Not being able to hear isolates you from people. Not being able to see isolates you from objects. Together they are working to better understand sound signals in background noise.

PhD student, Aswin Wijetillake, benefits from the advanced two-dimensional sound laboratory in his research with cochlear implantee Peter Goodman –

IMMANUEL KANT
THE HEARING COOPERATIVE RESEARCH CENTRE IS FOCUSED ON THE TWIN CHALLENGES OF MORE EFFECTIVE PREVENTION AND IMPROVED REMEDIATION OF HEARING LOSS.
The Hearing CRC is a multidisciplinary collaboration of five core and 21 support members, each of which contributes specific expertise and infrastructure to our research, commercialisation and education programs.

Core Members

Support Members

The CRC ing

The Hearing CRC
550 Swanston Street
Audiology, Hearing and Speech Sciences
The University of Melbourne

Neuro

monics

Tinnitus Treatment

hybrid

electronic

Acoustics Pty Ltd
(03) 9035 5347
(03) 9347 9736
enquiry@hearingcrc.org
www.hearingcrc.org

The Hearing Cooperative Research Centre is focused on the twin challenges of more effective prevention and improved remedia
tion of hearing loss.

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"Not being able to see isolates you from objects. Not being able to hear isolates you from people.”

IMMANUEL KANT

PhD student, Aswin Wijetillake, benefits from the advanced two-dimensional sound laboratory in his research with cochlear implantee Peter Goodman – together they are working to better understand sound signals in background noise.

"Creating sound value"
<table>
<thead>
<tr>
<th>Year</th>
<th>Event</th>
<th>Details/Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>1992</td>
<td>The CRC undertook the development of the Nucleus 24M implant system.</td>
<td>Many generations of language samples were analysed to determine the effectiveness of the Nucleus 24M technology in improving spoken language comprehension.</td>
</tr>
<tr>
<td>1996</td>
<td>The CRC filed the first patent for the Nucleus 24R implant system.</td>
<td>The development of the Nucleus 24R implant system, which included a curved electrode, enabled closer positioning to neural structures.</td>
</tr>
<tr>
<td>1999</td>
<td>The CRC worked with Cochlear Ltd on the development of the Nucleus 24R implant system.</td>
<td>The Nucleus 24R system was developed to improve hearing in profoundly deaf individuals.</td>
</tr>
<tr>
<td>2001</td>
<td>The CRC developed the Di-El technology.</td>
<td>The Di-El technology was integrated into hearing aid fitting algorithms, allowing for more natural and effective hearing aid prescription.</td>
</tr>
<tr>
<td>2006</td>
<td>The CRC developed the ADRO® sound processing software.</td>
<td>This soft-tipped version of the ADRO® technology was designed to minimise force and trauma to the tympanic membrane.</td>
</tr>
<tr>
<td>2008</td>
<td>The CRC successfully mapped the SRL technology.</td>
<td>The SRL technology was developed to improve hearing in individuals with profound hearing loss.</td>
</tr>
<tr>
<td>2012</td>
<td>The CRC launched the HEARNet project.</td>
<td>HEARNet is a national research network that provides a platform for hearing researchers and clinicians to collaborate and share knowledge.</td>
</tr>
<tr>
<td>2014</td>
<td>The CRC filed the first patent for the Nucleus 24R implant system (second generation).</td>
<td>The second generation of the Nucleus 24R implant system was designed to improve upon the first generation in terms of performance and patient satisfaction.</td>
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The CRC has contributed significantly to the field of cochlear implantation and hearing rehabilitation, developing innovative technologies and strategies to improve the quality of life for individuals with hearing loss.
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<td>1992</td>
<td>The Nucleus 24M stimulator that formed sound processors and adult and paediatric speech processors worldwide, enabling individuals with hearing loss to analyse spoken words and have been issued licences to 120,000 recipients.</td>
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<tr>
<td>1995</td>
<td>The CRC worked with Cochlear Ltd on the development and clinical trials to assess the contour electrode that enabled longer electrode preserves residual hearing and was implemented in over 51,000 recipients.</td>
</tr>
<tr>
<td>1996</td>
<td>The CRC developed the software for use by manufacturers, this technology was integrated into test equipment and audiological systems; implanted into over 40,000 recipients.</td>
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<td>The CRC developed the Nucleus 24R implant system for the manufacture and distribution of technology will increase hearing aid fitting software for manufacturers; integrated into commercial interest.</td>
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<td>2000</td>
<td>The CRC worked closely with the ear speech processors ESPrit22 and ESPrit 3G behind the contour electrode that required reengineering issues with body noise and continue to use.</td>
</tr>
<tr>
<td>2001</td>
<td>The CRC worked with Cochlear Ltd on the development and clinical trials of the Nucleus 5 systems. Three people trained off-stylet™ advance off-stylet™ and continue to use.</td>
</tr>
<tr>
<td>2002</td>
<td>The CRC established spin-off company Di-El, which developed the first proof-of-concept and recent translated into international standard.</td>
</tr>
<tr>
<td>2003</td>
<td>The CRC worked with the ear speech processors ESPrit22 and ESPrit 3G behind the contour electrode that required reengineering issues with body noise and continue to use. The CRC also developed support of the concept.</td>
</tr>
<tr>
<td>2004</td>
<td>The CRC developed the Nucleus 24 Contour Hybrid System; implanted into over 40,000 recipients. Issues with body noise and continue to use.</td>
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<tr>
<td>2005</td>
<td>The CRC filed the first patent application for the contour electrode that enabled longer electrode preserves residual hearing and was implanted in 51,000 recipients.</td>
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<td>The CRC sold its share in 2007, the national science week. The CRC launched the hearing survey as part of the Sydney and Apia (Samoa) hearing survey as part of the Sydney and Apia (Samoa) Rehabilitation tool for adults and children with hearing loss, clinical professionals and hearing loss. The CRC also developed support of the concept.</td>
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<td>2007</td>
<td>The CRC established the CRC for Cochlear with a $7.4M Federal Government investment in the CRC's Clinical Hearing Research program.</td>
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<td>2008</td>
<td>The CRC established the CA340 program with $3.5M from the Federal Government for the development of hearing aid fitting software.</td>
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<td>The CRC established the NCE220 program with $3.3M from the Federal Government for the development of hearing aid fitting software.</td>
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<tr>
<td>2010</td>
<td>The CRC established the SRL240 program with $3.1M from the Federal Government for the development of speech recognition technology.</td>
</tr>
<tr>
<td>2011</td>
<td>The CRC established the HEARLab program with $3.0M from the Federal Government for the development of hearing aid fitting software.</td>
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<tr>
<td>2012</td>
<td>The CRC established the HEARing Education Program with $2.9M from the Federal Government for the development of hearing aid fitting software.</td>
</tr>
<tr>
<td>2013</td>
<td>The CRC established the HEARing Survey Program with $2.8M from the Federal Government for the development of hearing aid fitting software.</td>
</tr>
<tr>
<td>2014</td>
<td>The CRC established the HEARing Research Network with $2.7M from the Federal Government for the development of hearing aid fitting software.</td>
</tr>
</tbody>
</table>
Hearing loss affects one in six Australians, reducing their ability to communicate and in turn impacting on education, employment and relationships. For children, hearing is critical to development of auditory skills as well as speech and language - difficulty hearing often impacts on literacy and learning.

Our 2006 study Listen Hear! reported that hearing loss is the second most prevalent disability in Australia and ranks with asthma and diabetes in terms of burden of disability; it should in fact be considered a national health priority.

Based on these daunting statistics, the HEARing Cooperative Research Centre (CRC) was established by the Commonwealth Government to find better ways of preventing hearing loss, and to improve approaches to remediation.

We are working towards improved outcomes for adults and children with hearing loss, as well as exploring innovative service delivery options to improve access, in particular for Australians in rural and remote locales.

In its first five years, the HEARing CRC has made some genuinely significant achievements. For example all of Australian Hearing’s paediatric clinics are now equipped with CRC-developed HEARLab® which is being used in association with its first test module, Aided Cortical Assessment (ACA). This module enables rapid, reliable assessment of infants’ capacity to hear speech sounds, even when they are not able to respond verbally. Licenced to USA-based Frye Electronics, HEARlab® and ACA are increasingly being used in Europe and Asia, with release in the USA pending FDA approval.

NAL-NL2 is a further success: it is a complex hearing aid fitting algorithm now licenced to all major hearing aid companies and used as one of two international standards to fit hearing aids.

Siemens’ new Trainable Hearing Aid is also based on HEARing CRC technology. An exclusive licence enabled Siemens to be first-to-market with a product that enables the users themselves to fine tune hearing devices to meet their individual needs and preferences.

These achievements underscore the HEARing CRC’s focus on developing technology that meets both industry and clinical service needs, ultimately benefitting end-users and generating revenue for Australia.

This report focuses on our achievements over the 2011/12 year, as well as reflecting on our growing momentum. We are pleased to report the realisation of some ambitious goals in developing quality products and services for industry and clinical use.

Accomplishments have been recognised by a number of awards received by the CRC and its staff this year, all focused on collaboration, education and commercialisation, the very heart of the organisation.

HEARing CRC outcomes also continue the high profile of Australian hearing research on the world stage, and return commercial revenues to the Centre to be re-invested in new, emerging research opportunities.

This success is testimony not only to the skilled research staff employed through our Members, but also to the governance and management of this multiparty, multidisciplinary collaboration.

The HEARing CRC Board and management have been required to address the challenges of a difficult financial environment and an uncertain future, while ensuring that the CRC continues to grow as a confident and mature organisation with a sharp strategic focus.

We would like to acknowledge the contribution of all of our Directors, of our Members for their ongoing support and of our staff for their commitment. We also particularly thank the adults, children and their families, who give so generously of their time to participate in our research.

MR RICHARD SEARBY AO QC
CHAIRMAN

ASSOCIATE PROFESSOR ROBERT COWAN
CHIEF EXECUTIVE OFFICER
Hearing loss can have a significant personal, professional and social impact, as well as carrying a broad financial cost to the individual and the State. Finding new ways to protect people’s hearing from noise-induced loss, to slow its age-related deterioration and if at all possible, to prevent hearing loss in the future are central to the HEARing CRC’s activity.

HEARing CRC research has developed and is now trialling prototype hearing protection that maintains the wearer’s ambient sound exposure below damaging 85 decibel (dB) levels, allowing the user to be aware of noises in their local environment (for example approaching trucks at mining sites) but also containing inbuilt microphones and speakers to ensure that wearers can easily communicate with one another.

The prototype is being upgraded by the addition of our Beamformer [see box, page 4] and Speech Reference Limiting (SRL) technology, enhancing functionality to ensure the user has high level protection combined with maximum speech intelligibility.

SRL is a next generation technology that has application to other hearing protection devices as well as the hearing aid market. “SRL improves listening comfort and speech clarity by reducing loud noises to conversational speech levels” explains Michael Fisher, the inventor of SRL, Senior Research Engineer at the National Acoustic Laboratories and CRC Project Leader.

For hearing protection to work, it must be used. CRC research, in collaboration with the National Acoustic Laboratories, is interested in individuals’ exposure to work and leisure noise, in particular how loudness, duration and lifetime experience influences the amount of hearing damage sustained, and to better understand what factors influence individual’s use of hearing protection.

Project Leader Warwick Williams and his team participated in WorkSafe Australia’s 2011 “Getting heard: effective prevention of hazardous occupational noise”.

This involved measurement of noise levels at 50 worksites across Brisbane, Sydney and Melbourne. From this, a series of workplace labelling trials were undertaken to clearly identify areas where noise levels were above 85dB and hearing protectors should be worn. The simplicity of the approach and success of these trials should ensure the expansion of label usage across worksites in Australia by integrating their use into the Workers Code of Practice.

Project partners working in collaboration with the HEARing CRC team created an iPhone/iPad App that enables workers to make sound level recordings in their work place and produce simple noise hazard or non-hazard labels. The ‘Construction Sound Meter’ App is available from the iTunes store.

*Top:* Intelligent hearing protection prototype.  
*Centre:* SRL continuously analyses the spectral content of the sound signal to find the dominant speech levels.  
*Bottom:* Noise hazard and non-hazard labels.
EARLY DETECTION – CAN GPs BE THE FIRST LINE IN SCREENING?

Hearing loss is the second most common disability in Australia and its prevalence is increasing. This is partly due to the ageing of our population, but also reflects the long-term effects of the noisier world we live in.

In Australia we are fortunate to have a newborn hearing screening program, however adults are not routinely tested for hearing or communication problems to enable early detection and appropriate referral.

Recent trends have shown the important role that General Practitioners (GPs) can play in early detection screening for cancers, diabetes and other diseases. Professor Louise Hickson, Head of the School of Health and Rehabilitation Sciences at the University of Queensland and a Project Leader in the CRC, is passionate about improving hearing healthcare. Her team have been investigating knowledge and attitudes to hearing in the community and recently reported that GPs have a good understanding and awareness of issues surrounding hearing health.

A companion survey of GPs found that many do not routinely evaluate hearing loss in patient consultations due to time restraints, management of multiple health conditions and individuals often denying a need for hearing intervention.

“Our combined research shows that with some support from hearing health professionals and targeted education programs, GPs could be a really good front line in detecting hearing loss, in particular with elderly patients” concludes Professor Hickson. This is an area of targeted future activity for the HEARing CRC, building on established links with the GP community.

In 2010, CRC Member Australian Hearing, released *Binge Listening*, a report that detailed attitudes to and effects of excessive noise exposure in young people.

Encouraging people to protect their hearing from leisure noise is often considered a challenging task, however our research into earplug use and noise exposure from clubbing suggests that young people are more receptive to using hearing protection in such venues than had been anticipated.

This work will inform future campaigns aimed at raising awareness of the risks associated with cumulative leisure noise exposure.

**DR RACHEL BURT** is a geneticist leading a HEARING CRC project team at the Murdoch Children’s Research Institute, in association with the Walter and Eliza Hall Institute for Medical Research.

Rachel has led ground breaking analysis of programmed cell death (better known in scientific circles as apoptosis) that can cause acquired hearing loss. Her work has shaped our understanding of the molecular regulation of this process in the ear.

In association with Murigen Therapeutics, the CRC has generated a novel, highly specific and potent series of compounds that can block apoptosis – this is a first step towards the development of a molecular therapeutic for the prevention or remediation of hearing loss in the longer term.

“The CRC has given our team the creative freedom to build a multidisciplinary program of research that would not otherwise have been possible – we hope that the synergy we have been able to foster between biologists and chemists will lead to exciting new therapeutic options for people with acquired hearing loss”. 

[Image of a book titled 'Binge Listening']

ANNUAL REPORT 2010/11: HEARING NOW AND FUTURE
Both of these devices rely heavily on sound processing. Having previously developed and licenced sound processing technology such as Adaptive Dynamic Range Optimisation (ADRO®), current CRC research is focused on better coding of pitch and timing information.

Peak Derived Timing (PDT) and e-Tone are new processing strategies aimed at conveying more of the subtle sound information that arrives at each ear. Tiny differences in the timing and volume of sounds as they arrive at each ear underpin ‘bilateral hearing’ and are used by the brain to better understand the sound environment, to hear well in background noise and also to comprehend pitch. Pitch perception is of course important in the enjoyment of music (something that is often lost for cochlear implantees) but it also plays an important role in understanding tonal languages. The Asia-Pacific region relies heavily on tonal language and as such the e-Tone strategy is being much anticipated by industry Members.

Hearing aids and cochlear implants are established technologies used for the management of hearing disabilities. Hearing aids effectively increase the volume of sound for the user, whereas cochlear implants by-pass damaged sense cells in the inner ear, conveying sound information through electrical stimulation of the auditory nerve.

Hearing in noise is a common problem for people using hearing devices. The Super Directional Beamformer works to minimise background noise for the hearing device wearer such that listeners can engage in effortless one-to-one communication without losing awareness of the sounds around them. The application has already been shown to be more effective than existing commercial directional microphones and can be used in hearing aids, cochlear implants and hearing protectors.

Adjunct Professor Harvey Dillon, Director of the National Acoustic Laboratories relayed his enthusiasm for the Beamformer:

“it is the most exciting innovation that I have seen in 30 years in the hearing aid industry. I expect it will change the way the general population think about hearing aids, as some hearing impaired people wearing them will for the first time hear better than the normal-hearing people around them”.

**DR JORGE MEIJA** is a speech engineer leading hearing CRC technology development projects at the National Acoustic Laboratories.

Millions of people world-wide use hearing aids to address their individual hearing loss. As hearing aid performance has improved, their usage and acceptance has also increased. This was confirmed by a recent study from the National Acoustic Laboratories that reported non-use rates of hearing aids in Australia had decreased from 25% in 2006 to just 13% in 2012.

Hearing aids must be fitted to the individual, ensuring that they are adjusted to address the specific needs and preferences of that user. In 1999 the CRC and the National Acoustic Laboratories launched NAL-NL1, a complex algorithm to underpin the hearing aid ‘fitting procedure’ carried out by audiologists.

In 2010, based on empirical data and feedback from clinicians and end-users, NAL-NL2 was released by the CRC and...
swiftly licenced to all major hearing aid and audiological equipment manufacturers. NAL-NL2 has been incorporated into software updates and made available to over 30,000 audiologists worldwide, rapidly taking the place of its predecessor as one of two international standards for fitting. The new algorithm creates the best possible speech intelligibility for hearing aid users, while also delivering preferred loudness in different acoustic environments across manufacturer’s products.

Occlusion is the change in sound and sensation that occurs when you close your ear canal, often resulting in low pitched sounds being louder and lending an unnatural quality to your voice. This is a common cause of discomfort for hearing aid users, in particular those fitted with custom earmolds with small vents. To address this, the HEARing CRC has developed an Active Occlusion Reduction mechanism that cancels sounds originating from the ear canal, such as own-voice bone-conducted sounds and other noises transmitted through leakages and vents. Hearing aid manufacturers have indicated strong commercial interest in this new technology.

An alternative approach to improving individual comfort and performance of hearing aids is to make them ‘trainable’ by the end-user. Trainability enables the hearing aid user to fine tune their device and record settings, the hearing aid samples the sound environment and stores the information such that it is able to adjust settings as the wearer moves around and experiences different sound levels. The more times the user fine tunes the settings, the more sensitive the hearing aid can be to preferences corresponding to subtle sound changes in the world around them.

This technology has been taken up by Siemens and implemented in their current hearing aid technology.

**COCHLEAR IMPLANTS**

Over the past 20 years, the CRC has worked closely with Cochlear Ltd on the development of a series of improved electrode arrays, speech processors and speech processing strategies, all of which have enhanced the benefits available to children and adults receiving their Nucleus cochlear implant systems.

Insertion studies in human temporal bones are essential to ensuring safety and efficacy of new designs of electrode array; these precede any type of clinical trial. For example, the CRC played a key role in the development of the much-awarded Nucleus 24 Contour™ electrode array (released in 2000), and later the Contour Advance™ electrode array (released in 2003). These pre-curved electrode arrays enable optimal positioning relative to neural elements of the cochlea, shown by the CRC’s microfocus x-ray radiography images from insertion studies.

The Contour Advance™ electrode was developed for atraumatic implantation via an ‘Advance Off-Stylet™’ electrode, also trialled clinically by the CRC. The learnings were used to develop training tools for surgeons which were distributed by Cochlear Ltd worldwide.

This core collaboration has continued in the conception, development and testing of the Hybrid L24 electrode array, a shorter and thinner electrode, designed for people who have lost high frequency hearing but retain the ability to hear low frequency sounds. The Hybrid L24 array was designed to minimise insertion trauma, providing better retention of residual hearing.

Used in combination with a hearing aid in the same ear, the array provides electro-acoustic hearing remediation and improved outcomes for people with high frequency hearing loss.

Electrode design and clinical trial work is ongoing; current focus is on a next generation perimodiolar electrode array (this is a full length, slim straight design) that has been optimised for preservation of delicate cochlear structures and residual hearing. This may enable earlier implantation and gradual switch over from acoustic to electrical hearing as the implantee’s own hearing deteriorates.
Current estimates suggest that only one in five Australians with a hearing loss seek professional help. The HEARing CRC, in association with the University of Queensland and a number of other Members, have been analysing epidemiological data to increase understanding around health-seeking behaviour in older age groups with regard to hearing loss; some of this data has come from the large ‘Blue Mountains Study’ in NSW.

The CRC’s research aims to identify approaches to boost the number of people actively pursuing hearing rehabilitation [see early detection box, page 3]. Mr Steven Grundy, Managing Director of Australian Hearing, commented on the value of this work, “it is very important for us to understand how best to serve the growing aged population with our current hearing services program – we can have the best remediation in the world, but if we can’t get it to the people who need it, its worthless”.

Associated work investigating referral pathways in the hearing healthcare journey is surveying GPs, ENT specialists, audiologists and clients to identify opportunities to improve or simplify existing processes.

Detailed studies are also being conducted into the roles, responsibilities and interactions of professional groups working in hearing rehabilitation with the aim of providing greater insight into how best to manage clients. Implementing change will require strategic communication and engagement with policy makers, professional groups, educators and of course healthcare professionals; HEARnet [see box, page 9] will play a central role in these activities.

**EVIDENCE BASED PRACTICE**

It is important that clients receive the best possible advice from their hearing health professionals and that appropriate evidence is available to support clinical decision making. This may reflect the types of device that are recommended or habilitation approaches that clients are advised to follow. Given the importance of hearing to development of speech and language, this is of particular interest to paediatric age groups.

The HEARing CRC is dedicated to creating a strong evidence base for audiological practice, carrying out a breadth of detailed clinical studies and driving multi-disciplinary communication of their findings.

The Longitudinal Outcomes of Children with Hearing Impairment (LOCHI) study is the first large scale investigation of hearing loss; it is following children from initial diagnosis through to age twelve.

The study is monitoring the speech, language and psychosocial outcomes of 450 children over time. To date, analysis of three and five year old data has identified a number of factors that could be used to predict outcomes. Of particular note is that fitting of hearing aids or cochlear implants within the child’s first six to 12 months is associated with development of speech and language skills comparable with hearing peers.

**PHD STUDENTS FOCUS ON CENTRAL AUDITORY PROCESSING DISORDERS**

Central Auditory Processing Disorder (CAPD) is an umbrella term for a variety of disorders that affect the way the brain processes auditory information, it occurs in roughly two to five percent of the population.

Language and literacy impairment is common in children with CAPD, and Dani Tomlin is investigating the level of auditory processing difficulty that causes significant, real-life problems for children in the classroom. This work will lead to the development of guidelines for improved diagnosis and management of children with CAPD, ultimately assisting healthcare professionals, parents and teachers in understanding a diagnosis of CAPD and how best to intervene.

Pia Gyldenkaerne is using magnetoencephalography (MEG) facilities at Macquarie University to assess the role of visual cues in speech intelligibility for children with CAPD. The study uses MEG and electroencephalography (EEG) as well as more traditional research approaches, with the ultimate aim of creating clinical recommendations.

Investigation into the effects of aging and hearing impairments on CAPD have focused on Spatial Processing Disorder (SPD is a common type of CAPD in those with normal peripheral hearing). Helen Glyde has shown that there is a significant relationship between degree of hearing impairment and SPD. This novel finding has generated excitement in the hearing community, suggesting an underlying mechanism for the relationship and an opportunity for novel remediation.
Procedures at the National Acoustic Laboratories and CRC Project Leader said “achieving early implantation is possible only with early detection and treatment. The evidence calls for vigilant monitoring of early outcomes and timely provision of targeted intervention for individual children”.

A separate suite of studies are focused on the impact of different therapeutic approaches on outcomes of children with hearing loss. They are examining language, speech production and speech perception as well as the primary caregiver’s role in communication development of young children.

Findings of this work will direct therapeutic interventions in the future, with the aim of enabling children to take full advantage of their auditory potential once they have a device fitted. “Fitting a hearing device on a child is simply not enough, their brain needs to be trained to use it by parents or caregivers. This exciting study is exploring some of the different approaches to this training and will help us identify how to best assist” said Associate Professor Dimity Dornan, founder and Executive Director of the Hear and Say Centre and CRC Co-Project Leader.

**MAGNETOENCEPHALOGRAPHIC STUDIES**

Clinical outcomes are of immense value, however, understanding associated changes at a neurological level will offer further insight into physiological changes.

**HEARLab®**

The HEARing CRC has developed HEARLab and its test module, Aided Cortical Assessment (ACA). This non-invasive, quick and efficient procedure measures minute electrical potentials originating from the brain’s auditory cortex in response to speech sounds.

This assessment of hearing function can be used with or without hearing aids and cochlear implants. The ACA module facilitates accurate testing and fitting of hearing technology to infants at the earliest possible moment. In addition, the module can be used with adults who cannot communicate reliably (e.g. those with dementia).

Dr Bram Van Dun is an electrophysiologist leading the HEARing CRC project team at the National Acoustic Laboratories “Pretty much all newborn infants in Australia needing a hearing aid are now being tested by HEARLab, it is a great system that facilitates quicker assessment and more reliable intervention”.

MEG is a new imaging method that reveals real-time, three-dimensional brain activity. MEG studies are being used in the HEARing CRC to observe the pattern of disturbance to ‘normal’ electrical activity in the auditory cortex of tinnitus patients, and to investigate the impact of different therapeutic interventions. Like Pia’s study (see box, page 6) this work will integrate MEG data with more traditional clinical approaches to help us better understand the relationships between.

An exciting extension of the HEARing CRC’s research capacity in this area is the development of a MEG system for use with cochlear implantees. The world-first system will be commissioned in the new Australian Hearing Hub facility at Macquarie University in 2013. It will enable previously impossible investigations into the effects of deafness and cochlear implantation on auditory and language processing in both children and adults.

CRC Project Leader and Macquarie University’s Distinguished Professor Stephen Crain, said “The new MEG system will enable us to add unprecedented clinical value to our fascinating research findings that different areas of the brain are active in adults who speak a tone language, such as Mandarin, as compared to adults who speak a non-tone language, such as English”.

This work is already informing best practice, nationwide guidelines have been implemented and the study results are assisting healthcare professionals to make decisions and advise parents about clinical options.

Dr Teresa Ching, Head of Rehabilitation Procedures at the National Acoustic Laboratories and CRC Project Leader said “achieving early implantation is possible only with early detection and treatment. The evidence calls for vigilant monitoring of early outcomes and timely provision of targeted intervention for individual children”.

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The HEARing CRC has developed HEARLab and its test module, Aided Cortical Assessment (ACA). This non-invasive, quick and efficient procedure measures minute electrical potentials originating from the brain’s auditory cortex in response to speech sounds.

This assessment of hearing function can be used with or without hearing aids and cochlear implants. The ACA module facilitates accurate testing and fitting of hearing technology to infants at the earliest possible moment. In addition, the module can be used with adults who cannot communicate reliably (e.g. those with dementia).

Dr Bram Van Dun is an electrophysiologist leading the HEARing CRC project team at the National Acoustic Laboratories “Pretty much all newborn infants in Australia needing a hearing aid are now being tested by HEARLab, it is a great system that facilitates quicker assessment and more reliable intervention”.

MEG is a new imaging method that reveals real-time, three-dimensional brain activity. MEG studies are being used in the HEARing CRC to observe the pattern of disturbance to ‘normal’ electrical activity in the auditory cortex of tinnitus patients, and to investigate the impact of different therapeutic interventions. Like Pia’s study (see box, page 6) this work will integrate MEG data with more traditional clinical approaches to help us better understand the relationships between.

An exciting extension of the HEARing CRC’s research capacity in this area is the development of a MEG system for use with cochlear implantees. The world-first system will be commissioned in the new Australian Hearing Hub facility at Macquarie University in 2013. It will enable previously impossible investigations into the effects of deafness and cochlear implantation on auditory and language processing in both children and adults.

CRC Project Leader and Macquarie University’s Distinguished Professor Stephen Crain, said “The new MEG system will enable us to add unprecedented clinical value to our fascinating research findings that different areas of the brain are active in adults who speak a tone language, such as Mandarin, as compared to adults who speak a non-tone language, such as English”.

This work is already informing best practice, nationwide guidelines have been implemented and the study results are assisting healthcare professionals to make decisions and advise parents about clinical options.

Dr Teresa Ching, Head of Rehabilitation Procedures at the National Acoustic Laboratories and CRC Project Leader said “achieving early implantation is possible only with early detection and treatment. The evidence calls for vigilant monitoring of early outcomes and timely provision of targeted intervention for individual children”.

A separate suite of studies are focused on the impact of different therapeutic approaches on outcomes of children with hearing loss. They are examining language, speech production and speech perception as well as the primary caregiver’s role in communication development of young children.

Findings of this work will direct therapeutic interventions in the future, with the aim of enabling children to take full advantage of their auditory potential once they have a device fitted. “Fitting a hearing device on a child is simply not enough, their brain needs to be trained to use it by parents or caregivers. This exciting study is exploring some of the different approaches to this training and will help us identify how to best assist” said Associate Professor Dimity Dornan, founder and Executive Director of the Hear and Say Centre and CRC Co-Project Leader.

**MAGNETOENCEPHALOGRAPHIC STUDIES**

Clinical outcomes are of immense value, however, understanding associated changes at a neurological level will offer further insight into physiological changes.
The fitting of any hearing rehabilitation device requires access to specialist clinics (with trained staff and appropriate infrastructure) to enable hearing assessment and an associated diagnosis of the type of hearing loss.

The HEARing CRC promotes equal access to quality hearing healthcare, regardless of location. We have applied information and telecommunication technologies in novel ways to pioneer new approaches to delivering hearing services.

**AUSTRALIA**

Compared to its urban populations, the delivery of health services to remote and Indigenous communities of Australia is regarded by many as inadequate. This situation is not unique to Australian healthcare providers however, and solutions have application worldwide.

The HEARing CRC and its Members the Royal Institute for Deaf and Blind Children and Australian Hearing, have been investigating approaches to delivering both initial paediatric hearing screening and full, follow up audiological assessment using internet-based applications.

Different combinations of technologies have been trialled to establish the validity of remote assessments in non-sound treated environments - with extremely encouraging results.

The procedures being developed will greatly increase access to paediatric audiological assessment in remote areas and will reduce the time delay between screening and diagnosis of hearing loss. Findings will ultimately provide clinical guideline development and a training module on HEARnet Learning (see box, page 9).

An extension of this work is its application to mapping of cochlear implants. Through Members the University of Queensland, the Hear and Say Centre, and the Sydney Cochlear Implant Centre (SCIC), the HEARing CRC is developing procedures that use software on one computer (based at an implant clinic) that can remotely access another computer (based in a rural/remote area). Using a specialised Australian telehealth support interface (eHab) developed by the University of Queensland, an individual who has received a cochlear implant can receive their follow up consultations remotely.

To date the validity of the procedure has been established for mapping implants in children three years and over; younger age groups are currently being trialled. “The potential for remote mapping applications to offer a solution for service gaps in rural and remote areas is great; by demonstrating that the outcomes from this approach are essentially the same as those obtained in the traditional face-to-face manner we hope to encourage clinicians in the field to consider remote programming of CIs” says Emma Rushbrooke, Clinical Director of the Hear and Say Centre who recently completed her MPhil on this subject with the CRC.

eHab teleaudiology in use with paediatric patients.
HEARING EDUCATION AND RESEARCH NETWORK

The HEARing Education and Research Network (HEARnet) is the CRC’s innovative approach to communicating research outcomes – enhancing access to information, training and resources.

HEARnet reaches out directly to:
- the general public and policy makers;
- healthcare professionals (including GPs, audiologists/audiometrists and ENT surgeons); and
- researchers working in the hearing field.

The HEARnet website provides easily digestible overviews on hearing health as well as information about existing and emerging hearing technologies. It acts as a hearing health information aggregator that links out to other credible and comprehensive websites.

For healthcare professionals and researchers, information is more resource focused, providing access to clinical guidelines and research presentations for example.

Key resources available through HEARnet include the Interactive Ear (an interactive animation), HEARnet Library (a searchable database of resources) and HEARnet Learning (accredited online training).

HEARnet will be an informed online hearing health resource, complimented by its social media networks through which content can be directly promoted to interested audiences. These networks will also facilitate direct interactions with audience members and offer tools for evaluation.

As a flexible site, HEARnet will continue to evolve – for example, the CRC is currently investigating how HEARnet Learning could be accessed via mobile devices such as tablets and smartphones.

Attendees of the 2012 Audiology Australia Conference were given an exclusive preview of HEARnet and HEARnet Learning’s first online module (Hearing aids and Directional Microphones) developed in association with Adjunct Professor Harvey Dillon, Research Director of the National Acoustic Laboratories.

In the future HEARnet will be used to underpin campaigns, such as improving community knowledge about the risks of noise-induced hearing loss.

DEVELOPING WORLD

These solutions are viable for the developed world but the World Health Organisation estimates there are over 200 million people living in the developing world with hearing loss, with less than 3% having access to professional hearing services.

This presents a need and an opportunity to use existing technology in a novel way, and CRC researchers based at the National Acoustic Laboratories have done just that - incorporating an audiometer (to assess hearing loss), a fitting algorithm (to apply the correct setting for the observed hearing loss) and trainability (to allow the user to tweak the hearing aid settings for comfort and preference) into a self-fitting hearing aid. The hearing aid can be assembled by the end-user and the device’s self-contained, on-board capabilities essentially provide hearing assessment and initial fitting in a box!

The HEARing CRC is currently working with audiologists in South Africa and Asia to further explore the application of this technology.

In parallel, our SCIC-based study has trialled off-the-shelf computing and internet networking technologies to provide cochlear implant mapping support to patients located in the Pacific nation of Samoa.

Preliminary results from this work have shown that 83% of the 70 clients who had their cochlear implants mapped remotely were pleased with the outcome. The HEARing CRC is now developing guidelines and user case studies to help remote hearing health clinics achieve similar outcomes, and to test approaches that support rural paediatric clients in New South Wales and Queensland.

The CRC is also investigating application of this technology for remote supervision of audiologists located in rural settings.
GETTING OUR RESEARCH HEARD

Publication in peer-reviewed journals and conference presentations are traditional forms of communication. The graph below shows the year-on-year increase in the number of journal papers and oral or poster presentations (at national and international scientific conferences) reporting HEARing CRC research outcomes.

HEARing CRC Project Leaders have high standing in their fields and many have been invited to publish books, book chapters or special journal editions in their specific expertise. Contributing to core learning texts and clinical guidebooks ensures that the outcomes and experience of the CRC are communicated long into the future.

From time to time the CRC identifies a critical mass of knowledge that requires detailed reporting. In 2006, the HEARing CRC and Victorian Deaf Society released *Listen Hear!* the first report of its kind, quantifying the economic impact of hearing loss by assessing direct financial costs as well as loss of well-being. In 2012 Project Leader Dr Gitte Keidser was guest editor of a *Trends in Amplification* special edition featuring CRC research on self-fitting hearing aids.

Given our broad membership, the HEARing CRC has close working relations with 26 of the top hearing related organisations in Australia, many of whom have an international reputation. We aim to use these relationships to gain wider recognition of our activities and increase our communication reach.

**AWARDS RECEIVED BY THE CRC**

<table>
<thead>
<tr>
<th>Year</th>
<th>Award Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000</td>
<td>AUSTRALIAN DESIGN AWARD: Nucleus 24 Contour™ electrode</td>
</tr>
<tr>
<td>2001</td>
<td>US SILVER MEDICAL DESIGN EXCELLENCE AWARD: Nucleus 24 Contour™ electrode</td>
</tr>
<tr>
<td>2002</td>
<td>CRC-ASSOCIATION TECHNOLOGY TRANSFER AWARD: Acoustic Sound Protection</td>
</tr>
<tr>
<td>2003</td>
<td>CRC-ASSOCIATION EXCELLENCE IN INNOVATION AWARD: Adaptive Dynamic Range Optimisation (ADRO®) technology</td>
</tr>
<tr>
<td>2005</td>
<td>CSIRO EARLY CAREER RESEARCHER AWARD: Carrie Newbold (then PhD student, now Project Leader)</td>
</tr>
<tr>
<td>2006</td>
<td>VICTORIAN MINISTERS PRIZE FOR RESEARCH INTO REDUCTION, REFINEMENT, REPLACEMENT: Carrie Newbold</td>
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Many of our other Members work directly with people with hearing loss and their families and are able to provide us great insight into their needs and wants. Through their networks we are afforded the opportunity to talk about our research, its findings and the direct implication it might have for the all-important, and ever more informed, end-user.

The CRC aims to generate media interest and make public comment as and when it is fitting to do so. Our research and its outcomes have been frequently discussed across television, radio and newspapers. As media moves increasingly into the online environment, we are developing relationships with organisations such as The Conversation to ensure that our researchers and their work can be identified and accessed among credible and informative content.

As noted previously, the CRC has many high profile Project Leaders and their opinions are often sought when media stories concern the hearing field, gaining further exposure for our work.

The uptake of social media presents great opportunities for engaging and communicating. The CRC has embraced this advance and has a YouTube channel (HEARnet TV), as well as a presence on Facebook and Twitter. Much of this activity is currently focused on identifying ourselves as a source of information in the field and pointing interested individuals towards our new communication resource, HEARnet (see box, page 9).

Involvement in public awareness activities such as Better Hearing Australia, Hearing Awareness Week and National Science Week are important opportunities to profile CRC research to different audiences. The HEARing CRC has undertaken various activities over the years, but Science Week 2012 was of particular note when we became involved in the ABC Citizen Science Project. Each year this project focuses on one topic, 2012 was hearing loss and its prevention and included a large scale survey called Sound Check Australia. This high profile campaign raised awareness of the importance of hearing and protecting against hearing loss.

The HEARing CRC is regularly involved with events such as CRC meets Parliament and Science Meets Parliament to engage Government decision makers. We, and many of our Members, made significant contribution to the 2010 Senate Enquiry into Hearing Health. In addition, CRC Chief Executive Officer, Associate Professor Robert Cowan is a long standing, invited member of the Commonwealth Minister’s Hearing Services Consultative Committee.
Our skilled researchers are experienced in collaborating over a distance, utilising tele- and videoconferencing to facilitate virtual meetings and secure networking to enable file sharing and data exchange. Their knowledge and expertise is one of the CRC’s most valuable assets.

The Member base of the HEARing CRC affords access to cutting edge research infrastructure and expertise in the field of hearing research, this includes:

- **INTERNATIONAL CLINICAL TRIALS NETWORK:** national and international collaborations enable clinical studies ranging from first-time-in-human evaluation of implantable and externally-worn devices, approaches to clinical programming, development and evaluation of new sound coding strategies as well as evidence-based recommendations and guidance for clinical practice. Multi-centre involvement in these studies ensure that the findings are applicable globally and can be incorporated, for example, into Cochlear’s products and services for maximum clinical benefit.

- **MICROFOCUS RADIOGRAPHY:** using high magnification microfocus x-ray fluoroscopy, this laboratory was established by the CRC in 2000 as the only one of its kind in Australia. The technique enables detailed assessment and accurate evaluation of cochlear implant insertion studies using human temporal bones. The existing analogue system will be upgraded to digital (contingent on funding) to enhance workflow follow-up with fixed-specimen histological analysis.

### INTERNATIONAL RESEARCH COLLABORATIONS

The HEARing CRC has a number of international collaborators that bring specific expertise to research projects (collaborations active during the 2011-12 year are shown in blue, those that were active in previous years are shown in purple.

**INDIA**
1: All India Institute of Speech and Hearing
9: Case Western Reserve University

**CHINA**
2: Beijing Institute of Otolaryngology
3: Beijing Language and Culture University
4: Chinese University of Hong Kong
10: Ohio University
11: North Carolina State University
12: The University of California
13: The University of Wisconsin
14: University of Iowa
15: University of Colorado
16: University of Texas
17: The University of Washington

**USA**
5: Columbia University
6: New York University Medical Centre
7: Biotectix
8: Boston University
18: Kanazawa Institute of Technology

**GERMANY**
19: Medizinische Hochschule Hannover
20: The University of Freiburg, Cochlear Implant Centre

**DENMARK**
21: The Technical University of Denmark

**NEW ZEALAND**
22: The University of Auckland

**UK**
23: The University of Birmingham
24: University College London
25: The University of Manchester

**BELGIUM**
27: Cochlear Technology Centre

**SOUTH AFRICA**
28: The University of Pretoria

**CANADA**
29: The University of Toronto, Sick Children’s Hospital Cochlear Implant Clinic

**FRANCE**
30: University of Western Ontario
31: University of Montreal

**FRANCE**
32: Hospital Purpan
33: France Telecom
MAGNETOENCEPHALOGRAPHIC (MEG) IMAGING: the CRC works closely with the KIT-Macquarie Brain Research Laboratory which has a dual MEG system incorporating:

- a 160-channel MEG system for adult use (commissioned 2006); and
- a 64-channel MEG system for paediatric use (commissioned 2008).

These systems have various custom designed compatibilities including an Electroencephalography system, a polygraphic system (with eight channels of electromyography and eight polygraphic channels), eye tracking capability, a projector, earphones and tube phone system specifically designed by the CRC and Member, National Acoustic Laboratories for hearing and language research.

REAL WORLD SOUND ARRAYS: the CRC has:

- a two-dimensional sound array (16 speakers arranged through 360 degrees in a single plane, commissioned in 2009 as part of the $3.5M custom designed refurbishment of The University of Melbourne facility); and
- a three-dimensional sound array (40 speakers arranged on a dome structure, commissioned in 2011 at the National Acoustic Laboratories in Sydney).

These speaker arrays and associated recording and playing software enable the recreation of the rich acoustic environments of everyday life - in a laboratory. They are currently in use for hearing aid, cochlear implant and hearing protection research.

AUSTRALIAN HEARING HUB: a purpose-built facility to be opened in 2013 at CRC Member, Macquarie University, to facilitate collaborative research into hearing and related speech and language disorders. Built on long-term relationships established by the HEARing CRC.

Top: Microfocus radiograph of two differently designed cochlear implants in situ.
Bottom: Girl having brain activity measured by MEG imaging system.
Commercialising research outcomes is the final step in delivering CRC innovations to people who will use them – be that protection from, or remediation of hearing loss. Each of our Research Projects include commercialisation strategies* aimed at achieving impact. All HEARing CRC commercial activity is managed through our commercial arm, HEARworks Pty Ltd.

Commercialisation strategies are applied on a case by case basis depending on the type of technology, market opportunities and industry engagement. The following are some examples of commercial strategies:

- **FIRST RIGHTS**: industry Members have first rights to technology in their field which provides them with a first to market competitive advantage or exclusive licencing options (this also encourages engagement of industry Members in technology development);

- **LICENCING**: technology may be licenced to one manufacturer (exclusive e.g. HEARLab) or to several (non-exclusive e.g. NAL-NL2) dependent on markets and end-user needs. Products under licence can also provide a royalty stream to HEARworks based on product sales;

- **END-USER LICENCING**: some of our products and software are licenced directly to professionals or consumers; and

- **PARTNERSHIP WITH MEMBERS**: a Member commercialises a product, with a royalty stream provided to HEARworks.

Returns from commercialisation are re-invested in research either directly through the HEARing CRC or through its Members.

* if projects are not commercial in nature, these strategies describe alternate routes to the end-user, for example development of clinical guidelines or contribution to CRC campaigns through HEARnet (see box, page 9).
EDUCATING THE NEXT GENERATION

"EDUCATION IS NOT THE FILLING OF A PAIL, BUT THE LIGHTING OF A FIRE” WILLIAM YEATS.

The HEARing CRC’s educational activities are aimed at up-skilling, empowering and enthusing the next generation of researchers, audiologists, surgeons and specialists. We look for opportunities to promote end-user as well as commercial benefits, and approaches to achieving maximum impact as core themes to all we do.

The HEARing CRC has 36 PhD students integrated into its Research Projects. To date, we have achieved a greater than 95% completion rate and our graduates are placed in industry, research and educational sectors. HEARing CRC PhD students have received a number of Australian accolades.

Aside from being immersed in an organisation that links research, clinics and industry, many of our students have supervisors or mentors from the clinical and industry sectors to add extra dimensions to their studies. An annual symposium brings the students together from across the HEARing CRC’s five university Members to share their research findings and develop networks as leaders of the future.

Training activities are held in connection with these meets and have included topics such as IP and commercialisation, and communicating complex scientific information.

CRC Member, Audiology Australia (ASA), is the professional body for audiologists. We work closely with ASA to deliver lectures, seminars, workshops and other activities to integrate into their Continuing Professional Development Program - focused on maintaining a high quality practice of audiology and underpinning members’ Certificate of Clinical Practice. The development of HEARnet Learning (see box, page 9), will provide opportunities for audiologists to work through ASA-accredited online modules.

Since 1992, the CRC has been delivering four-day cochlear implant training workshops in association with Members Cochlear Ltd, The Royal Victorian Eye and Ear Hospital and The University of Melbourne. They include an interactive live surgery, hands-on surgical training for surgeons and hands-on speech optimisation for audiologists and other healthcare professionals.

The workshops also offer opportunities to meet implant patients and discuss cutting edge advances with researchers. In line with HEARing CRC’s educational strategies, some workshop sessions will in future be delivered through HEARnet Learning as online training modules.

The CRC plays a key role in Cochlear Ltd’s Visiting Implant Specialist to Australia (VISTA) program. This provides current information on research and development in the cochlear implant field to small international groups and is usually held twice a year.

CRC CEO Associate Professor Robert Cowan has worked with industry specialist Dr John Bates to develop The University of Melbourne’s Specialist Certificate in Clinical Research (Biomedical Research Management) Course, offering advanced training in biomedical research project delivery. The course covers management issues across a range of biotechnology and biomedical project types including drugs, devices and procedures development and clinical trials.

INTO THE FUTURE

The HEARing CRC and HEARworks Directors and management have extensive commercial experience and track records in attracting research, commercial and venture capital funding.

This leadership equips the CRC with the ability to develop and implement strategic plans that exploit new opportunities and address future funding uncertainty.

To support future transitions, the HEARing CRC and HEARworks are developing and expanding efforts in competitive funding to support new research projects outside of the current CRC scope of activities.
BOARD AND ORGANISATION

HEARING CRC

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Proprietary company limited by shares, created by the Members, for the purposes of acting as Trustee for IP (created by the previous CRC HEAR) and undertaking commercialisation of research outcomes. HEARworks operates under a Management Deed and Trust Deed with the HEARing CRC Limited and its Members.

HEAR IP PTY LTD ABN 75 299 348 104
Incorporated in November 2008 as a trustee company, was created for the purposes of acting as Trustee for IP created by the HEARing CRC.
THE HEARING CRC IS A MULTIDISCIPLINARY COLLABORATION OF FIVE CORE AND 21 SUPPORT MEMBERS, EACH OF WHICH CONTRIBUTES SPECIFIC EXPERTISE AND INFRASTRUCTURE TO OUR RESEARCH, COMMERCIALIZATION AND EDUCATION PROGRAMS.

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THE HEARING CRC IS FOCUSED ON THE TWIN CHALLENGES OF MORE EFFECTIVE PREVENTION AND IMPROVED REMEDIATION OF HEARING LOSS.

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"Not being able to see isolates you from objects. Not being able to hear isolates you from people."
IMMANUEL KANT

PhD student, Aswin Wijetillake, benefits from the advanced two-dimensional sound laboratory in his research with cochlear implantee Peter Goodman – together they are working to better understand sound signals in background noise.

Background imagery: A microfocus radiograph of a Contour electrode in a temporal bone Designed by Dynamic Creations