Variability Reduction in Cortical Potentials Evoked by Pitch Matched Electroacoustic Stimulation

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Abstract—Cochlear implant (CI) restores hearing sensation in profoundly deafen patients by directly stimulating auditory nerve with electric pulses using an array of tonotopically inserted electrodes. Each intracochlear electrode is stimulated in response to input frequency that matches with the natural characteristic frequency at the electrode position in cochlear. However, current technology does not permit a coverage of electrodes that would have a good match between these two frequencies. This mismatch problem is even more apparent in unilaterally implanted users who has residual hearing in the contra-lateral ear. In this paper, we examined the underlying neuro-physiological mechanism when these CI users pitch matched the electrical stimulation at one electrode by adjusting the frequency of an acoustic tone presented in their unimplanted ear with EEG recording. Given these electro-acoustic stimulations may modulate the evoked cortical response of each CI subject differently, we apply the wavelet scattering transform to extract a deformation invariant cortical response from EEG recordings of 10 CI subjects when they were listening to their self-pitch matched electroacoustic stimulations. Results show that the proposed method captures the variability introduced by different subjects, and is a robust alternative to reveal the underlying neurophysiological responses.

I. INTRODUCTION

Direct electrical stimulation to cochlear nerve using a intracochlear electrode does not necessarily regain the tonotopicty in a profoundly impaired cochlear. Many constraints like different cochlear size and electrode array length, further reduce the possibility of having the electrical stimulation strictly in response to the natural characteristic frequency at where the intra-cochlear electrode is placed. Individualized tuning of appropriate speech processing and electrical simulation parameters are clearly necessary for CI users.

To date, this tuning process is usually done with an audiologist. This process is both time and energy consuming and might not be helpful for very young users. Furthermore, CI users will need time to adapt to their devices to resolve this impoverish representation of speech provided by electrical stimulation to derive benefits. Cortical response to pitch matched stimuli was found to be an useful feedback for this tuning process. In our previous study, unilateral CI users with residual hearing in their non implanted ear were studied behaviorally and physiologically in matching electroacoustic stimulation [1]. CI users were asked to match the pitch percepts elicited by electrical stimulation with those elicited by adjustable acoustic tone presented in the contra-lateral ear. EEG was also recorded when pitch matched stimuli were presented to these CI users.

However, extracting a meaningful cortical response from EEG recordings is challenging. High level of variability in EEG recording across subjects makes it hard to establish a meaningful relationship between evoked cortical response and the frequency mismatch. We propose wavelet scattering to reduce the existing variability to extract a evoked cortical response that correlates to this mismatch phenomena.

II. EXPERIMENTAL RESULTS

We apply a three stage algorithm for reducing variability of EEG signal depicted in Figure 1. In the first step, the single channel EEG signal is analyzed with the scattering transform. We use a two layer ($l = 2$) scattering network with the normalized Morlet wavelet. In the second stage, the wavelet coefficients are normalized and the log function is applied to compress the range in order to obtain a better contrast. The last step, is ensemble averaging among different experiments to reduce noise.

Fig. 1. The three step variability reduction Algorithm.

In these experiments we analyze a single EEG channel at the center of scalp (CZ) recorded from 10 subjects under 6 test conditions with only the third most apical electrode in their implanted ear. In non implanted ear, the stimuli are a pure tone at 6 different frequencies: 250, 375, 500, 625, 1,000 Hz and their self-pitch-matched frequency. In standard clinical map, the electrode in stimulation was responding to an input frequency of about 500Hz. These frequencies in the non implanted ear are chosen input into be one octave higher or lower the target frequency of 500 Hz and at the center of apical or basal electrodes. Figure 2 depicts the ensemble average of the scattering transform for 10 CI subjects. As seen, the algorithm output shows a high degree of similarity for different subjects.

Fig. 2. Different subjects show a high similarity after removing the variability.

III. CONCLUSION

In this paper, the wavelet scattering transform was found to remove the variability in EEG signal. This processing framework provides a more robust alternative to the classical technique in mining the neuro-physiological correlate to pitch matched stimuli in unilateral CI users with residual hearing in their contra-lateral non-implanted ear.

REFERENCES