Fourteenth Quarterly Progress Report

July 1 through September 30, 2005
NIH Project N01-DC-2-1002

Speech Processors for Auditory Prostheses

Prepared by

Dewey Lawson, Xiaoan Sun, and Blake Wilson

Center for Auditory Prosthesis Research
Research Triangle Institute
Research Triangle Park, NC

CONTENTS

I. Introduction

The main objective of this project is to design, develop, and evaluate speech processors for implantable auditory prostheses. Ideally, such processors will represent the information content of speech in a way that can be perceived and utilized by implant patients. An additional objective is to record responses of the auditory nerve to a variety of electrical stimuli in studies with patients. Results from such recordings can provide important information on the physiological function of the nerve, on an electrode-by-electrode basis, and can be used to evaluate the ability of speech processing strategies to produce desired spatial or temporal patterns of neural activity.

Work and activities in this quarter included:

- Blake Wilson was an invited lecturer at the University of Innsbruck, July 9 – 13, 2005.
- Dewey Lawson, Blake Wilson, and Xiaoan Sun attended the Conference on Implantable Auditory Prostheses (CIAP), Asilomar Conference Grounds, Pacific Grove, CA, July 30 – August 4, 2005.
- Blake Wilson presented a moderator's overview and introduction to the session on Signal Processing and Speech in Noise at the CIAP, July 30 - August 4, 2005.
- The Center for Auditory Prosthesis Research (CAPR) moved into its newly renovated facility at 200 Park, RTP, NC, beginning with the speech reception lab on August 22, 2005.
- Studies with Nucleus percutaneous subject NP-7 July 13 – 19, August 31 – September 2, and September 26 – 30, 2005.
- Studies with EAS subject ME-26 August 8 – 20, 2005, supported in part by internal Research and Development funds from RTI.
- Participation by Dr. Oliver Adunka, currently at the University of North Carolina in Chapel Hill, in the studies with subject ME-26
- Studies with Pulsar subject ME-27 September 12 – 23, supported in part by internal Research and Development funds from RTI.
- Participation by consultant Reinhold Schatzer, University of Innsbruck, in studies with subjects NP-7 and ME-27.

In addition to the above-mentioned activities, work continued on analysis of previously collected data and on the preparation of manuscripts for publication.

In the present report we describe further progress on the current Nucleus percutaneous studies.

II. Further progress in the Nucleus percutaneous studies

The Devices

Our research implants are Cochlear Pty. CI24R systems, offering percutaneous access to the Nucleus Contour electrode array. Those devices and our laboratory apparatus were described in QPR 13 for the current contract [Lawson *et al.* (2005a)].

The Remaining Nucleus Percutaneous Subjects

NP-7

Born in 1942, NP-7's hearing loss was first noticed following a blow to the head at age 12. There was no family history of hearing loss. She began use of a hearing aid in her left ear at age 19 and bilateral aids at age 30. She reports having had many ear infections. Progressing hearing loss resulted in her ceasing to use aids at age 47, by which time she was receiving no benefit in the right ear. Her left ear was implanted at age 61.

Testing is continuing with this subject, 21 days having been completed through the current quarter.

NP-8

Subject NP-8 was born in 1956. Her hearing loss, associated with Wegener's granulomatosis disease, progressed from mild in late 2000 to profound bilaterally by late 2001. At the time of her left ear implant surgery many other symptoms associated with her Wegener's had improved markedly, including her returning to ambulatory status. At surgery, however, active formation of tissue characteristic of Wegener's was observed, and healing of her surgical incision required multiple hyperbaric oxygen treatments and IV antibiotics. 13 days of testing were completed with NP-8 early in our studies and her overall speech reception performance was easily the best among the four subjects. Recurring problems with her surgical incision resulted in readmission to hospital for additional hyperbaric and antibiotic treatments, culminating in surgery on August 10. At surgery it was determined that the percutaneous device should be explanted immediately in the interest of the subject's health, terminating her participation our studies.

The Processors

A core set of 100 distinct processing strategies has been chosen for comparisons across these four subjects. Because of the unique opportunities afforded by percutaneous access to the Contour electrode array, priority has been given to strategies that require one or more of those opportunities – *e.g.* simultaneous stimulation of multiple electrodes, use of unusual pulse forms, and/or location of electrodes close to the modiolar wall of scala tympani. Also included are processors designed to serve as controls for assessing benefits of the new approaches. A detailed description and a table indicating the attributes of each of the selected strategies may be found in QPR 13 for the current project [Lawson *et al.* (2005a)]. Many of the new processing approaches included among these strategies were described generally in QPRs 6, 7, and 9 for the current project [Schatzer *et al.* (2003a), Wilson *et al.* (2003), and Wilson *et al.* (2004)].

The unexpectedly limited time available with subject NP-6 reduced to 37 the number of processors that could be evaluated across all four subjects. It was anticipated that each of the other processors would be compared across three subjects. While studies are proceeding well with subject SR-7, the early loss of subject SR-8 because of unforeseen medical complications has further reduced the number of possible comparisons across all four percutaneous subjects to 11.

Fortunately, other research ongoing in our laboratory offers a way of supplementing the number of subjects tested with the processing strategies selected for this percutaneous study. A unique interface developed in cooperation with colleagues at the University of Innsbruck allows us great flexibility in the control of transcutaneous Med-El PULSAR implants, including the ability to implement processing strategies equivalent to those developed for our current Nucleus Percutaneous studies [Schatzer *et al.* 2004, Lawson *et al.* 2005].

In the course of recent pilot studies with PULSAR subject ME-27 we have been able to demonstrate that ability, and have included several processing strategies from the Nucleus percutaneous series among those already tested on the PULSAR platform. This has increased the number of those strategies now evaluated across 3 or 4 subjects. The Med-El PULSAR electrode array, while different from the Nucleus Contour array, is also one currently being implanted clinically.

The core processors may be grouped conveniently into 7 fundamental **types**: continuous interleaved samplers (**CIS**), fine structure (**FS**) [including some processors using virtual channels as well as single electrodes], conditioner pulses (**CP**), dual-resonance nonlinear filter (**DRNL**), combined DRNL and FS, simultaneous stimulation across channels (**SS**) and hybrid peak-picking/CIS (**PP**). Specific attributes of all the core processors were discussed and presented in tabular form in QPR 13 for the current project.

Specific parameter values for the core processors were chosen so that each strategy could be compared directly across all the percutaneous subjects. The psychophysical attributes

of those subjects allowed selection of pulse widths of 27 µs/phase for many of the strategies sharing the rate of 833 p/s. Such short pulse widths are not possible for all cochlear implant users, however, including PULSAR subject ME-27 for whom MCLs can be achieved for rates of 791 p/s only with pulse widths of 50 µs/phase or greater. Consequently, ME-27 was tested with four processors from the percutaneous study core set that had been assigned pulse widths of 60 µs/phase at 833 p/s. One of the four was of the CIS type and the other three of the FS type. The CIS processor had 10 channels. The FS processors included 6/18, 7/21, and 10/21 designs, with 3 stimulation options available to each channel in each case, and with each stimulation option assigned uniquely to a single channel in the 6/18 and 7/21 cases and shared between adjacent channels in the 10/21 case. Virtual channel techniques were used to extend the number of stimulation options beyond the 12 physical electrodes available in the PULSAR array.

Such a pulse width restriction is not an issue with other PULSAR users. ME-25, for instance, the subject with whom we did our first evaluations of the PULSAR interface [Lawson *et al.*, 2005], was tested with a variety of processor types at rates of 791 and 1515 p/s with pulse widths of 24 µs/phase. The tested configurations included 11/34, 17/34, and 11/44 channels, illustrating the potential for realizing processors equivalent to the whole range of our Nucleus percutaneous core set for evaluation with PULSAR subjects.

All the strategies were realized on our laboratory's master processor hardware and software, either running in real time or pre-processed for streaming mode presentation [Schatzer *et al.* (2003)].

During the next quarter we will be continuing testing with subject NP-7, and exploring any possibilities for additional across-subject comparisons of the core strategies of these studies using Nucleus percutaneous subjects from Cochlear America's studies ongoing in Denver and/or subjects implanted with the Med-El PULSAR device.

As they become more complete, test results will be reported and discussed in a subsequent quarterly report.

Subject ME-27

Born in East Germany in 1957, subject ME-27 was first diagnosed with hearing loss – attributed to otosclerosis – as a university student at age 25. She began use of hearing aids bilaterally in 1987, and abandoned use of that in the left ear in 1997. She was found to have profound hearing loss bilaterally in 1999, and received a Med-El C40+ implant on the left side in early 2000, with immediate excellent results. In March of 2004 she received an additional PULSAR device in her right ear. Her devices were implanted by Drs. Jan Helms and Joachim Müller, respectively, in Würzburg, Germany. She routinely uses both devices together. The left ear device alone supports better speech reception than that on the right alone.

References

Lawson D, Wilson B, Schatzer R, and Sun X, "Initial studies with a recipient of a PULSAR implant system." Twelfth Quarterly Progress Report, NIH Project N01-DC-2-1002 (2005).

Lawson D, Wilson B, and Sun X, "Progress in the Nucleus percutaneous studies" Thirteenth Quarterly Progress Report, NIH Project N01-DC-2-1002 (2005a).

Schatzer R, Zerbi M, Sun X, Cox J, Wolford R, Lawson D, and Wilson B, "Recent Enhancements of the Speech Laboratory System" Fifth Quarterly Progress Report, NIH Project N01-DC-2-1002 (2003).

Schatzer R, Wilson B, Wolford D, and Lawson D, "Signal Processing Strategies for a Closer Mimicking of Normal Auditory Functions" Sixth Quarterly Progress Report, NIH Project N01-DC-2-1002 (2003a).

Schatzer R, Zerbi M, Wilson B, Cox J, Lawson D, and Sun X, "Laboratory interface for the new Med-El PULSAR implant" Eleventh Quarterly Progress Report, NIH Project N01-DC-2-1002 (2004)

Wilson B, Wolford R, Schatzer R, Sun X, and Lawson D, "Combined Use of DRNL Filters and Virtual Channels" Seventh Quarterly Progress Report, NIH Project N01-DC-2-1002 (2003).

Wilson B, Sun X, Schatzer R, and Wolford R, "Representation of Fine Structure or Fine Frequency Information with Cochlear Implants" *International Congress Series* **1273**: 3-6, (2004) [also included in Ninth Quarterly Progress Report, NIH Project N01-DC-2-1002 (2004)].

III. Plans for the next quarter

Among the activities planned for the next quarter are:

- Continued testing with Nucleus percutaneous subject NP-7.
- Blake Wilson will be guest of honor at the Hearing Preservation Workshop IV held at the International Center of Hearing and Speech, Warsaw-Kajetany, Poland, October 14 – 15, 2005.
- Blake Wilson will present an invited lecture at the International Binaural Symposium 2005, Manchester, UK, October 29 – 31, 2005. .
- Matthew Bakke and Yifang Xu from Gallaudet University will visit our laboratories October 24, 2005.
- Blake Wilson will address a plenary session at the North American Neuromodulation Society's 9th Annual Meeting in Washington DC, November 10-12, 2005.

IV. Acknowledgments

We thank volunteer research subjects NP-7, ME-26, and ME-27 for their participation in studies conducted during this quarter. And we especially thank subject NP-8 for her previous contributions to our studies.

Appendix 1: Summary of reporting activity for this quarter

Invited talks

Wilson BS: Moderator's overview and introduction, session on Signal Processing and Speech in Noise. *2005 Conference on Implantable Auditory Prostheses*, Pacific Grove, CA, July 30 to August 4, 2005.

Publications

Wilson BS, Schatzer R., Lopez-Poveda EA, Sun X, Lawson DT, Wolford RD: Two new directions in speech processor design for cochlear implants. Ear and Hearing **26**: 73S-81S, 2005.

Wilson BS, Schatzer R, Lopez-Poveda EA: Possibilities for a closer mimicking of normal auditory functions with cochlear implants. In *Cochlear Implants, 2nd Edition*, edited by SB Waltzman and JT Roland, Jr., Thieme Medical Publishers, New York, in press (scheduled for publication in 2005).