Influence of hearing impairment on alpha power during retention of auditory stimuli

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In the human electroencephalogram, alpha activity (~10 Hz) during retention of auditory stimuli increases with hearing decline. The effect of manipulating the background noise level on the alpha activity was determined by hearing impairment.

Introduction

The working memory (**WM**) assists us during listening by processing and storing auditory information which can be combined into comprehensible speech [1].

Hearing impairment is believed to affect the WM by causing internal degradation of the auditory input [2,3].

The auditory Sternberg task allows us to investigate the interaction between processing and storage in the WM, by varying both the level of noise masker (processing) and the number of items to remember (storage) [4].

In the electroencephalography (**EEG**) increased WM involvement is associated with increased **alpha activity** (6-12 Hz). Alpha activity is a sign of functional inhibition of irrelevant processes, in order to focus on solving the task at hand [5].

Aim of the study is to investigate how alpha power during the stimulus-free retention of auditory stimuli is affected by hearing impairment, background noise level, and memory load.

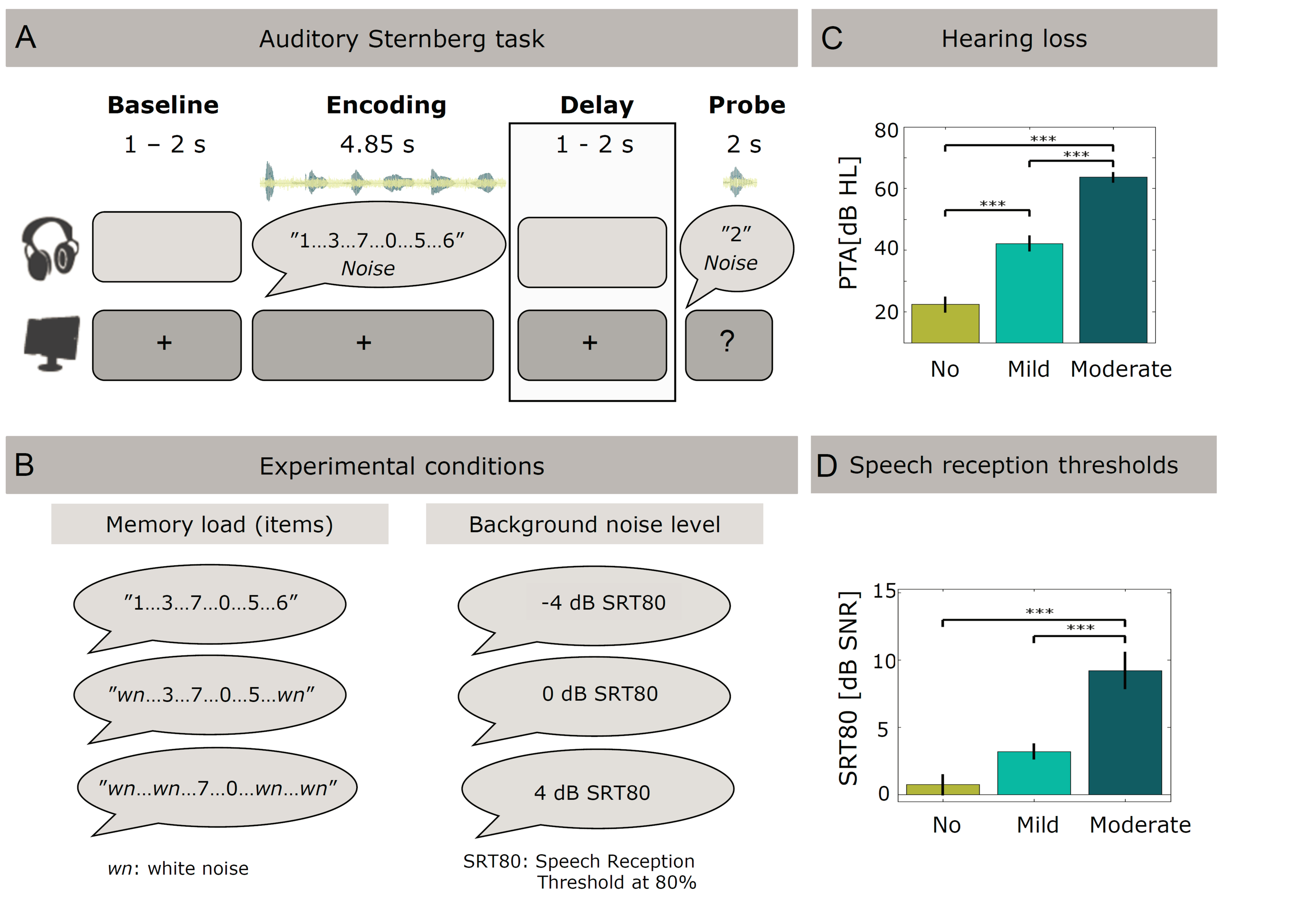

Figure 1. Experimental setup of the Auditory Sternberg task **(A)** and experimental conditions **(B)** together with participant's hearing loss measured as PTA (mean pure-tone average at 0.5, 1, 2, 4, and 8 kHz) **(C)** and individual speech reception thresholds at 80% (SRT80) **(D)**.

Methods

Participants

28 elderly participants with normal to moderately impaired hearing (**Figure 1C**), with an age range of 62-86 (mean age 72.2), and a total of 16 females.

All participants were wearing **individually fitted hearing aids** (Agil, Oticon A/S, Denmark). All stimuli were presented through the direct audio input of the hearing aids, i.e., no free field sound presentation.

Adaptive HINT tests were used to identify the speech reception threshold at 80% intelligibility level (**SRT80**) for individualization of the noise level (**Figure 1D**). The SRT80 denotes the signal-to-noise ratio at which 80% of the speech in noise is intelligible.

Test paradigm and EEG recording

An auditory Sternberg task [4] with 3 background noise levels and 3 memory loads was used (**Figure 1A & B**).

Noise levels were individualized based on the SRT80 (**Figure 1D**). The SRT80 was used as the intermediate condition (**0 dB SRT80**) and the flanking conditions were created by adding and subtracting 4 dB (**4 dB SRT80** and **-4 dB SRT80**).

EEG recorded using EGI system (Electrical Geodesic Inc., OR, USA), with 128 electrodes (26 electrodes were removed for other purposes).

Analysis

Hearing loss, quantified as the mean of the pure-tone average (**PTA**) at 0.5, 1, 2, 4, and 8 kHz, was residualized with respect to age, denoted **rPTA**, due to a significant correlation between age and PTA ($r = 0.44$, $p = 0.018$).

Preliminary inspection of the alpha power showed a quadratic relationship hearing loss (**Figure 2**), **rPTA-squared** was therefore included as a predictor in the statistical analysis.

Repeated-measures ANCOVA with rPTA and rPTA-squared as covariates was applied for the average alpha power within each time interval, as well as for the task accuracy.

Results

- Task accuracy decreased with higher noise levels ($p < 0.01$) and higher memory load ($p = 0.005$). Hearing loss (rPTA) did not influence task accuracy ($p = 0.185$).
- Alpha power during the delay was significantly affected by rPTA ($p = 0.048$, **Figure 3A**), but not by background noise ($p = 0.299$) or memory load ($p = 0.989$).

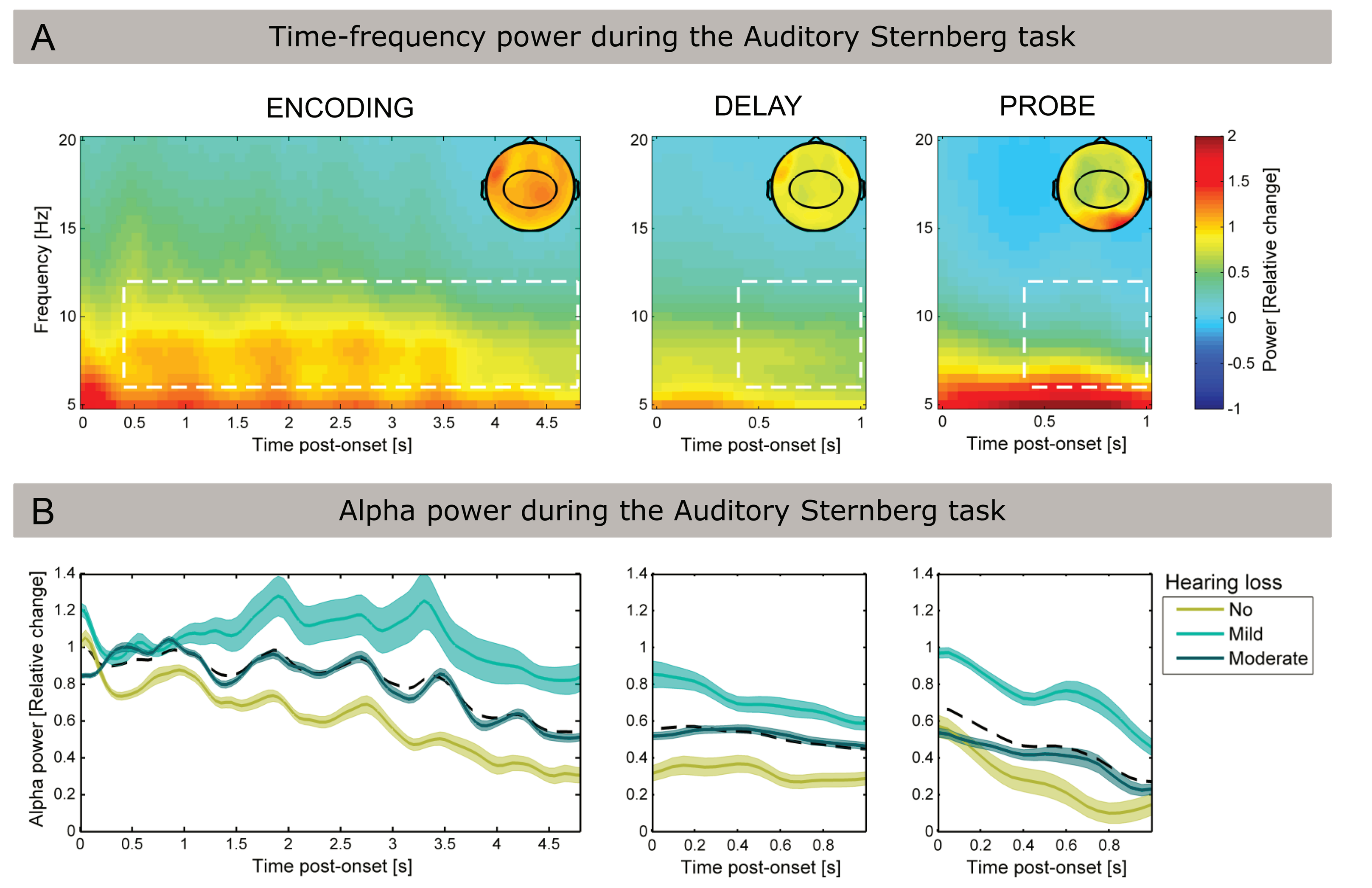

Figure 2. The grand average power **(A)** for the 31 electrodes highlighted in the topographic maps. The topographic maps shows the distribution of the alpha power within the time-frequency intervals marked with white squares **(B)** shows the average alpha power (dotted black line), as well as the power for each of the three hearing loss groups. The colored areas indicate ±1 SEM.

- The significant interaction effect between background noise level and rPTA-squared ($p = 0.004$, **Figure 3B**) and between background noise level, memory load, and rPTA-squared ($p = 0.042$, **Figure 3C**) indicated a breakdown in alpha power for the moderately impaired participants.
- No significant effects were found during the encoding of the auditory stimuli (all $p > 0.12$).
- A significant effect of rPTA ($p = 0.004$) was found on the alpha power during the probe. Alpha power during the probe was positively correlated with response time ($r = 0.35$, $p = 0.068$).

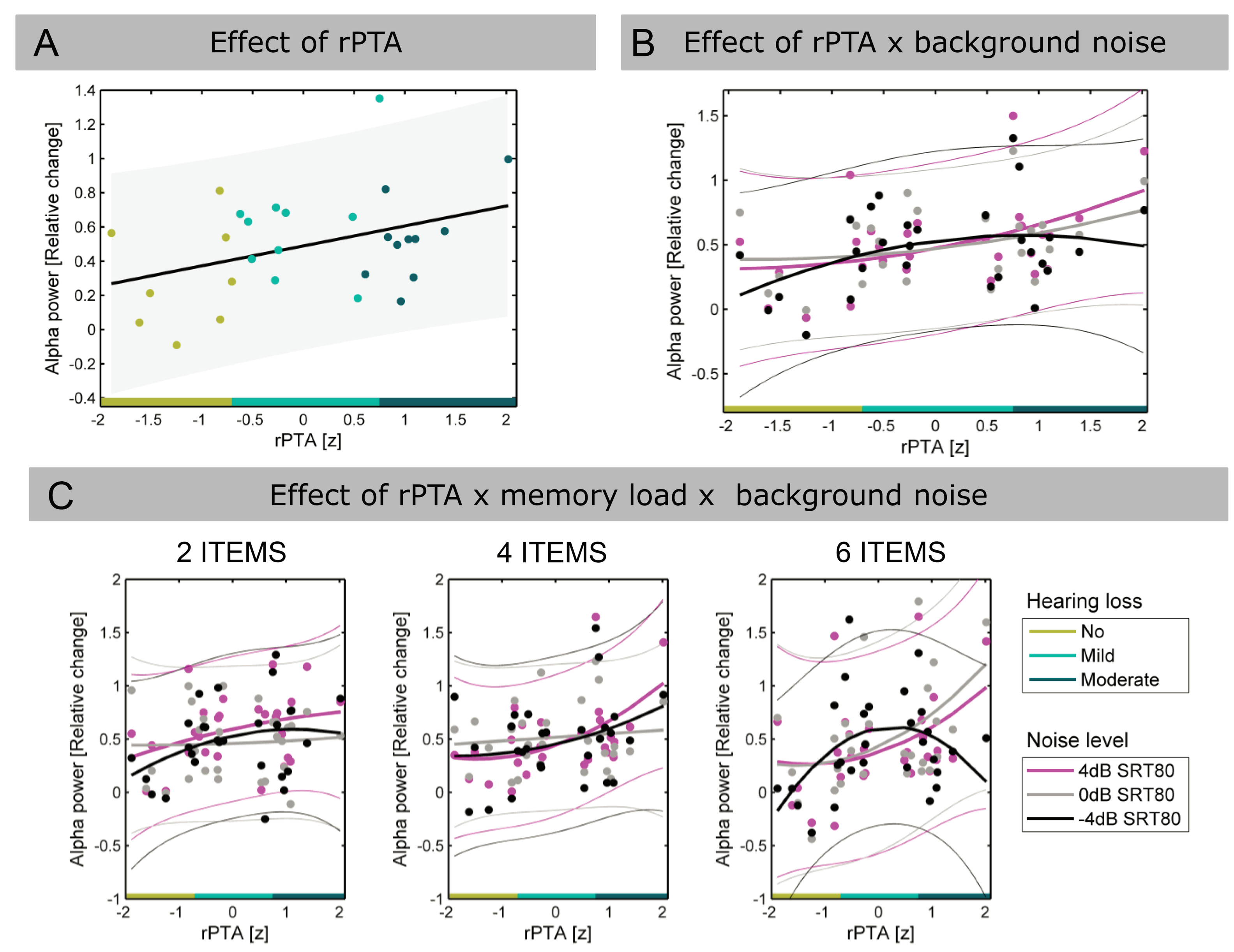

Figure 3. Statistical effects on the alpha power during the delay period all as a function of rPTA (hearing loss groups are indicated on the x-axis).

Discussion

- We did not find an effect of hearing impairment on task accuracy suggesting adequate individualization and amplification in the auditory WM task.
- The negative influence of hearing loss on the WM has been addressed in multiple studies [2,3], here we show that indeed worse hearing result in higher alpha power.
- Increasing WM demands result in an alpha power breakdown for the moderately impaired participants. This suggests that the moderately impaired participants reach an alpha power ceiling and experience a consequent decrease in alpha power.
- A similar activity breakdown has been observed in WM tasks with increasing age in fMRI studies, with no consequent performance decrease [6].

Conclusions

- Both internal and external degradation of the auditory input affected the alpha power during stimuli retention.
- Alpha power, independent of WM conditions, scaled with hearing loss, proposing that higher WM involvement is needed to overcome worse hearing impairment.
- The moderately hearing impaired exhibited a breakdown in alpha power with increasing WM involvement, suggesting that an alpha power ceiling was reached.

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