**FINAL REPORT**

**Final Publishable Summary Report**

**Key Results**

* *Identified* cues which improve cochlear implant speech-in-noise understanding
* *Advanced* our understanding of neural processing of complex sounds by cochlear implant users
* *Developed* cutting edge technologies to easily measure and assess brain response in cochlear implant users

**Impact**

* Better speech understanding in noise for cochlear implant users
* Optimize cochlear implant fitting process, improving outcomes and reducing work load
* Support and development for CI research in Ireland.
* Commerilization of technologies, leading to economic growth

Cochlear implants (CIs) are the most successful neural prosthesis that has yet been developed. Routine cochlear implantation began in the 1970s and since then CIs have helped restore hearing in over 220,000 deaf people world-wide. Advances in speech processing strategies and implant design mean that most CI users, if implanted as prelingual children or as postlingually deafened adults, can understand speech in a quiet environment and can converse over the telephone. However, to achieve this level of speech perception the CI requires extensive initial fitting and frequent tuning. As the number of implant users increase, so does the work load for medical professionals. Another significant problem for CI users is speech recognition in noise and understanding multi-talker speech. Recent studies have shown that CI users with residual low frequency hearing have both better speech recognition in noise and improved melody recognition. The aim of this project was to use neural, EEG methods, to understand these issues and improve cochlear implant outcomes.

The project’s first study examined the cues that underlie speech-in-noise perception in CI users and revealed that, in addition to a low frequency acoustic cue, CI uses could make use of differences in stimulation rate to improve speech-in-noise perception. A speech perception model showed that this improvement was probably due to a listening in the gaps cue rather that a temporal pitch cue. This new knowledge will facilitate the design of cochlear implant speech processing strategies which perform better in noisy environments

To study the relationship between behavioral outcomes, such as speech perception, and the underlying neural mechanism a paired EEG – psychoacoustic testing method was developed and evaluated in CI and normal hearing subjects. A good correlation with behavioral and neural thresholds was found for a number of different stimuli. These results shed light on the neural processing of these complex stimuli and indicate a cortical origin for the processing.

Cortex

Brainstem

Nerve

 Implant

Behavior

BTE Processor

Settings

Audiologist

**CLOSED-LOOP**

**OPEN-LOOP**

A closed-loop cochlear implant.

While measuring EEG in CI subjects two new methods of significant clinical relevance were developed. One allows a standard CI to be used as a recording device to measure EEG, the other is a new method to separate the EEG signal from the CI related artifact. It has been shown that combining the CI recording technique with the spectrally rippled stimuli provides a clinically significant evaluation procedure: by simply pressing a button on the CI an audiologist can get a quick estimate of a user’s speech perception. This will greatly improve the treatment and follow offered to CI users.

This new technology means that it may now be possible to develop a closed-loop cochlear implant (see inset). Instead of the audiologist fitting the implant in an open-loop way, as is currently done, a closed-loop CI could automatically measure neural response and optimize stimulation accordingly.

**Use and Dissemination of Foreground**

**Section A (Public)- Dissemination Measures**

**Technology Commercialization Activities**The technologies developed in the project were present at two Trinity Research & Innovation Annual Showcase Events. These events provide a forum for researchers to present their technologies to a wide range of stakeholders ranging including private and commercial investors, fellow researchers and the general public. The technologies were well received and discussions with potential commercialization partners are on-going.

The technology transfer offices of both Trinity College Dublin and University of California Irvine and actively seeking to licensing agreements for the technologies developed by the project.

**Publications**

[1] “Towards A Closed-Loop Cochlear Implant System: Application of Embedded Monitoring of Peripheral and Central Neural Activity”, M. Mc Laughlin, T. Lu, A. Dimitrijevic, and F. G. Zeng. IEEE transactions on neural systems and rehabilitation engineering, vol. 20, no. 4, pp. 443–54, Feb. 2012. PMID: 22328183

[2] “Cochlear Implant Artifact Attenuation in Late Auditory Evoked Potentials: A Single Channel Approach”, M. Mc Laughlin, A. Lopez Valdes, R. B. Reilly, and F.-G. Zeng, Hearing Research, vol 302, pp 84-95, Aug. 2013. PMID: 23727626

[3] “Rate and onset cues can improve cochlear implant synthetic vowel recognition in noise”, M. Mc Laughlin, R. B. Reilly, and F.-G. Zeng. Journal of the Acoustical Society of America, vol 133(3), pp 1546-60. Mar 2013, PMID: 23464025

[4] “Auditory Mismatch Negativity in Cochlear Implant Users: A Window to Spectral Discrimination”, A. Lopez Valdes, M. Mc Laughlin, L. Viani, J. Smith, F. Zeng, and R. Reilly. 35th International Conference of the IEEE Engineering in Medicine and Biology Society. vol 2013, pp 3555-8, 2013. PMID: 24110497.

*Accepted*

[5] “ Objective assessment of spectral resolution in cochlear implant listeners using cortical evoked potentials”, Alejandro Lopez Valdes, Myles Mc Laughlin, Laura Viani, Peter Walshe, Jaclyn Smith, Fang-Gang Zeng and Richard B. Reilly. PLOS One, Accepted Dec 2013

*Submitted*

[6] “Late Auditory Evoked Potentials in Responses to Informational Masking Stimuli”, M. Richardson, P. Bremen, J. Middlebrooks, F.G. Zeng and M. Mc Laughlin. Submitted Hearing Research, Dec 2013

[7] “Peripheral Filter Width and Dynamic Range Affect Central Processing in Cochlear Implant Listeners”, Carol Q. Pham, Peter Bremen, Weidong Shen, Shiming Yang, John C. Middlebrooks, Fan-Gang Zeng, Myles Mc Laughlin. Submitted JARO Dec 2013

*In preparation*

[8] “Spectral ripple discrimination in cochlear implant users: A comparison of three objective assessment methods”, Alejandro Lopez Valdes, Richard B. Reilly, Laura Viani, Peter Walshe, Jaclyn Smith, Fan-Gang Zeng and, Myles Mc Laughlin. In preparation.

**Conference Presentations**

A total of 9 conference presentations in podium podium or poster format were made. They include: 2 poster presentations at the Conference on Implantable Auditory Prostheses (2011, 2013); 1 podium and 1 poster presentation at the 7th International Symposium on Objective Measures in Auditory Implants (2012); 1 podium and 3 poster presentations at the Association for Research in Otolaryngology (2012, 2013); 1 poster presentation at the International Conference of the IEEE Engineering in Medicine and Biology Society (2013).

**Section A (Confidential)**

 **Patents**

[1] “Systems and Methods for a Closed-loop Cochlear Implant”, F.-G. Zeng, M. Mc Laughlin, and T. Lu. Filed Jan.2012, U.S. Patent application serial no. 61/592,329

[2] “Cochlear Implant Evoked Potential Artifact Cancellation”, M. Mc Laughlin, F.-G. Zeng, R. B. Reilly and Alejandro Lopez Valdes. Filed March 2013. U.S. Patent application serial no. 61/775,345