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USING MEASURES OF AMPLITUDE MODULATION PROCESSING TO UNDERSTAND FUNCTION OF ELECTRICALLY STIMULATED AUDITORY PATHWAYS

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ABSTRACT

For cochlear implant (CI) listeners, speech information transmission is reliant upon the ability to process the amplitude-modulated (AM) envelope of speech sounds independently in different channels. This can be hindered for many reasons, not least due to spread of electrical current or neural degeneration.

We employed a psychoacoustic task to explore AM processing. We recruited normal-hearing adults and adult CI listeners (Nucleus and Advanced Bionics). Acoustic sinusoids of two different rates (for example, 13 versus 40 Hz) were discriminated in a three-interval two-alternative forced choice task, where the modulation depth was adjusted adaptively to derive an AM discrimination threshold. Testing was conducted with and without speech envelope interferers on neighbouring channels.

Stimuli were delivered through headphones (HD600s). All front-end noise reduction features were de-activated. We explored AM processing across the frequency range.

Initial findings suggest that AM discrimination was poorer in the presence of interferers. There is variability across CI listeners and within the dataset of individual listeners. We interpret the measure as an indicator of neural function when interferers are absent and indicative of channel interaction when interferers are present. We will calculate the normative ranges for the measures.

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problems of neural survival and channel interaction. Ongoing work will compare findings to objective measures of viability of the electrode-neurone interface and speech in noise measures.

Keywords: *cochlear implant, amplitude modulation, rate discrimination, psychophysics.*

1. INTRODUCTION

Modern cochlear implants (CIs) typically work by filtering the received acoustic signal into a limited number of frequency channels, each corresponding to a stimulating electrode. The slowly varying amplitude envelope is extracted in each channel, and this is used to modulate the amplitude of fixed-rate electrical pulses delivered by the corresponding electrode to stimulate auditory nerve fibers. Information transmission, and subsequent perception, relies upon the ability to detect, track, discriminate, and process temporal envelope independently across different channels. This can be hindered in many ways - but two key factors concern the spread of electrical current and the degree of neuronal survival. Any tool capable of estimating these factors on an individual basis would likely prove helpful in guiding implant fitting [e.g., 1, 2, 3].

This short paper summarizes the on-going development of a psychoacoustic task to explore within- and between-channel envelope discrimination abilities in adults with CIs. The basic task requires the discrimination of two rates of sinusoidal amplitude modulation (SAM), where the depth of modulation is varied experimentally. This measure can be considered an index of within-channel envelope sensitivity [4, 5]. Discrimination is also conducted in the presence of speech-envelope shaped interferers presented on adjacent or adjacent ± 1 channels . We hypothesize that the extent to which interferers impair performance may be an indication of across-channel interference from factors such as current spread. Here, we present preliminary work exploring the effects of changing the SAM rate of the target signal (Investigation I) and the carrier frequencies of target and interferer signals (Investigation II). Carrier frequency manipulations were employed to vary the stimulating electrode channel targeted by the acoustic stimulus.

The overall goal of this project is to identify channels with poor envelope (AM) processing and channels most affected by interferers. This work builds on previous versions of this task which observed a relationship between AM discrimination and speech in noise perception in Advanced Bionics [6] and normal-hearing (NH) listeners using vocoded speech stimuli (unpublished).

2. INVESTIGATION 1

2.1 Listeners

Four CI listeners contributed to this investigation - three with postlingual and one [CI-01] with prelingual hearing loss [CI-01 = 33 years old, CI-02 = 74, CI-05 = 70, CI14 = 61]. All used Cochlear® devices. During the experiment, listeners wore a speech processor programmed with their everyday map, but with any noise reduction, AGC, and automatic scene classification (SCAN) features disabled via clinical software.

2.2 Stimuli

All stimuli were created from 2-s sinusoidal carriers. The test signal typically comprised a 1000-Hz tone, corresponding to the centre frequency (CF) of electrode 16 under default Cochlear® electrode frequency allocation. When present, two interferers were typically presented with carrier frequencies of 875 Hz and 1125 Hz – corresponding to the CFs of electrodes 17 and 15. Test signal and interferer frequencies were adjusted for one listener [CI-01] with non-standard electrode frequency allocation due to deactivated remote electrodes. In this instance, carrier frequencies were adjusted so to still correspond to the CFs of electrodes 15,16, and 17.

Listeners were required to discriminate a ‘target’ test signal from a ‘reference’. The target SAM rate was always higher than that of the reference. In three conditions, the target and reference SAM rates were set to either 8 & 4 Hz, 40 & 13 Hz, or 95 & 40 Hz.

When present, interferers were modulated with an envelope extracted from an independent sample of speech [7], lowpass filtered at 50 Hz.

Stimuli were presented acoustically via an RME Fireface UCX soundcard (Haimhausen, Germany) and Sennheiser HD-600 headphones (Hannover, Germany). Signal components were each presented at 65 dB SPL, as calibrated using a Tektronix MDO3024 oscilloscope (Beaverton, OR, USA).

2.3 Method

The experiment used a 3I-3AFC adaptive procedure, in which listeners discriminated a target test signal from two reference signals. There was a 500 ms silence between intervals. Listeners responded via a touch-screen, and visual feedback was provided.

The experiment used a two-down, one-up adaptive procedure to estimate the 71% correct point on the psychometric function [8]. The depth of SAM applied to the test signal was varied adaptively, starting at 80% (i.e., with 100% corresponding to full modulation). The step size was a factor of 1.7 for the first two reversals, reduced to 1.4 for another two reversals, and finally held at 1.15 for four final reversals. The geometric mean of the final four reversals was taken as the threshold estimate.

The depth of modulation applied to the interferers was inversely related to the depth of modulation applied to the test signal. Interferer modulation depth began at 10%, but was *increased* when test signal modulation was *decreased* and vice versa. At each step change, interferer modulation depth was scaled by the same factor as the test signal.

Listeners completed two runs of each of the six experimental conditions (3 test SAM rates × interferers absent or present), and their final threshold estimate was taken as the geometric mean of the estimates derived from both runs.

2.4 Results

The task was understood and completed by all listeners, and the results are shown in Figure 1. The following trends were observed: Listeners appeared able to discriminate SAM at shallower modulation depths when the interferers were absent – the presence of interferers made the task considerably more challenging. Average thresholds also appeared to increase as the test signal modulation rates increased.

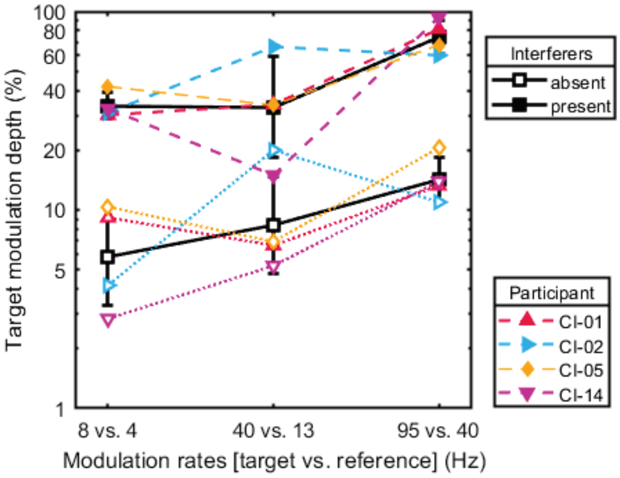

Figure 1. Results from Investigation 1. AM discrimination for a test signal targeting electrode 16 (typically 1000 Hz), and three AM rate comparisons (ordinate). Results are plotted as test signal modulation depth at threshold (abscissa) to allow comparison between interferer conditions, but refer to the main text for a description of how test signal and interferer modulation depths were co-varied. The bold black line indicates the group mean, and error bars indicate ±1 standard deviation.

3. INVESTIGATION 2

3.1 Listeners

Five CI listeners took part in the investigation – two of whom did not contribute to Investigation 1 [CI-10 = 67, CI16 = 68]. Both additional listeners experienced postlingual hearing loss, and used Cochlear® devices.

3.2 Stimuli and method

Only test signal SAM rates of 40 Hz (target) and 13 Hz (reference) were used. For time efficiency, the duration of the stimuli was reduced to 700 ms.
We explored performance across a range of carrier frequencies in regions important for transmission of speech cues. The test signal carrier frequency was either 625, 1000, 1438, 2188, or 3313 Hz – corresponding to the CFs of electrodes 19, 17, 13, 10, or 7. Interferer carrier frequencies were set to the CF of ±2 electrodes from the test signal – for example, for a test signal targeting electrode 19 (625 Hz), the interferers targeted electrodes 21 (375 Hz) and 17 (875 Hz). As for Investigation 1, carrier frequencies were adjusted for CI-01 to accommodate their non-standard frequency allocation. Note that this listener did not have electrodes deactivated inside the range tested in the experiment.

The method was identical to that of Investigation 1.

3.3 Results

As some listeners did not complete all experimental conditions at the time of writing, thresholds are averaged across e19 & e17 (apical) and e10 & 7 (basal). Through this averaging every listener was able to contribute to every condition or condition pair, albeit with the caveat that certain individual thresholds are estimated from fewer runs than others. The results are shown in Figure 2; as for Investigation 1, listeners appeared able to discriminate SAM at shallower modulation depths when the interferers were absent. There was also a trend for better performance overall at more apical electrodes (higher electrode number). However, on an individual level, this effect was not apparent for two out of the five listeners. The pattern observed without interferers was typically paralleled by that with interferers.

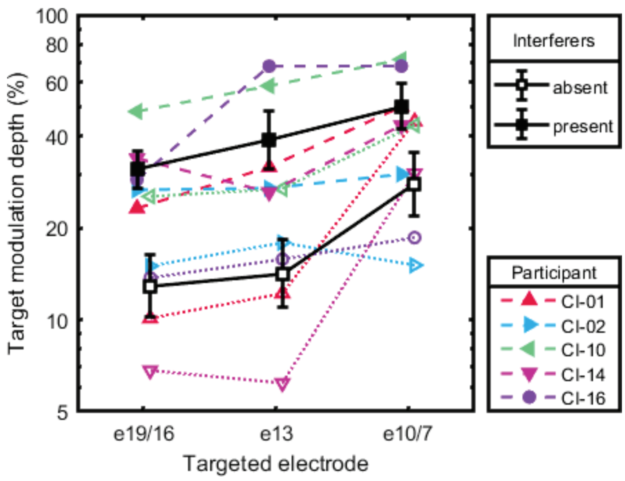

Figure 2. Results from Investigation 2. As for Figure 1, except the performance at different carrier frequencies (expressed as targeted electrode) is plotted along the ordinate.

4. DISCUSSION

The two investigations presented here show the preliminary findings of an AM discrimination task to help measure within- and across-channel AM processing. Although there are insufficient data to draw firm conclusions, the task is appropriate for CI users who are capable of behavioral testing. At present, we are continuing data collection for

Investigation 2. We will validate our hypothesis that the task can be used as a diagnostic measure of neural survival (i.e., from overall sensitivity to AM) and/or current spread (i.e., from the extent interferers impair performance). On-going work will compare our AM discrimination findings with CI listeners to other measures such as as the Auditory Change Complex (ACC) to changes in AM rate [9], measures of speech in noise performance, and panoramic eCAPs [3]. Future work may explore the influence of test signal/interferer frequency separation, and manners in which the test may be adapted for clinical use. If the measure can be developed to a sufficient extent, we may also explore re-mapping approaches based on test results.

5. ACKNOWLEDGMENTS

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