

## Interlude

### INTERLUDE

#### MY FAVOURITE ACOUSTICS BOOKS

For those of you who have not edited a journal such as *Acoustics Australia* — and I expect that is nearly everyone — there are matters that are hidden from view, or at least that should be. Have you ever noticed that every issue of the journal has a number of pages that is a multiple of four? How is this managed? It would perhaps be relatively simple to do if the Editors possessed a pile of material that was awaiting publication from which to select items of appropriate length and style, but unfortunately this is rarely the case. So, with Marion Burgess away overseas attending the INTERNOISE conference in Prague, I am faced with an issue that is one page short of the necessary quadruple multiple, and there is nothing in the IN-tray with which to fill it! Hence this interlude.

What, I asked myself, would be an appropriately interesting filler? As I look around my office I see bookshelves filled with volumes on many branches of physical science, and among them many volumes on acoustics. The collection, of course, reflects my own individual interests, so that there are large gaps — environmental acoustics being the most noticeable one. But what is left? I have a good collection of books dealing with the fundamentals of the subject, but particularly books on musical and biological acoustics. I hope you will be interested if I share with you my views on some of the best of these. If I have found them interesting and helpful, I am sure you will too.

#### General and Historical Acoustics

Several excellent books have been written about the history of acoustics, which goes back to the time of Pythagoras some 2500 years ago. Among those I find most informative and interesting are Frederick Hunt's *Origins in Acoustics* [1] and Robert Beyer's *Sounds of Our Times* [2]. In addition, of course, I have copies of Rayleigh's *The Theory of Sound* (1894), Helmholtz's *On the Sensations of Tone* (1885) and James Jeans' *Science and Music* (1937), all available as Dover reprints.

#### Acoustical Fundamentals

Apart from numerous conference proceedings, the most general set of books I have is the *Encyclopedia of Acoustics*, a modern comprehensive treatment of the subject edited by Malcolm Crocker [3]. This is where I go to find out in detail about many subjects with which I am not familiar. It covers everything from fairly basic to highly applied in a compact and informative manner.

If I wanted to remind myself of fundamentals, then I would consult *Fundamentals of Acoustics* by Kinsler and Frey, or the more recent edition with two extra authors [4], an easily readable and comprehensive book designed for advanced undergraduates. More technical and more detailed is the excellent *Acoustics* by Leo Beranek, reprinted in soft covers by the Acoustical Society of America [5].

booths, speech and music recording labs, speech/music analysis editing and synthesis facilities, purpose-built infant testing labs, simulation lab, movement analysis lab incorporating PEAK Motus and Optotrak movement tracking devices, a Portable Audience Response Facility, an anechoic chamber and 3D audio lab, and an EEG/ERP (event related potential) lab.

#### Organisations Associated with MARCS

MARCS is the administrative hub for the Australian Music & Psychology Society (AMPS). AMPS hosts seminars on the nexus between psychology and music, drawing an audience of staff and graduate students from psychology, music, education, physics, architecture, and acoustics.

MARCS Director Denis Burnham is the President of ASSTA, the Australian Speech Science and Technology Association, the peak speech science and technology association in Australia. He is also Vice Chairman of AVISA, the Auditory-Visual Speech Association, which is a Special Interest Group of ISCA, the International Speech Communication Association (ASSTA's international counterpart).

#### An Invitation ...

MARCS is always ready to collaborate with people in areas of mutual interest; that is how we and others learn and push back the frontiers of science. We invite researchers, industry personnel, individuals to contact us about possible joint projects, consultancies, contract research. Consider the research reported above and find out more on our web page. You might like to visit MARCS and give an informal talk at one of our MMs (Monday MARCS Meetings – see web address below), have a look around, and talk about your research and possible collaborations. (We are just 25 minutes from the city, and right next to the M5!) For all these or any other questions please contact MARCS Director, Professor Denis Burnham at [d.burnham@uws.edu.au](mailto:d.burnham@uws.edu.au)

We look forward to hearing from you.

#### Web Addresses

MARCS Auditory Laboratories,

[UWS: http://marcs.uws.edu.au/](http://marcs.uws.edu.au/)

Monday MARCS Meetings:

<http://marcs.uws.edu.au/events/mmm/index.htm>

Centre for Advanced Systems Engineering, UWS:

<http://www.uws.edu.au/research/researchcentres/case>

Precision Robotics Research Group, UWS:

<http://www.uws.edu.au/about/acadorg/cste/researchtraining/researchlinks/prrg#2>

Australian Music & Psychology Society (AMPS):

<http://marcs.uws.edu.au/links/amps/> See this website and/or contact the convenor, Kate Stevens ([kj.stevens@uws.edu.au](mailto:kj.stevens@uws.edu.au)) to receive details of AMPS seminars.

Australian Speech Science and Technology Association:

<http://www.assta.org/>

AVISA, the Auditory-Visual Speech Association:

<http://marcs.uws.edu.au/links/avisa/default.htm>

ISCA, the International Speech Communication Association:

<http://www.isca-speech.org/>

#### Publications

A list of publications from MARCS researchers, classified by field, can be viewed on the web-site <http://marcs.uws.edu.au/>