RESEARCH TRIANGLE INSTITUTE

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Speech Processors for Auditory Prostheses

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Introduction

The purpose of this project is to design and evaluate speech processors for multichannel auditory prostheses. Ideally, the processors will extract (or preserve) from conversational speech those parameters that are essential for intelligibility and then appropriately encode these parameters for electrical stimulation of the auditory nerve on a sector-by-sector basis. Major tasks in our project include the following: (1) identify and contrast the most promising approaches to the design of speech processors for auditory prostheses; (2) build a computer-based simulator that is capable of rapid and practical emulation of all these approaches in software; and (3) evaluate all the approaches in tests with single subjects so that meaningful comparisons of processor performance can be made. Much of the effort expended in the present quarter was directed at the first two tasks. In addition, a substantial amount of time was spent in establishing the details of our collaboration with the cochlear implant group at the University of California at San Francisco (UCSF) and in evaluating the possibility of a parallel collaboration with the Duke University Medical Center (DUMC). Results of these planning activities suggest that the extent of RTI's participation in the testing of patients at UCSF should be greatly increased over the level that was originally proposed and that a parallel collaboration with DUMC would complement our ongoing collaboration with UCSF. Because our work on tasks 1 and 2 mentioned above is just beginning, we will limit discussion in this report to our planning activities. Separate sections will be presented on our collaboration with UCSF; our potential collaboration with DUMC; and on recommendations for changes in the emphasis and scope of this project. Finally, we will outline our plans for the next quarter.

ments for each patient need to be carefully selected. To define the options, both RTI and UCSF should prepare lists of speech processors and psychophysical experiments well before the end of February, 1984, when the next patient is tentatively scheduled for surgery at UCSF. The groups should then meet a few weeks prior to surgery to decide on the final set of tests to be conducted and on the personnel requirements for each test.

2) RTI personnel should be involved in patient testing to an extent much greater than that originally indicated in RTI's proposal for this project. First, greater involvement is the only way RTI personnel can appreciate and react to the data as they are obtained and, second, heavy commitments during patient testing essentially preclude effective use of our computer-based simulator by key personnel at UCSF (e.g., by White and Shannon). RTI personnel should therefore participate directly in the tests and be primarily responsible for evaluation of speech processors that are best simulated in the software of RTI's block-diagram compiler. Evaluation of the real-time processor developed at UCSF should be conducted in parallel experiments to determine the suitability of the particular approach used and to provide a benchmark of performance against which the performance of other processors can be compared. The UCSF processor should also be emulated in the computer simulator so that we can be sure that results obtained with the computer simulator are the same as results obtained with real-time models. Everyone involved in the discussions on patient testing agreed that RTI's original plan, of just building the

computer simulator and providing it for use by UCSF personnel, is flawed for the reasons mentioned above. We all hope (and expect) that UCSF personnel will exploit the potential power of the computer simulator in the future, but practical considerations dictate an approach for the present in which RTI must also make significant contributions to patient testing, if our project is to succeed.

3) The design of the hardware interface between the Eclipse computer and patient electrodes should be revised to allow independent control of all eight bipolar pairs in the electrode array. The present interface allows simultaneous control of four bipolar pairs, which are selected by reed relays or manual switching. Although plans have already been made to increase the number of D/A converter and stimulus isolator channels to six, many plausible hypotheses for speech-processor design suggest that even six channels will be inadequate for conveying intelligible speech without the aid of lipreading. Participants in the meeting on the hardware interface agreed that eight channels of simultaneous control would be highly desirable and, indeed, that sixteen channels of control might be used in future devices to limit further the spread of current between adjacent electrodes (by having all electrodes "active"). However, the changes in interface design required for increasing the number of channels beyond four are hardly trivial and we therefore concluded that an engineering evaluation should be conducted to identify the tradeoffs between hardware changes, software changes, system complexity, and expense. If possible, this evaluation should be done by RTI. RTI should

then present its recommendations to the UCSF group, and consensus should be reached on the best approach. This approach should be implemented in a joint effort by RTI and UCSF before the end of February.

4) There should be a mechanism for RTI to assist UCSF in special tasks that are clearly germane to speech-processor design, but are outside the scope of our present contract. Two examples are assistance in digitizing the Minimal Auditory Capabilities Battery (the "MAC test") and assistance in the design and use of speech synthesizers. The digitized records of the MAC test could be used for better randomization and control of stimulus presentations during patient evaluations, and as inputs to the signal-processing software of our block-diagram compiler. In addition, these records could be made available to other investigators so that an all-digital standard of the MAC test could be used for comparing speech processors across laboratories. Appropriate use of speech synthesizers, of course, would allow manipulation of speech tokens at the feature level. Such manipulation could be a powerful tool in the evaluation of speech processors for auditory prostheses in that distortions in the transmission of features can be directly measured. Our present thought is to use the Klatt synthesizer (Klatt, 1980) in the experiments for the next patient. However, the programs for this synthesizer have to be modified for execution on the Eclipse computer (the programs were originally written for execution on DEC machines). RTI is probably in the best position to make the required program conversions.

5) RTI should purchase an AOS operating system for its Eclipse computer to facilitate exchange of software between RTI and UCSF. The RTI computer presently runs under the RDOS operating system, which in general is incompatible with the AOS system.

DUMC Collaboration

Initial plans have been made for development and clinical application of auditory prostheses at the Duke University Medical Center. One of the specific approaches under consideration involves Duke's participation in the upcoming clinical trials for the present UCSF prosthesis and Duke's participation in this project, to develop speech processors for multichannel prostheses using electrode arrays and testing procedures supplied by UCSF. If such a collaboration between UCSF, Duke and RTI can be arranged, then the number of patients included in this project could be approximately doubled; in addition, workers at RTI could interact with workers and patients at Duke on a daily basis. Thus, we have an opportunity here to define in greater detail the variations in performance across patients with given speech processors and electrode arrays, and an opportunity to establish a local collaboration that should enrich and complement our ongoing collaboration with UCSF.

The possibility of a collaboration between our three groups was discussed during my visit to UCSF. Mike Merzenich indicated a willingness of the UCSF group to work with the group at Duke in initiating a program for parallel development of speech processors. In particular, the suggestion was made that Duke participate in the UCSF program as one of three or four "experimental" collaborators. These experimental collaborators will receive electrode arrays with percutaneous plugs from

UCSF and Storz Instruments, manufacturers of the present UCSF prosthesis. In addition, UCSF will provide instruction on testing procedures and other technical matters. With this help from UCSF, we could perform experiments at both UCSF and Duke to develop speech processors for auditory prostheses. I therefore recommend that Duke should be included as a collaborator in this project, and that part of RTI's effort in building a parallel program at Duke should be funded under this contract.

Recommendations

In addition to the recommendations just made, regarding Duke's participation in our project, I would like to recommend a change in the emphasis of the project. At present, work in the project is divided into two, one-year phases, where the objective of the first phase is to "design and implement a computer-based, multichannel auditory signal processor for use in evaluating promising speech extraction and stimulus encoding schemes," and the objective of the second phase is to "design and fabricate wearable speech processors based on results obtained with the computer-based simulated designs." However, we are now convinced that (1) a productive collaboration with UCSF will require much more effort than originally thought, as outlined in the second section of this report; (2) a parallel program at Duke would increase the probability of success for this project, as outlined in the previous section of this report; (3) solution of problems associated with the basic design of speech processors for multichannel prostheses will not be reached in one year of effort, for the reasons mentioned above; and (4) solution of these problems must precede development of hardware devices, if the devices are to provide full recognition of speech without the aid of lipreading. Therefore, in this project we would like to concentrate on solution of problems associated with the basic design of speech processors, as opposed to dividing our effort between processor design and production of hardware devices. Such a change in emphasis would allow us to increase our participation in the testing of patients at UCSF and to help initiate a parallel program to develop speech processors at Duke. If production of hardware devices can be deferred for a possible project following this one, then we can address all the new tasks outlined in this report without increasing the cost of the present contract.

Plans for the Next Quarter

Pending approval of the project officer for this contract, we will redirect our effort in the next quarter to emphasize solution of problems associated with the basic design of speech processors. In particular, we plan to (1) revise the present design of the hardware interface used at UCSF for computer-controlled delivery of stimuli to implanted electrodes; (2) digitize the MAC test; and (3) attempt to recode the Klatt synthesizer for use on the the Eclipse computer. We hope to have all these tasks completed before the end of February, in time for the next patient at UCSF. In addition, we will complete our lists of experiments and speech processors for this patient, and continue work on the programming of our computer-based simulator of speech processors. If at all possible, we will have the first version of the computer simulator also ready for use at the end of February. Finally, we will continue our effort to establish a productive collaboration between UCSF, Duke and RTI.

New Personnel

An outstanding individual has been hired at RTI to work on this and one other project. He is Charlie Finley, and his CV is attached as an appendix to this report. Initially, Charlie will have primary responsibility for redesign of the hardware interface between the Eclipse and patient electrodes. Once this work is completed, he will assist in the programming of the computer simulator and in evaluating the performance of speech processors in tests with patients. We are certainly pleased to have Dr. Finley working with us on this project.

References

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PUBLICATIONS:

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