Effects of Remaining Hair Cells on Cochlear Implant Function

18th Quarterly Progress Report

Neural Prosthesis Program
Contract N01-DC-2-1005
(Quarter spanning October-December, 2006)

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Summary of Activities in This Quarter (October 1 – December 31, 2006)

1. Introduction

This report covers activities within the second quarter of the no-cost extension period on the contract. The primary goal of the research during this period is to more fully address issues specifically related to the interaction of acoustic and electric stimulation. Over the course of the contract, we have described effects both at single-fiber level and in the compound action potential in response to electrical stimulation. While we have explored effects of acoustic input level (as required in the work statement), we plan to more thoroughly investigate effects of acoustic stimulus characteristics on these interactions. Those interactions have been demonstrated to be quite complex, especially the effects of adaptation and recovery after stimulation, most notably, non-monotonic recovery functions. We propose, in the extension period, to further expand the stimulus variations both in the animal model and computer modeling to more fully investigate these characteristics of the response.

Goals for no cost extension period are to:

1. Complete publication of experimental results accomplished during this contract.

A. Two publications have been submitted to Hearing Research summarizing the effects of acoustic noise on the electrically evoked compound action potential.

Nourski, K.V., Abbas, P.J., Miller, C.A., Robinson, B.K. Acoustic-electric interactions in the auditory nerve: Masking of the electrically evoked compound action potential by acoustic noise.

Nourski, K.V., Abbas, P.J., Miller, C.A., Robinson, B.K., Jeng, F.C. Forward masking of the auditory nerve electrically evoked compound action potential in animals with residual hair cell function.

B. One publication detailing electrically evoked single-fiber responses in acoustically sensitive ears now appears in the September edition of JARO:

Miller, C.A., Abbas, P.J., Robinson, B.K., Nourski, K.V., Zhang,F, Jeng, F-C. (2006) Electrical Excitation of the Acoustically Sensitive Auditory Nerve: Single-Fiber Responses to Electric Pulse Trains, JARO 7 (3), 195-210.

2. Further investigate the effects of nonmonotonic recovery, specifically examining the effect of acoustic stimulus duration on the recovery.

The previous progress report summarized out recent efforts to evaluate the effect of acoustic stimulus duration on the response to electrical stimulation.

3. To assess the effects of electric stimulation on the responses to subsequent acoustic stimulation.

In the last progress report we reported data from one subject using a 300 ms electrical pulse train (1000 pps), immediately followed by a 200 ms acoustic noise burst. By measuring the response to the noise with and without the pulse train we were able to assess the effect of electrical stimulation on the subsequent response to noise. We reported data from one animal in which we observed a number of fibers where the effect was quite minimal. That is, despite significant responses to the electrical stimulation, there was little or no effect on the acoustic responses.

We have now collected data using this paradigm from a total of 5 animals. Our analysis is consistent with the initial observations, in that some fibers exhibit a clear effect of electric stimulation on the response to subsequent acoustic noise. That effect can persist for 100 ms or more. Nevertheless there are many fibers where there is no effect, despite high levels of electrically induced activity. This is in contrast to previous data that we have reported relative to the effect of acoustic noise on the response to electrical stimulation.

Based on our initial observations we proposed to examine effects of electrical stimulation on the response to acoustic noise based on fiber CF (fiber location in the cochlea relative to the stimulating electrode may affect stimulation), spontaneous activity (high and low spontaneous rate fibers may have different adaptation properties), noise level (high levels of noise may reduce the effectiveness of the electrical adaptation), and interpulse interval of the electrical pulse train (high pulse rates may produce greater electrical adaptation. We have begun to investigate these effects during this quarter. Data our preliminary but our initial analyses on all three of these dimensions have not provided strong predictors of the degree of effective adaptation. For instance, both high and low CF fibers have demonstrated little or no effect of electrical stimulation on acoustic response. Examples of no effect have been observed in both low and high spontaneous rate fibers. When there is an effect on the acoustic response, it varies little with acoustic level. Finally, we have observed some examples of using different electric pulse rates at the same current level. In those cases, the response rate to the electrical stimulus tends to increase with pulse rate but the effect on the acoustic response changes little. Data from two fibers are shown in Figure 1. One shows a clear effect of electrical stimulus on the noise; the other shows little effect. Neither fiber show clear effect of interpulse interval on the response to noise.

We note that limited data have been analyzed to date. We plan to complete data collection and analysis of these effects in the final two quarters and will report more detailed analyses in upcoming QPRs.

4. Finally, we have proposed to continue with the development of the model simulations, specific to these experiments. Modeling efforts thus far (Nourski et al., 2006) have demonstrated that there is considerable interaction between processes affecting acoustic and electric adaptation. We have begun work to incorporate a Hodgkin-Huxley type membrane model into those simulations. Our goal is a more realistic model of the adaptation effects that we have observed based on membrane properties.

Plans for the Next Quarter

1. Complete data collection and continue analysis of data on the effect of electrical stimulation on acoustic responses.

2. Continue to evaluate and improve the computational model of acoustic/electric interactions.

3. Complete and submit for publication another manuscript detailing auditory nerve single-fiber responses to combined electric and acoustic stimuli.

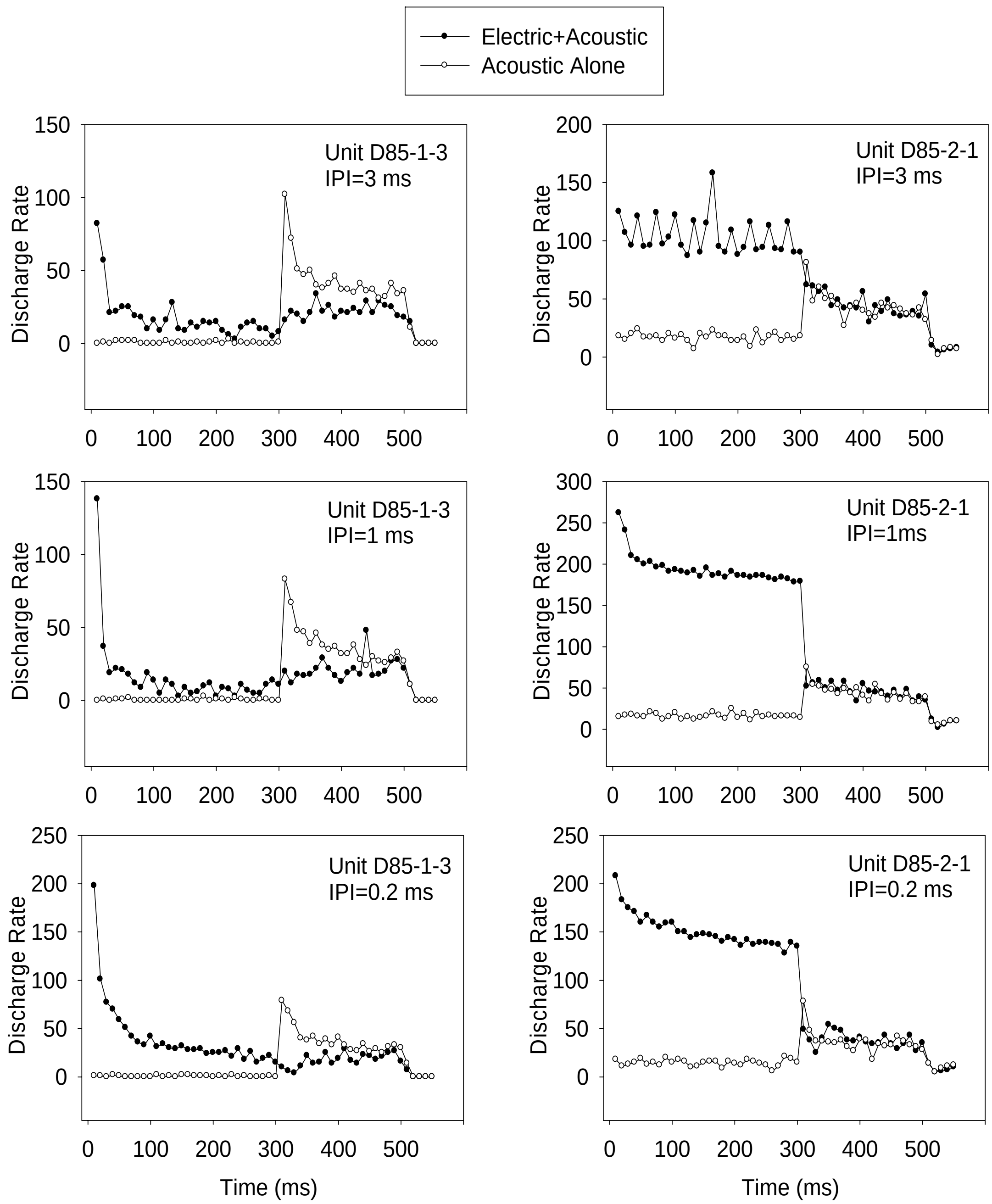

Figure 1. Single-fiber discharge rates in response to the combined electric pulse train (300 ms) followed by an acoustic noise (200 ms). In each plot, the response to the acoustic stimulus presented alone is plotted as well as the response to the combined stimuli (electric train / acoustic noise) as indicated in the legend. The difference between these two conditions during period 300-500 ms is indicative of the effect of the electric stimulus on the response to the acoustic noise. In the left column, data are plotted from a fiber that showed a clear decrease in the acoustic response. In the right column, similar data are plotted from a fiber that showed essentially no effect, despite considerable response to the electric stimulus as indicated in the histograms. For each fiber data were collected at 3 different interpulse intervals (IPI) as plotted in each row and indicated on the graph. Little effect of IPI is evident for either fiber.