Low and high-frequency hearing mechanisms in ageing and tinnitus

Sarah Verhulst*†[1], Sarineh Keshishzadeh[1], Baziel Taghon[1], Hannah Keppler[2], and Ingeborg Dhooge[3]

[1]Hearing Technology @ WAVES, Dept. of information technology, Ghent University – Belgium
[2]Audiology, Dept. of Rehabilitation Sciences, Ghent University – Belgium
[3]Otolaryngology, Dept. of Head and Skin, Ghent University – Belgium

Abstract

Tinnitus and age-related hearing difficulties can occur while audiometric hearing sensitivity remains normal. Early-onset sensorineural hearing damage, such as extended high-frequency outer-hair-cell (OHC) damage or cochlear synaptopathy (CS) are associated with either etiology, but the exact mechanisms underpinning the negative functional consequences (tinnitus or degraded speech intelligibility) remain poorly understood. In this work, we took a combined behavioral, physiological, and computational approach to study low- and high-frequency hearing in age-matched younger (22.7 ± 1.1 y/o, PTA_upto8kHz = 4.2 ± 2.9, N=31) and older (48.8 ± 5.6 y/o, PTA_upto8kHz = 13.8 ± 4.7, N=23) subject groups with or without sustained tinnitus. Specifically, we focused on physiological markers supra-threshold hearing (1-kHz tone-burst ABR, or 4-kHz envelope-following responses) and related these to click-ABR markers of brainstem gain, hearing sensitivity and speech intelligibility for low (< 1.5 kHz) or high-frequency (> 1.6 kHz) filtered speech presented in quiet or noise. Our experimental design can disentangle tinnitus from age-related effects, while focusing on which mechanisms (temporal fine-structure or temporal envelope coding) are impaired in ageing with or without tinnitus.
The hearing profile included standard clinical measures (audiogram, tympanogram, tinnitus questionnaires) as well as extended high-frequency thresholds (EHFT, up to 20 kHz), envelope-following-response (EFR) markers of CS and brainstem gain markers. EFR stimuli were 120-Hz rectangularly amplitude-modulated (RAM) pure tones (120-Hz, 70 dB SPL, 4-kHz carrier) and brainstem gain was determined as the ratio between the wave-I and V amplitudes of the auditory brainstem response (ABR; stimulus: 80 and 100 dB peSPL, 11 Hz clicks). Speech intelligibility was quantified using the speech reception threshold (SRT) derived using a 5-word Matrix sentence test presented in quiet or in 70-dB stationary noise. We computed the SRT in low or high-frequency bands and investigated its relation to the other sensorineural hearing loss (SNHL) markers. Lastly, we adopted several numerical approaches (linear and nonlinear SVM, logistic regression) as a data-driven approach to understand which combination of auditory features best separated tinnitus from non-tinnitus patients.

RAM-EFR and ABR wave-I markers of CS were significantly smaller in the older than younger group and did not differ between tinnitus and non-tinnitus subjects within the age

*Speaker
†Corresponding author: sarah.verhulst@ugent.be

groups. This supports the view that CS is associated with ageing rather than with tinnitus. Elevated SRTs were observed in older listeners, and in those with weaker RAM-EFRs or elevated hearing thresholds. Tinnitus did not affect these outcomes, demonstrating a stronger importance of SNHL than tinnitus in predicting speech perception difficulties. Possible alterations in brainstem gain after CS were evaluated by studying the effects of age, tinnitus, the RAM-EFR or HFTs on the ABR wave-I/V ratio. We found no systematic dependencies, and thus no straightforward connection to this brainstem gain marker. Lastly, the feature extraction approach pointed to low-frequency hearing deficits (lower TB ABR amplitudes and elevated SRTs) in tinnitus compared to non-tinnitus patients, and this warrants further investigation.

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