Auditory figure-ground segregation is impaired in aging and age-related hearing loss

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Introduction

Listening in noisy environments is one of the fundamental capabilities of the human hearing system that is crucial for survival and successful coping in everyday situations. While the use of hearing aids clearly improve the perception of sounds in aging users, noisy situations still present a challenge for them (Wu et al., 2013). Amplification, therefore, is not sufficient to compensate for the loss of this ability in aging. Teki et al. (2011) developed a novel auditory stimulus termed the Stochastic Figure-Ground (SFG). The SFG stimulus has been shown to provide a good approximation to the real-life situation of extracting a sound stream from a noisy background (Dykstra et al., 2017; Teki et al., 2013). The successful parsing of such stimuli (figure-ground segregation - FGS) is accompanied by two ERPs: an ORN and a P600 component (Dykstra et al., 2017; Tóth et al., 2016). We presented an adapted version of the SFG stimulus (O'Sullivan et al., 2015), which consists of random noise made of pure tones ("ground") and optionally an embedded set of tones consistently rising together in parallel ("figure" – see Fig. 1) in a series of behavioral and electrophysiological experiments testing age related effects on the ability to detect a stream in a noisy environment.

Materials and Methods

Participants: Three groups: Young (N=21, mean age=21.2 yrs), Elderly with normal hearing (N=13, mean age=67.3 yrs), Hearing impaired elderly (N=16, 68.7 yrs)
Stimuli: SFG with or without a figure (see Fig. 1)
Pre-tests: Audiometric examination and a digit span test was administered to evaluate hearing and general frontal functionality.
Stimulus calibration: Using an adaptive staircase method, the number of consistently rising parallel tones ("figure coherence") was set individually for each participant such that they performed the figure detection task at 80% accuracy ("high-SNR" condition). Next the number of background tones ("noise") was increased with a second staircase procedure, until performance dropped to 60% ("low-SNR" condition).

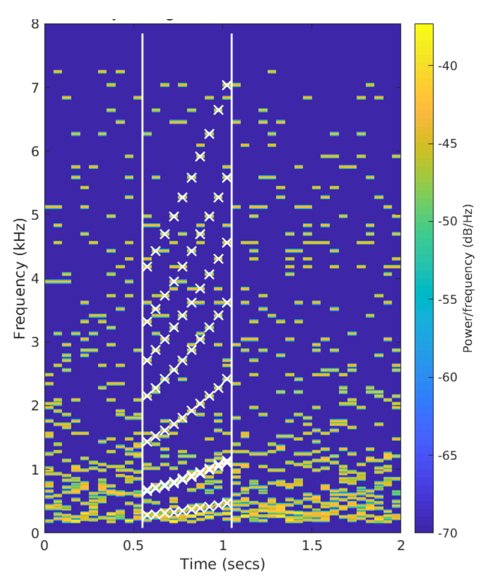

Figure 1: Spectrogram of an example SFG stimulus. The x axis represents time, the y axis denotes the frequency of the tones while tone intensity is presented as a heat map (scale shown on the right). The figure consists of temporally coherent tones that are highlighted with x symbols.

Task: Participants listened to a random series of high- and low-SNR SFG stimuli (.5 probability, each), each either containing a figure or not (.5 probability, each). They were instructed to judge whether the figure was present or not.
Recorded data: Behavioral measures (accuracy, reaction time) and EEG

Behavioral results

Stimulus calibration successfully compensated for individual performance differences. While we found significantly higher accuracy (d') and lower reaction times in the high- relative to the low-SNR condition, there was no significant group difference. Thus, both the individual adjustments and the SNR manipulation were successful.

Hearing impairment has an effect on FGS ability The figure coherence values needed to reach the same performance in the high-SNR condition were significantly higher for the hearing impaired elderly than for the other two groups. Similarly, the hearing impaired group needed a significantly higher ratio between figure coherence and noise to reach the same performance in the low-SNR condition than the other two groups.

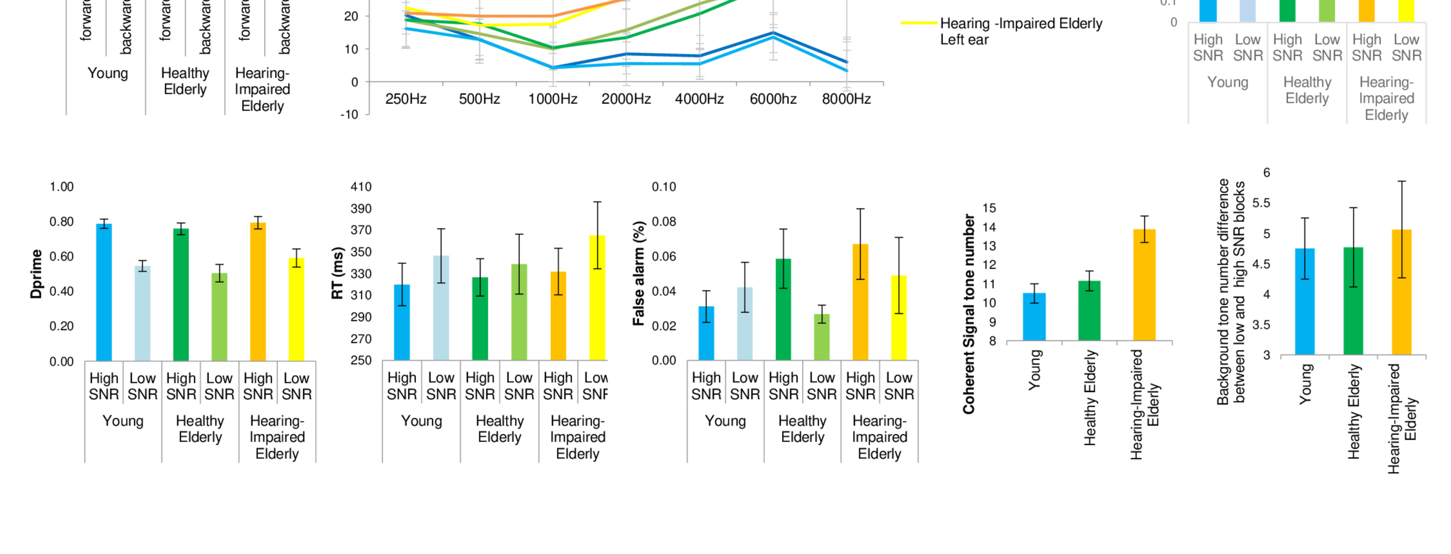

Figure 2: Behavioral results

EEG results

The ORN amplitude showed an effect of SNR but no effect of age or hearing impairment. The main effect of SNR was significant due to a higher ORN for high- than low-SNR trials.

The P600 amplitude showed an effect of age but no effect of SNR or hearing impairment. The P600 response showed higher amplitude in young subjects than in elderly subjects with or without hearing impairment. The two elderly groups did not significantly differ from each other.

According to source localization, the ORN was elicited in left Heschl's gyrus, STG, IFG, MFG, MTG, SMG whereas the P600 component was strongest in the anterior and posterior cingular cortices and in posterior brain regions (lingual and pericalcarine gyri).

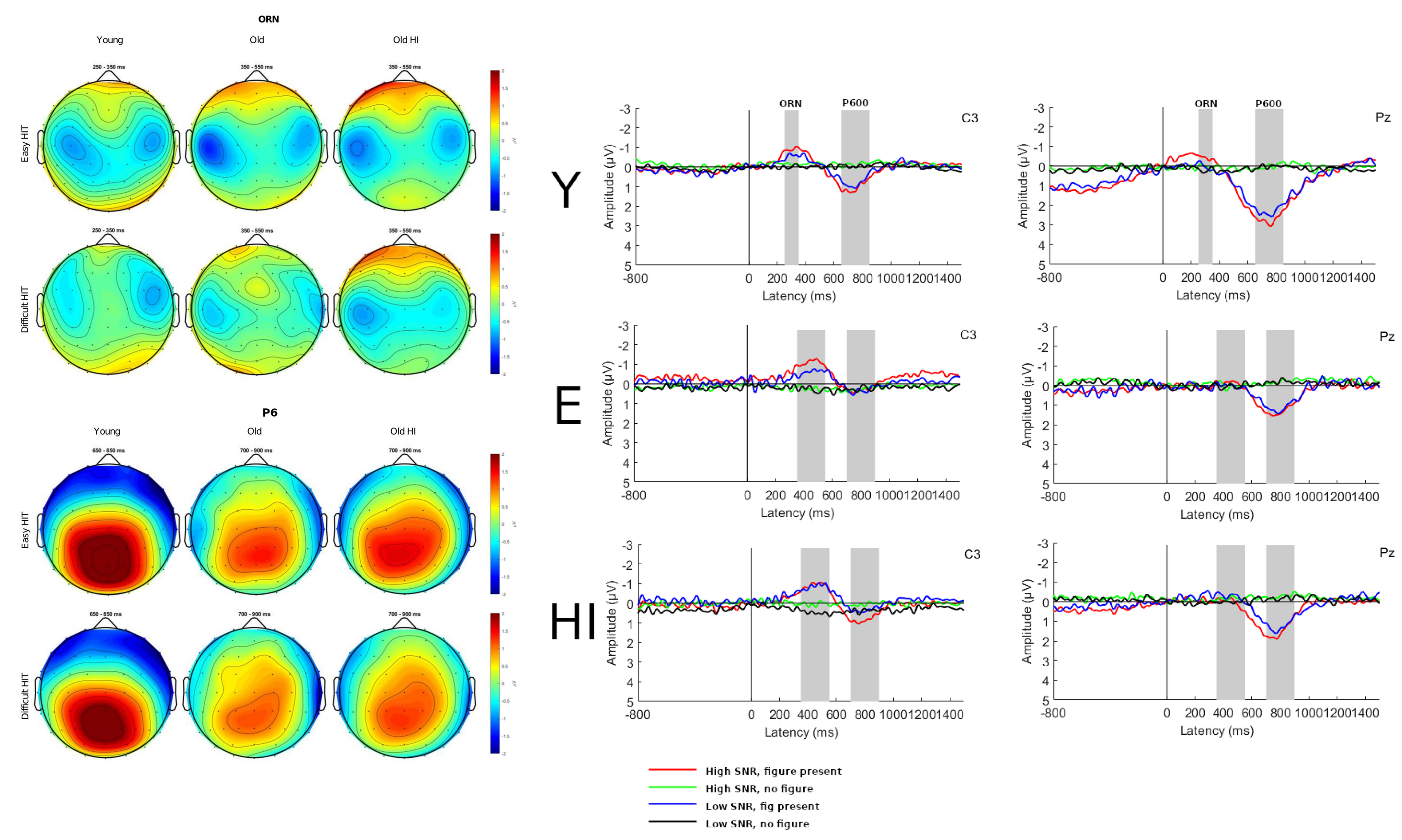

Figure 3: ORN and P600 event-related potentials (respective time windows marked in grey) on the C3 and Pz electrodes for each group: Y = young, E = elderly with normal hearing, HI = hearing impaired elderly

Conclusions

The preliminary data obtained in this study corroborates the hypothesis that the aging related impairment of auditory object detection in noise is partly due to changes in brain functionality that are independent of hearing impairment and can also be observed when hearing thresholds are within the normal range. Specifying this conclusion, the ERP results suggest that the age related listening impairments in listening under noisy conditions mainly stem from later stages of sound processing while early, low-level object detection mechanisms remain intact. Given the high level of neural plasticity still present even in the aging brain (Grady, 2012), information about impaired neural processes that are independent of peripheral deterioration opens future possibilities of developing new training programs. In addition to better hearing, such trainings could improve the quality of life of the elderly, by increasing their sense of security, reducing social isolation and the risk of dementia (Slade et al., 2020).

Future Research

Functional connectivity analysis will complement our current findings with further data that might prove informative with regards to the exact neural processes involved. Furthermore, a subsequent study will address the question of whether figure-ground segregation training can improve the ability to listen in noisy environments in the elderly.

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