Fifth Quarterly Progress Report

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Speech Processors for Auditory Prostheses

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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 also can be used to evaluate the ability of speech processing strategies to produce desired spatial or temporal patterns of neural activity.

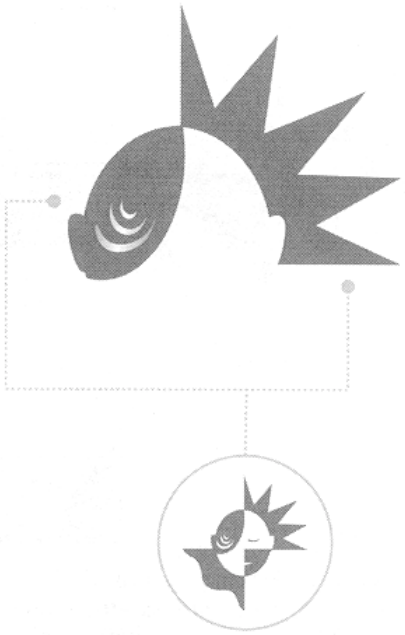
Work in this quarter included:

- Ongoing studies with Ineraid subject SR2. Studies in this quarter included (1) completion of an extensive series of measures to evaluate effects of manipulations in rate of stimulation and in the cutoff frequency for the lowpass filters in the envelope detectors in CIS processors and (2) evaluation of the TIMIT speech data base as a source of difficult sentences for sensitive measures of speech reception by a high-performance subject.
- Studies with Ineraid subject SR10, for the week beginning August 2 and August 9. The studies included (1) longitudinal measures with his portable CIS (CIS-Link) processor, (2) extension of prior studies conducted with this subject to evaluate effects of manipulations in rate of stimulation and in the cutoff frequency for the lowpass filters in the envelope detectors in CIS processors, and (3) measures of consonant identification for CIS processors using a wide range of compression functions.
- Continued development of an Access database of processor designs and study results, to bring this information together in one place for fast access and in a structure that will allow retrieval of prior designs and results on the basis of shared attributes and parameter values.
- Participation by Blake Wilson and Stefan Brill in a workshop in Frankfurt, Germany, on bilateral implants and binaural processing, at the invitation of the Med El company. (Invited speakers for the Workshop included J. Müller, F. Schön, and H. Kühn-Inacker of the Julius-Maximilians Universität in Würzburg, G. Smoorenburg of the University of Utrecht, B. Wilson of RTI, and J. Tillein of the J.W. Goethe Universität in Frankfurt. Approximately 30 people attended the workshop.)
- A visit by Wilson to the J.W. Goethe Universität in Frankfurt, at the invitation of Professor Dr. von Ilberg. Results from studies at the university to evaluate combined electric and acoustic stimulation of the same cochlea were discussed in detail, as were possibilities for future joint studies between the university and RTI to evaluate additional conditions for combined stimulation.
- A visit by Wilson to the Julius-Maximilians Universität in Würzburg, in part for further development of plans for cooperative studies between the university and RTI with recipients of bilateral COMBI 40+ implants.
- Presentation of project results in invited lectures at the *Bilateral Research Meeting* in Frankfurt and at the *30th Neural Prosthesis Workshop.*
- Continued preparation for studies with patients having bilateral COMBI 40+ implants or bilateral CI24M implants, principally by Stefan Brill, Charles Finley and consultant Marian Zerbi.
- Continued analysis of psychophysical, speech reception, and evoked potential data from current and prior studies.
- Continued preparation of manuscripts for publication.

In this report we present a detailed review of strategies developed to date for representing speech information with cochlear implants. The review provides a historical perspective for current efforts to develop better strategies and offers comments about the importance of fitting, strategy implementations, and the patient variable on performance with implants. A final section in the review mentions some possibilities for further development.

This review was originally published in the book *Cochlear Implants: Principles & Practices,* edited by J.K. Niparko, K.I. Kirk, N.K. Mellon, A. McConkey Robbins, D.L. Tucci, and B.S. Wilson (Lippincott Williams & Wilkins, Philadelphia, 2000). The reader is referred to other chapters in that book for additional information about the current status and clinical application of cochlear prostheses. Preparation of the chapter reproduced here was supported by this project (N01-DC-8-2105).

Results from the studies indicated in the bulleted list above will be presented in future reports.



Strategies for Representing Speech Information with Cochlear Implants

Blake S. Wilson

Remarkable progress has been made in the design and application of speech-processing strategies for cochlear implants. In particular, use of the new *continuous interleaved sampling* (CIS) and *spectral peak* (SPEAK) strategies have produced large improvements in speech reception performance compared with prior strategies (Skinner *et al.*, 1994; Wilson *et al.*, 1991a). All major manufacturers of multichannel implant systems now offer CIS or CIS-like strategies in their speech processors, with one offering both SPEAK and CIS. According to the 1995 National Institutes of Health Consensus Statement on Cochlear Implants in Adults and Children, "A majority of those individuals with the latest speech processors for their implants will score above 80-percent correct on high-context sentences, even without visual cues." Additional information on levels of performance is presented later in this chapter and in Chapter 10.

Although great progress has been made, much remains to be done. Patients with the best performance still do not hear as well as people with normal hearing, especially in adverse acoustic environments, and many patients do not enjoy high levels of performance even with the new processing strategies. The range of performance across patients is large with any of the current multichannel implant systems.

The purpose of the speech processor is to transform microphone inputs into patterns of electrical stimulation that convey the information content of speech and other sounds (see Chapter 6). This chapter describes how information is encoded in the production of speech and how such information can represented or partially represented with cochlear implants.

ELEMENTS OF SPEECH

A simple but useful model of speech production is shown in Fig. 7.1. This source-filter model (Flanagan, 1972) recognizes the first-order independence between excitation of the vocal tract and its resonant response to the excitation. Unvoiced sounds of speech are produced with a source of broadband turbulent noise. This noise is generated by forcing air through a narrow constriction (for production of unvoiced fricatives such as /s/) or by building pressure behind an obstruction and suddenly releasing the pressure with removal of the obstruction. Stop consonants, such as /t/, are produced in this way.

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