Characterization of cochlear compressive nonlinearities using forward-masked compound action potentials

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Abstract

Cochlear compressive nonlinearities introduce level-dependent effects in sound processing by the inner ear, which are perceptually relevant for normal hearing and altered with sensorineural hearing loss. With increasing sound level, cochlear filters broaden and, in some situations, auditory-nerve (AN) activity is reduced (e.g., two-tone suppression). Compressive nonlinearities complicate studying the peripheral auditory system, notably in humans, for which measures of AN activity or basilar-membrane motion are difficult to acquire. Psychophysical masking experiments have revealed some nonlinear effects, as have several non-invasive physiological methods (e.g., otoacoustic emission (OAE) or compound action potential (CAP) suppression tuning curves). However, physiological estimates of cochlear frequency selectivity in humans (e.g., from OAE group delays) generally provide a single representation of quality factor versus frequency, reflecting tuning only for a particular sound level.
Recently, we developed a mathematical framework to enhance the estimation of cochlear frequency selectivity based on forward-masked CAPs. The technique relies primarily on the estimation of masking as a function of intensity at the cochlear-filter output. Based on these functions, cochlear 'excitation patterns' are defined and convolved by a unitary response to predict the waveforms of the forward-masked CAPs. Model parameters, including those characterizing frequency selectivity, are fine-tuned by minimizing waveform-prediction errors across many different masking conditions, producing robust estimations. This new technique has proven to be accurate for estimating cochlear tuning in normal-hearing chinchillas at low-moderate sound levels, but compressive nonlinearities have not been considered to date. In this talk, we present an extension of our mathematical framework to account for compressive non-linearities and their effects on frequency selectivity.

We recorded round-window click-evoked CAPs from anesthetized chinchillas using a set of forward-maskers specifically designed to probe various nonlinear aspects of cochlear signal processing. To estimate growth of masking and frequency selectivity in the 5-kHz region, a set of 24 maskers was created; half of them with 4-6 kHz bands of varying intensity (to help estimate masking input-output curves) and the other half with notches of varying width (to help estimate frequency selectivity). All maskers were generated from Gaussian noise and also included a high-frequency band (6-12 kHz) to mask basal contributions. The maskers were presented at 6 different sound levels (40-65 dB SPL in 5-dB steps). We then employed two strategies to account for compressive nonlinearities: i) fitting the forward-masked CAPs with our model at the 6 different sound levels independently; ii) fitting all CAPs at once

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with a single model that includes compression to capture the systematic level dependence in frequency selectivity.

Results will be presented comparing relative merits of each strategy in accounting for the effects of compressive nonlinearities on frequency selectivity and input-output functions in normal-hearing chinchillas. Data will also be presented from several pre-clinical chinchilla models of sensorineural hearing loss, both with and without outer-hair-cell dysfunction, to test the sensitivity and specificity of this approach to reductions in cochlear nonlinearities. Successful development of this efficient convolutional-model-based empirical approach may have long-term implications for translation to objective characterization of cochlear nonlinearities in humans using electrocochleography.