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Traveling Wave Based Group Delays for Cochlear Implant Speech Processing

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Abstract

Cochlear implant speech processors seek to generate a neural response that mimics normal hearing. However, the cochlear phase response is generally discarded, together with other fine scale temporal aspects of sound. We sought to incorporate and compare a variety of cochlear traveling wave delays (i.e. group delays) in a clinical speech processing strategy. Traveling wave delays resulted in a significant improvement in the perception of speech in noise, a longstanding difficulty for cochlear implant patients.

Index Terms: hearing prosthesis, group delay, phase

1. Introduction

The cochlea performs a frequency-to-place decomposition of sound. Cochlear implants exploit this place coding of sound by mapping the instantaneous amplitude spectrum to stimulation levels along an electrode array.

In addition to the magnitude response, there normally exists a cochlear filter phase response whereby low frequency sounds (resonating apically in the cochlea) are delayed relative to high frequencies. This group delay is often referred to as a traveling wave delay. The delay for a 200 Hz tone in the cochlea, for example, is greater than six milliseconds [1].

Frequency dependent delays are not currently modeled in standard cochlear implant speech processing strategies; we sought to incorporate them and investigate whether they played a role in speech perception.

2. Methods

A realistic (albeit arbitrary) starting set of group delays was estimated for electrodes inserted 4mm and spaced 0.625mm around the cochlea, spiral ganglion compression [2] and a delay equation [1]. This set was scaled to create six different traveling wave delay conditions (Fig. 1). Delays were applied to band-pass filters (as group delays) in a MATLAB® model of the clinical ACE speech processing strategy.

Open-set sentence perception of four subjects was tested for each delay condition in a counterbalanced protocol at 65 dB SPL amidst four-talker babble. To avoid floor and ceiling effects, subjects' signal-to-noise ratios ranged from 7-12 dB.

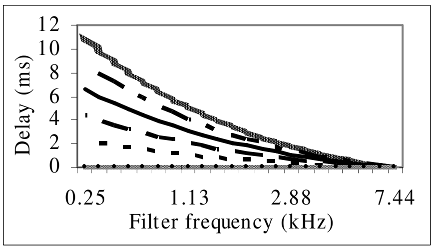

Figure 1: *Traveling wave delays scaled from 0–11 ms.*

3. Results

A two-way ANOVA was performed with delay and patient as factors. Traveling wave delays had a significant effect on speech perception in noise ($F(5,144)=2.77$, $p=.02$). The greatest improvement in mean score was 13% and occurred when delays were scaled to 0–6.6 ms (Fig. 2), which is similar to the normal cochlea. There was no significant interaction between patient and delay size.

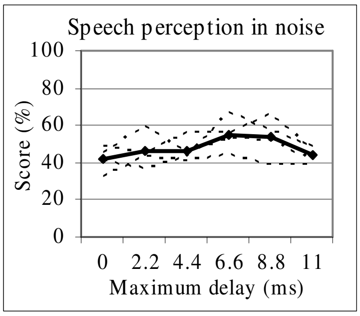

Figure 2: *Perceptual sensitivity to group delays. Individual subjects are shown as dashed lines; group data is the solid line.*

4. Conclusion

Traveling wave delays are a feature worth mimicking in cochlear implant speech processing by desynchronizing frequency bands as the normal cochlea does.
Accurate modeling or fine tuning of these delays may not be necessary, as the sensitivity peak is quite broad.
Future study will investigate a more extensive set of delays and seek mechanisms to explain this effect. We will also examine traveling wave delays in other speech processing strategies such as the STAR strategy [3].

5. Acknowledgements

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6. References

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