Perceptual Adaptation to Degraded Speech in Older Adults: Behavioral and Neural Signatures

Julia Erb & Jonas Obleser

Max Planck Research Group "Auditory Cognition", Max Planck Institute for Human Cognitive and Brain Sciences, Leipzig, Germany

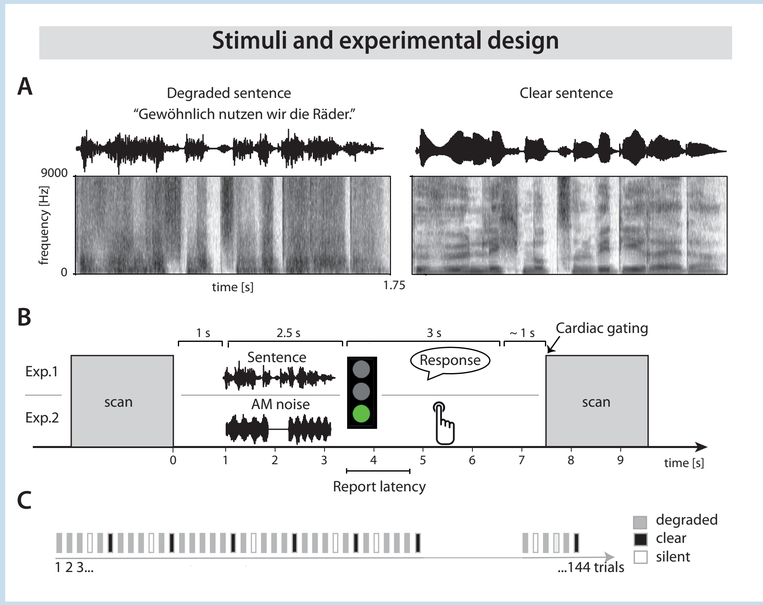
jerb@cbs.mpg.de

Introduction

- Older adults' perceptual adaptation abilities are not well established [1]. Here, we aimed to identify the behavioral and neural mechanisms of short-term perceptual adaptation to vocoded speech, in which the temporal envelope of the acoustic signal is preserved, while spectral information is highly degraded [2].
- Combining this with an additional experiment on amplitude modulation (AM) rate discrimination, we quantified the convergence of neural mechanisms underlying effortful perception of degraded speech and non-speech acoustic envelope.
- We hypothesized that older adults recruit cognitive-control-related brain regions [3, 4] to support sensory processing of auditory temporal envelope.

Methods

- **Participants** were a group of older adults (aged 56–77, n=15), with varying hearing degrees of sensorineural hearing loss, and a cohort of young adults (aged 22–31, n=30, self-reported normal hearing).
- **Degraded speech perception.** Stimuli were 100 low-predictable 4-band vocoded German SPIN sentences [5]; 24 clear-speech trials were included as baseline. Listeners verbally repeated back after each sentence what they had understood [6].
- **AM rate discrimination.** In a 2-AFC task, subjects listened to amplitude modulated white noises; standard stimulus was modulated at 4 Hz and the deviant at either a *discriminable AM rate* (range 2-6 Hz, linearly spaced, 6 levels à 16 trials) or at the *identical AM rate* (4 Hz, 16 trials) [6].
- Functional MRI scans were collected on a 3T Siemens Verio scanner using an EPI sequence [TR ≈ 9000 ms (was variable due to cardiac gating), TA = 2000 ms, TE = 30 ms, voxel size = 3 x 3 x 3 mm]. Structural brain scans were acquired using an MPRAGE sequence. Data were preprocessed (realigned and unwarped, coregistered with the structural scan, segmented and normalized to MNI standard space, smoothed at 8 mm FWHM) and statistically analysed using a GLM in SPM8.



Results

1

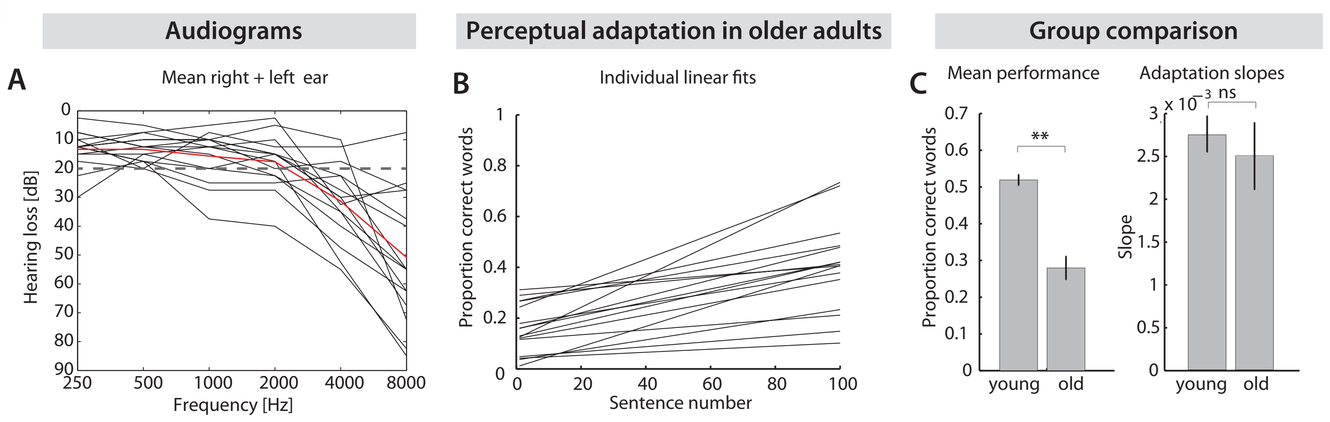


Figure 1. (**A**) Audiograms of older adults and (**B**) linear fits to report scores, showing individual differences in adaptation to vocoded speech. The slope of the linear fit was taken as measure for perceptual adaptation to vocoded speech (adaptation slope). (**C**)Young and older adults differ in mean speech comprehension but not adaptation slopes (** $p < 0.01$, ns = non significant)

2

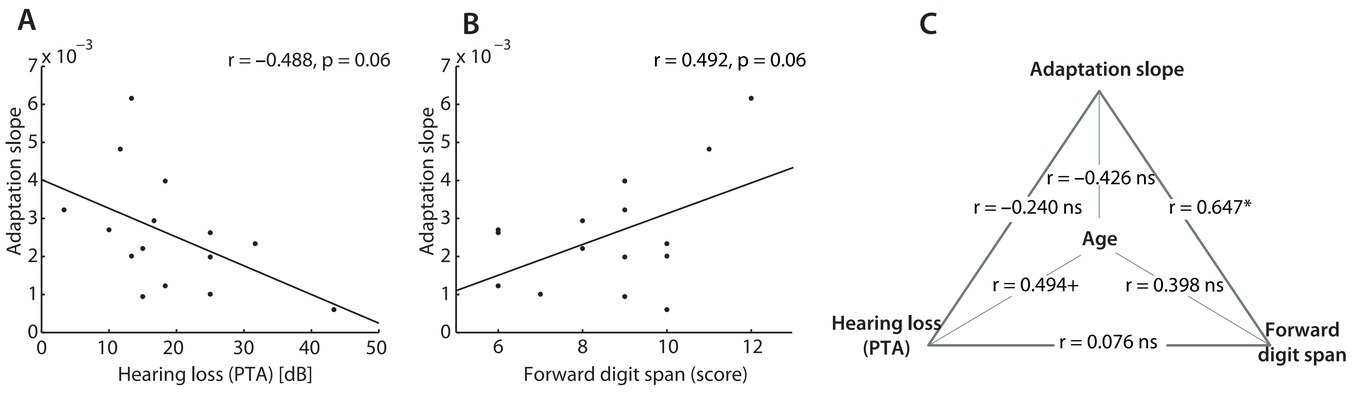


Figure 2. (**A**) Adaptation slope correlates negatively with hearing loss and (**B**) positively with forward digit span at trend-level. (**C**) The latter correlation becomes significant when controlling for age and hearing loss, as shown by the partial correlations between all four measures, where two measures are partialled out at a time (* $p < 0.05$, + $p < 0.1$, ns = non significant).

3

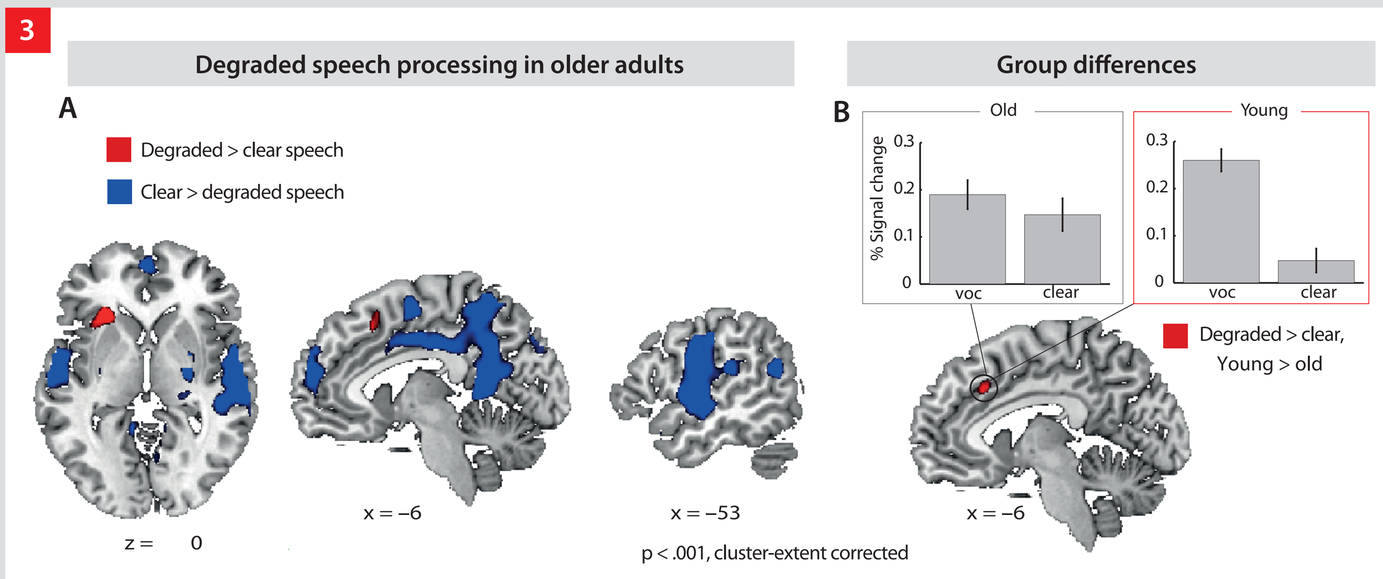


Figure 3. (**A**) For degraded speech perception, older adults activated the anterior insula. (**B**) Young adults additionally recruited the anterior cingulate cortex (ACC). This condition-by-group interaction was driven by reduced dynamic range in older adults, who displayed high levels of ACC activation during perception of both clear and vocoded speech.

4

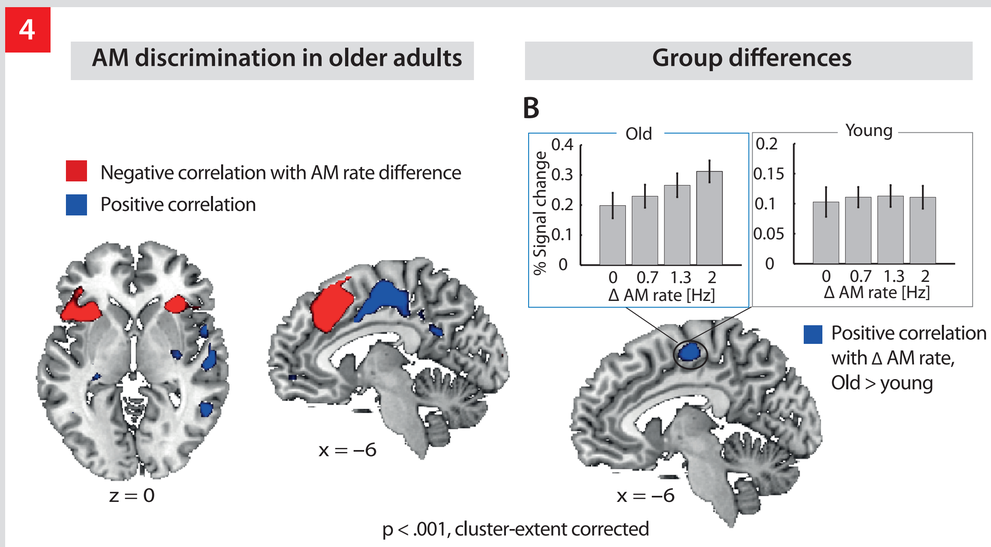


Figure 4. (**A**) For the AM-discrimination task, older adults exhibited a parametric modulation by discrimination difficulty in the anterior insula and ACC, with more difficult discriminations eliciting higher activation. Conversely, activity in the left supplementary motor area (SMA) increased as discriminations became easier. (**B**) Young listeners did not recruit the SMA for easier AM-rate discriminations, but rather relied on Heschl's gyrus [6].

Conclusions

- Although overall vocoded speech comprehension declines with age, older adults adapted to degraded speech at the same rate as young listeners.
- Within the older adults, individuals with larger digit span adapted faster to degraded speech, even after partialling out age and hearing loss. In contrast, the negative correlation of hearing loss with adaptation slope was best explained by the covariation with age.
- Neurally, older adults had a reduced dynamic range in the ACC, displaying high levels of ACC activity in both the vocoded and clear speech condition, consistent with a persistent upregulation of a cognitive-control-related brain region.
- For the AM-discrimination task, older adults exhibited a parametric modulation by discrimination difficulty in the left SMA, whereas young listeners had the same parametric modulation in Heschl's gyrus [6]. This suggests the additional involvement of a cognitive-control-related structure in a task for which younger listeners made use only of sensory cortices.
- Taken together, the results of the two experiments are suggestive of a compensatory mechanism, whereby with increasing age, higher-order brain structures must be recruited [3, 4] when solving even easy listening tasks.

References

[1] Peelle et al. (2005). *J Exp Psychol Hum Percept Perform 31*, 1315-1330.
[2] Shannon et al. (1995). *Science 270*, 303-304.
[3] Eckert et al. (2008). *J Assoc Res Otolaryngol 9*, 252-259.
[4] Harris et al. (2009). *J Neurosci 29*, 6078-6087.
[5] Erb et al. (2012). *Neuropsychologia 50*, 2154-2164.
[6] Erb et al. (in press). *J Neurosci*.