(2)

UN ERKELEY

BERK DIEGO • SAN FRANCISCO SANTA BARBARA • SANTA CRUZ

COLLEGE OF ENGINEERING
DEPARTMENT OF ELECTRICAL ENGINEERING
AND COMPUTER SCIENCES

BERKELEY, CALIFORNIA 94720

24 June, 1991

Dr. Teresa McMullen
800 North Quincy Street
Code 1142PS
Room 823
Division of Cognitive Neurological Sciences
Office of Naval Research
Arlington, VA 22217

Dear Dr. McMullen,

This is our semiannual report for the first six months of activity on Grant N00014-91-J-1333. The covered reporting period is 1 Jan 91 through 30 Jun 91.

As you know, we intend to collaborate closely with Dr. Schreiner and his colleagues, who are working on complementary, ONR-supported project. At our fist meeting to coordinate the projects, Dr. Schreiner and I decided to maintain close contact (regarding the two projects) with the auditory modeling group at Apple Computer Corporation.

The personnel working on project N00014-91-J-1333 during the reporting period were E.R. Lewis (PI), B.R. Parnas (doctoral student, research assistant), W.J. Lee (first-year graduate student, junior specialist), and I. Ladabaum (undergraduate student). During the reporting period we used our existing SUN 3/80 workstations for software development for the project. When the funds for the project were made available to the Berkeley campus from ONR (in April, 1991), we immediately placed an order for the SUN SPARCstation II listed in the project proposal. This machine was delivered to the University (Receiving Department) on June 15, and we expect it to arrive in our lab in the next few days. We expect to be able to transfer the developed software to the new (and faster) system with no difficulty.

Our software development comprised the following steps: (1) transport of our previously-developed code for modeling cochlear and VIIIth-nerve signal processing from PCAT DOS format to the SUN, UNIX format in an X-Windows environment. (2) Modification of this code to improve modularity: cochlear signal processing and VIIIth-nerve signal processing (spike initiation) now are completely independent. (3) Development of a new spike-initiator module

(based on the Hill model). (4) Development of display software for three-dimensional presentation of neural response data and user-interactive manipulation of those presentations. (5) Development of a cochlear filter module based on FFT computation. (6) Development of user-interactive software to smooth REVCOR-derived cochlear filter functions so that they can be used in cochlear-filter modules.

Transport of the old code to the SUN cost very little time. The phase of step (1) involving translation to X Windows was more time-consuming, but was done to make the code easier for us and others (outside our lab) to use. This phase is nearly complete. Step (2) has been completed, and allows us to easily insert alternative models for the cochlear filters and for the VIIIth-nerve spike initiator. Initially, we had a multichannel, cochlear-filter module that employed continuous convolution of the auditory signal with FIR models of the individual cochlear channels. This module was computationally efficient for filters of low to moderate dynamic order, but became excessively time consuming as we began to use high-order filters, more representative of those in real cochleae. Initially, we also had a spike-initiator module based on a one-time-constant, fixed-threshold, integrate-and-fire neural model, with intrinsic noise. In step (3), we developed a module based on an integrate-and-fire model with three time constants and a variable threshold. With the three time constants (time constant of excitation, and two time constant of accommodation-- k, λ and β in Hill's model) adjusted appropriately, we found that this model provides good replications of a variety of responses of auditory axons-- including primary type, with fast adaptation. It seems to be a good compromise between biophysical reality and computational efficiency. We also constructed modules based on the Hodgkin-Huxley model and on the Frankenhaeuser-Dodge model. The construction of the simulation system allowed us to switch between these various modules easily, and thus to compare their effects on the simulated VIIIth-nerve images and on computation time. In step (4), we developed software for viewing and manipulating these images on the computer console. Although this software is now operational, we expect to continue improving it throughout the entire project period. In step (5), we developed a multi-channel cochlear-filter module that can handle filter models of high dynamic order more efficiently than the convolution-based module could. Again, we were able to insert this module easily into the modeling system, as revised in step (2). Step (6) has been completed, but we have not put the resulting software to use yet.

Our interest in the spike-initiation process stems from our belief that spikes and spike timing are crucial for conveying precise temporal information to the auditory brainstem. Most current cochlear-VIIIth-nerve models (including those of our colleagues at Apple Computer) do not include spike initiation, but instead produce analog output (which one might take to correspond to mean spike rate). What this analog scheme lacks is the ability to signal subtle temporal events, such as singularities in acoustic waveforms, that might be signatures of specific sources as well as

cues for spatial localization. With sufficiently large numbers of independent VIIIth-nerve axon models in the simulation system, such events will be signalled by large-scale spike synchrony, just as they are in the VIIIth nerve. For that reason, Dr. Schreiner and I both agree that incorporation of realistic spike initiation is crucial to our modeling efforts. During the reporting period, my student colleague, B.R. Parnas, has devoted considerable time to studying the literature on spike-initiation models and neural coding. He has become especially interested in prediction of ensemble properties from single-unit properties, as studied previously by Knight, and in the interplay between noise and signals in spike initiators, as studied previously by Stein. He intends to extend both of these studies to our system in the coming project period.

During the coming period, we also plan to focus on the cochlear-filter modules, exploring the simulated VIIIth-nerve images generated with the FFT-based module with idealized cochlear filter parameters and with cochlear filter parameters based on our REVCOR data, and developing a module using wavelet transforms waveforms. In order to maintain an integrative perspective, we also intend to begin work on AVCN, MSO and LSO modules. Regarding hardware, we have arranged with CSP Inc. to try one of their accelerator (Supercard-S) boards as soon as the SPARCstation II arrives. We expect the board to decrease the computation times for the combined cochlear-filter and VIIIth-nerve modules by a factor of 25. It also should enhance the efficiency of our display software. If it meets our expectation, we shall purchase and install it.

Sincerely yours,

Edwin R. Lewis

cc: Administrative Grants Officer
Director, Naval Research Laboratory
Defense Technical Information Center