# Effects of Remaining Hair Cells on Cochlear Implant Function

## 17th Quarterly Progress Report

Neural Prosthesis Program
Contract N01-DC-2-1005
*(Quarter spanning July-September, 2006)*

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## Summary of Activities in This Quarter **(July 1 – September 30, 2006)**

1. Introduction

The objectives of this contract are to understand the effects of remaining hair cells on the activation of auditory nerve fibers by cochlear electrodes and to control these effects for optimum cochlear implant function. A substantial part of the work to accomplish those goals has been to utilize animal models to determine whether the presence of hair cells can affect the firing of auditory nerve cells that are directly activated by a cochlear electrode. That work has proceeded and demonstrated substantial interactions between acoustic and electric stimulation as documented in previous progress reports.

Experiments that are part of this contract with guinea pig compound action potential (ECAP) measures have demonstrated complex, nonmonotonic recovery patterns (Nourski et al., 2005). Our hypothesis has been that nonmonotonic recovery may be the result of differential time course of rate and synchrony recovery. Based on that hypothesis we conducted single fiber recordings in cats and investigated changes in both discharge rate and synchrony in response to pulse trains following acoustic noise stimulation after relatively short duration noise bursts (100-300 ms, Miller et al., 2005). That data showed decreased response and increased synchrony in response to the electric pulse train after noise offset. Further ECAP recordings demonstrated that nonmonotic recovery patterns were more evident for longer duration stimuli. During this quarter we have begun single fiber measures with the longer duration adapters, up to 600 ms, to further assess these effects of duration on both rate and synchrony measures during recovery from adaptation.

Secondly, based on ECAP and single fiber measures made to date we have begun modeling the adaptation and recovery in response to both acoustic and electrical maskers (Nourski et al., 2006). An important issue that has arisen in those considerations is the effect of electric stimulation on the response to acoustic stimulation. During this quarter we have begun single fiber measures, examining the response to an acoustic probe after offset of an electrical adapting stimulus.

2. <u>Single fiber recovery properties: effects of acoustic adapter duration</u>

*Methods*

Surgical and recording procedures are essentially the same as our previous work. In placing the intracochlear electrode for stimulation an effort was made to preserve hearing so that combined acoustic and electric responses could be evaluated.

Stimuli are essentially the same as described in previous work (Miller et al, 2004). The adapting stimulus was a noise burst with duration 100 - 600 ms embedded in a low-rate (250 pulse/s) electric pulse train. Noise onset was always 50 ms after pulse train onset. In that way we could evaluate the response to the pulse train before, during and after the acoustic noise. Presentation of the pulse train alone was alternated with presentation of the pulse train with acoustic noise. Our standard techniques were used for artifact cancellation and responses were analyzed across the duration of the pulse train. To quantify discharge rate and jitter (synchrony) we defined time windows before noise onset, during the noise burst, and after noise offset. Data reported below are based on two intervals after noise offset: Interval 5: 5-30 ms and Interval 6: 100-200 ms. In each fiber we chose a level of noise that provided a clear driven response above spontaneous activity.

*Results*

Preliminary analysis was conducted on data from 29 fibers from subject D74. Additional data will be analyzed from subject D72. The initial analysis assessed noise duration effects by comparing responses with 100 ms noise adapter to those using a 600 ms noise adapter. We noted the following trends:

- Acoustic noise is effective in decreasing discharge rate to the electric pulse trains in both intervals. Statistical tests compared responses with and without the noise adapter. Responses in both post-noise intervals (5 and 6), showed a clear decrease in discharge rate ($p < 0.0001$).

- Acoustic noise is effective in increasing synchrony of response to electric pulse train. Similar tests of spike jitter (standard deviation of spike times) showed significant decrease ($p<0.0001$) in jitter in interval 5 for both durations but in interval 6 the decreased jitter was not significant for 100 ms noise duration ($p=0.16$). These results suggest that the longer duration adapter had a more persistent effect on jitter.

- We were particularly interested in the extent to which adaptation properties change with noise duration. We therefore characterized the degree of adaptation in each interval as the ratio of the response with and without the noise masker; i.e., ratio of discharge rate and ratio of jitter for each interval. We then used t-tests to compare the ratios for the two noise durations. For both intervals, ratios of discharge rates were less for 600 ms than for 100 ms noise durations ($p <0.002$), i.e., the effect of the longer duration noise was greater. For both intervals, ratio of jitter was not significantly different for the two noise durations (interval 5, $p=0.92$; interval 6 $p=0.059$). We plan to re-examine these trends as we analyze data from other subjects.

- We also noted fibers where the noise level was set relatively low and, consequently, there were low discharge rates in response to the noise. In several of those cases we observed little or no decrease in the response to the electric pulse train after noise offset but still observed consistent changes in the jitter.

*Discussion*

These observations are consistent with the hypothesis that changes in spike rate and jitter after an adapting stimulus can be independent and consequently may contribute to the nonmonotonic recovery of the ECAP amplitude after adapter offset.

4. <u>Effect of electrical stimulation on acoustic response</u>

The stimulus for these experiments was a 300 ms electrical pulse train (1000 pps), immediately followed by a 200 ms acoustic noise burst. The responses are measured in response to the noise burst alone and in response to the noise burst preceded by the electric pulse train. In that way we can evaluate the effect of the electrical stimulation on the acoustic response.

We have analyzed data from 21 fibers in one experimental animal (D76) to date. We have observed instances where there is significant decrease in the acoustic response after electrical stimulus offset. In many cases, however, we have observed significant response to the electrical stimulus but essentially no effect on the acoustic response. Two examples, from two different fibers are shown in Figure 1.

Response to the electrical pulse train is similar in both cases but the effect on acoustic discharge rate was quite different.

In preliminary analysis we calculated the discharge rate to the first 30 ms of the noise burst. We then calculated a ratio equivalent to that used above, i.e., the response to the noise with electrical adapter divided by that without the adapter. Data from 21 fibers, many at several levels of acoustic and electrical stimulation, showed a range of ratios form 0.1 to 1.2. In 48% of cases however the effect was 0.8 or greater, indicating little or no effect.

We plan in future experiments to more thoroughly investigate the effects of stimulus level, spontaneous activity and fiber CF on these measures.

## Plans for the Next Quarter

1. Continue to collect data on both stimulus paradigms described in the QPR.

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

## References

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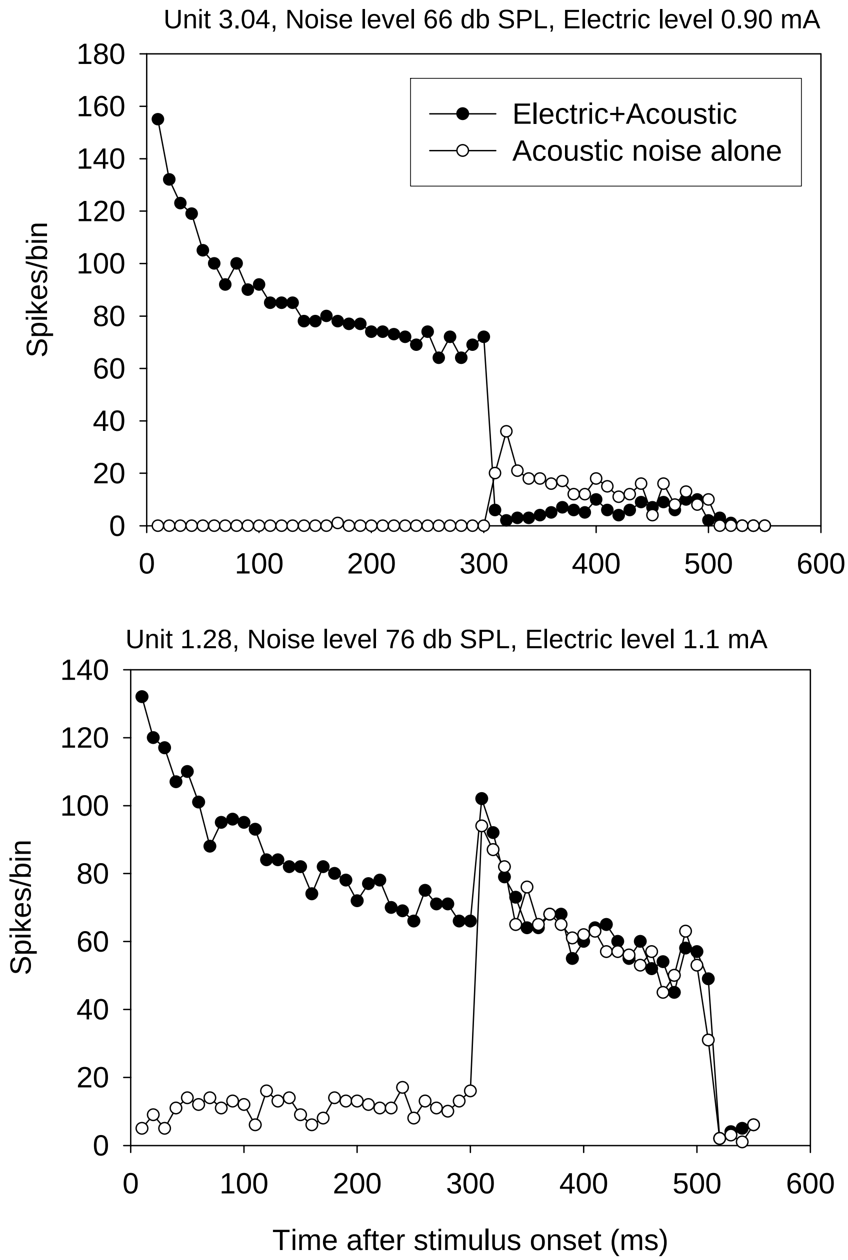


**Figure 1.** PST histograms from two fibers in response to the electric pulse train followed by the acoustic noise (filled symbols) and in response to the acoustic noise alone (open symbols). Electric pulse train is 300 ms in duration, 40 us/phase biphasic pulses, at 1000 pps. Acoustic noise is 200 ms in duration with onset at 300 ms (pulse train offset).