Neural encoding of stimulus envelope and temporal fine structure in frequency following responses: Can they explain individual speech-in-noise performance?

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Abstract

The scalp-recorded Frequency Following Response (FFR) constitutes an objective, non-invasive way of evaluating the fidelity of neural encoding in the auditory periphery. Adding and subtracting FFRs to positive and negative stimulus polarities allows for a differential assessment of neural representations of stimulus envelope (ENV) and temporal fine structure (TFS), which are both important cues of speech signals. FFR thus offers a valuable tool to evaluate how neural encoding up to the brainstem level impacts speech encoding and perception in humans.
Past studies observed a strong magnitude reduction of FFRs in older listeners with hearing loss compared to young normal-hearing listeners, a result that was interpreted as primarily reflecting the effect of aging. Yet, it remains unclear whether cochlear damage per se – i.e. independent of age – also contributes to this reduction. Besides, further research is still needed to understand the extent to which neural representations of ENV and TFS derived from FFR measurements can either account for behavioral differences in speech-in-noise perception.

Here, we addressed these questions by performing a set of FFR and speech-in-noise intelligibility measurements in two groups of older listeners (40-60 yrs) having normal hearing (oNH, n=18) or mild to moderate hearing loss (oHI, n=10). Speech reception thresholds (SRTs) were measured in steady-state, speech-shaped noise under several frequency-filtering conditions specifically designed to differentially reflect the contribution of ENV and TFS cues; speech and noise materials were either kept intact, low-pass filtered to target TFS cues, or high-pass filtered to target ENV cues. We also assessed in the same listeners the neural coding of stimulus ENV and TFS by measuring FFRs to a high-frequency amplitude-modulated tone and a low-frequency steady-state synthetic vowel, respectively.

Behavioral data analyses suggested that the speech-in-noise performance of oHI listeners was primarily limited by their impairment in ENV processing in the high frequencies resulting from cochlear damage. In contrast, results of oNH listeners showed that SRTs in the intact condition were correlated with SRTs in the low-pass filtering condition, suggesting that TFS coding fidelity was the factor limiting speech-in-noise performance in this group.

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Electrophysiological data showed that the magnitude of neural representations of ENV was significantly smaller in oHI compared to oNH listeners, but we did not observe significant differences regarding their neural representations of TFS. Finally, we found no significant correlations between SRTs across conditions and the magnitude of either ENV and TFS neural representations.
Taken together, these results indicate that among older listeners, cochlear damage per se further impairs the neural encoding of ENV, but not TFS cues. Our electrophysiological data do not provide evidence that speech-in-noise performance of older listeners without audiometric deficits are constrained by their neural encoding of TFS, as suggested by our behavioral data. All these results will be discussed in light with theoretical effects of outer hair cell loss and cochlear synaptopathy on FFRs simulated with a biophysical model of the auditory periphery.