Differing effects of noise on subcortical speech representation in younger and older adults

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Background

Older adults often report that during a conversation they can hear what is said, but cannot understand the meaning, particularly in a noisy environment. These difficulties may arise from deficits in auditory temporal processing [1]. A loss of temporal precision may be a key factor underlying subcortical timing delays and decreases in response consistency and magnitude in older adults [2]. The frequency following response (FFR) is an efficacious measure for predicting self-reported speech-in-noise perception difficulties in older adults [3]. Here, we compared the effects of noise on subcortical responses in younger and older adults with normal hearing, hypothesizing that the response of younger adults will be more robust to noise than the one of older adults in FFR due to the fact that temporal precision in older adults is already compromised in quiet.

Materials and Method

Participants

- Participants were native speakers of English: 15 young adults (20 – 28 years old, mean ± SD, 23.13 ± 2.58years) and 15 older adults (60 - 76 years old, mean ± SD, 64.46 ± 4.95 years).
- All participants had clinically normal hearing and no history of neurological or middle ear disorders.
- Participants had normal IQ scores [mean ± SD, 110.8 ± 9.87 for younger adults, and mean ± SD, 116.26 ± 15.2 in older adults on the Wechsler Abbreviated Scale of Intelligence] [4].
- Older adults were also screened for dementia on the Montreal Cognitive Assessment (MOCA) [5] [mean ± SD, 26.2 ± 2.04].

EEG recordings

- A 170 ms speech syllable /da/ synthesized at 100 Hz with a Klatt-based synthesizer presented diotically with alternating polarities at 80 dB SPL at a rate of 4 Hz through electromagnetically shielded insert earphones.
- Subjects were tested in two different conditions:

1) /da/ presented in quiet.
2) /da/ presented in one-talker bable (0 SNR).

- Three thousands sweeps per condition were recorded from each participant from the Cz electrode (Average ear lobes as reference and forehead as ground) using the Biosemi system.
- Threshold for rejecting sweeps was ±30 μV.
- Envelope was extracted by summating the two polarities in order to reduce the stimulus-artifact

Behavioral data

The Quick Speech-in-Noise test (QuickSIN) [6] was used to objectively measure the participant's sentence recognition in noise. Four lists were used for each participant and were averaged to produce a final score.

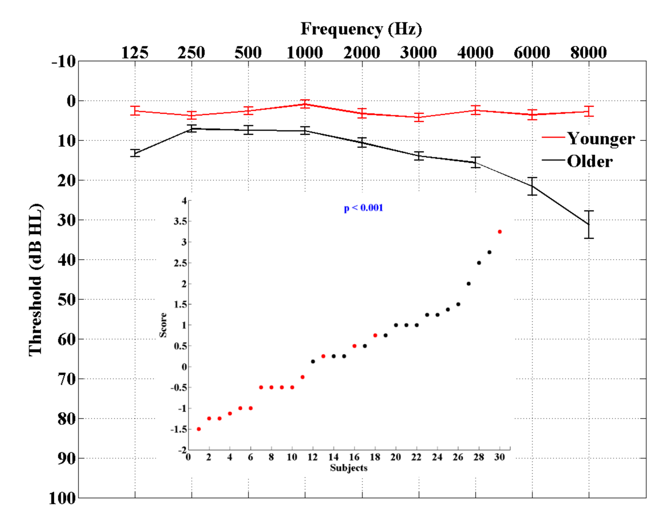

Fig.1 Audiogram (mean ± 1SE) for younger (red) and older (black) adults. The inset shows the results of the QuickSIN for each participant in ascending order (the lower the score, the better the understanding of speech in noise)

EEG Analysis

- Raw data were averaged and bandpass filtered between 70 - 2000 Hz using a zero-phase, 4th order Butterworth filter.
- Grand-averages of the time series envelope of younger and older adults were calculated for the two conditions (quiet and noise).
- FFT (1 Hz frequency resolution) was applied to the transient and steady-state response of the envelope
- A time-frequency analysis was carried out to analyze both the envelope (ENV) and the temporal fine structure (TFS) by using complex Morlet mother wavelet [6]

Results

Time Domain Analysis

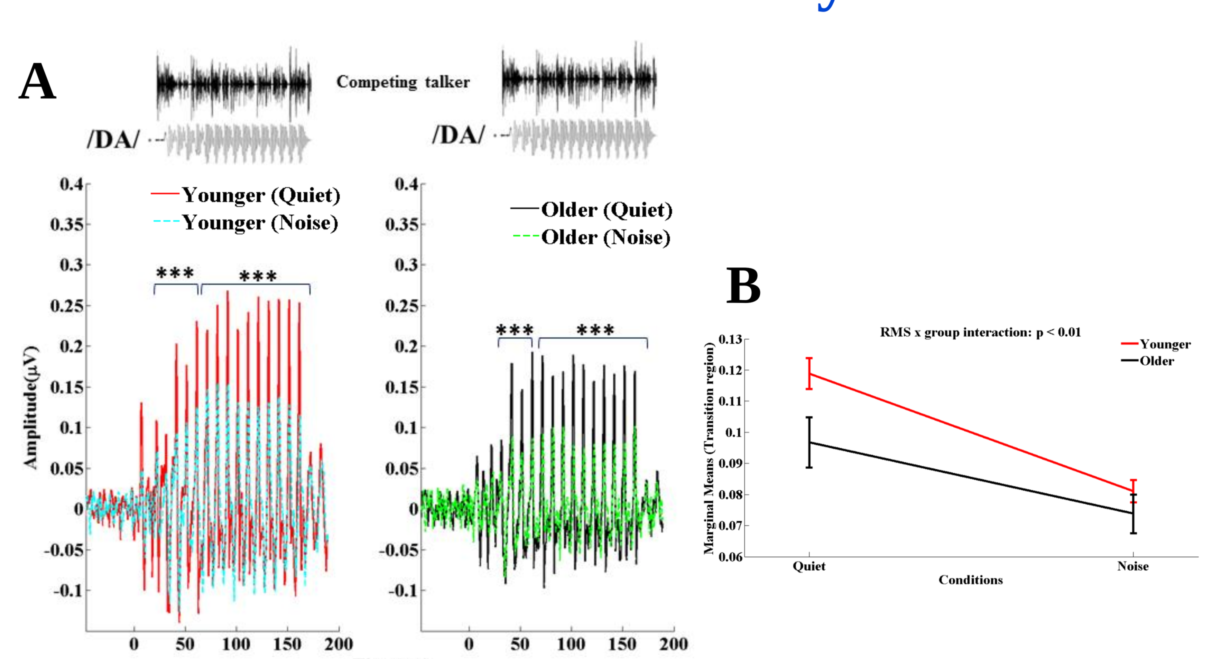

Fig.2 A) *Top.* Time series of the speech syllable /da/ and example of a competing single talker. *Bottom.* Grand average (n = 15) of the envelope for the two conditions of younger (left; quiet = red, noise = light blue) and older (Right; quiet = black, noise = green) adults. In the transition and steady-state regions, noise resulted in a significant decrease ($p < 0.001$) in the RMS amplitude in both younger and older adults. **B)** A 2-level repeated measures ANOVA showed RMS x group interaction effect in the transient region ($p < 0.01$), but not in the steady-state region ($p > 0.05$). *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$

Response Correlations by Subject

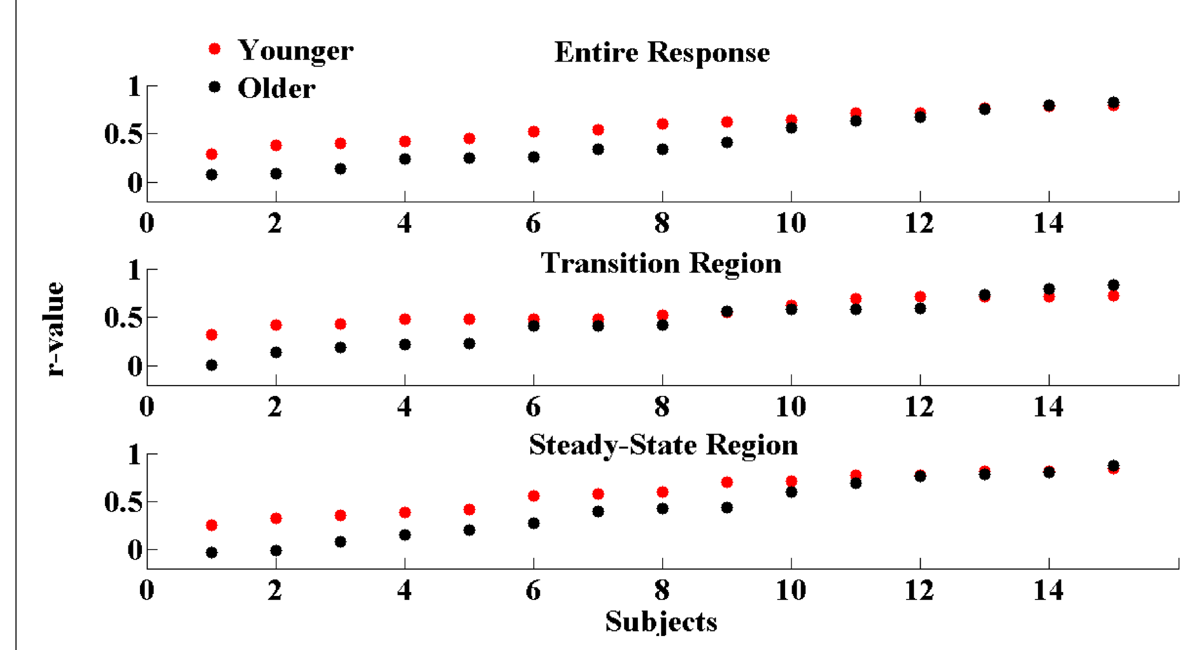

Fig.3 *Top*. Correlation values calculated for the entire response between the response in quiet and noise *Middle*. Correlation values calculated in the Transition region between the response in quiet and noise. *Bottom*. Correlation values calculated in the Steady-State region between the response in quiet and noise. Overall, younger adults show stronger resistance to noise (higher correlation values) than older adults, even though the difference does not reach significance value ($p = 0.065$ for the entire response, $p = 0.147$ in the transition region and $p = 0.094$ in the steady-state region). All the correlation values have been plotted in ascending order.

Frequency Domain Analysis

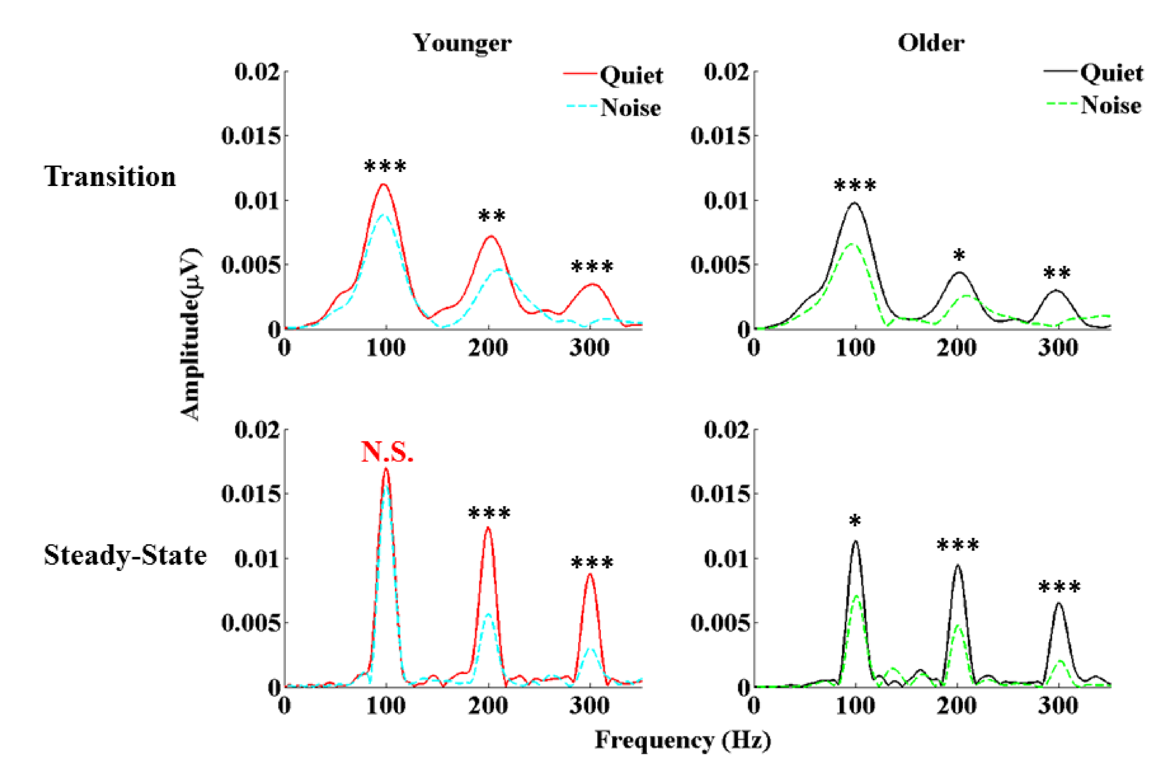

Fig.4 *Top*. Spectral amplitudes of the transition (top) and of the steady-state (bottom) region of the envelope for younger (left) and older adults (right). In the transition region, noise resulted in a significant decrease in the fundamental (F0) and the in first two harmonics (H2 and H3) both in younger adults ($p < 0.001$, $p < 0.01$ and $p < 0.001$ respectively) and in older adults ($p < 0.001$, $p < 0.05$ and $p < 0.01$ respectively). In the steady-state region, only the harmonics were significantly reduced in younger adults ($p < 0.001$ for H2 and $p < 0.001$ for H3) while in older adults both F0 and the harmonics were significantly different ($p < 0.05$ for F0, $p < 0.001$ for H2 and $p < 0.001$ for H3). A repeated measures ANOVA showed a presentation condition x group interaction for the steady-state region ($p < 0.05$). *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$

Time-Frequency Analysis

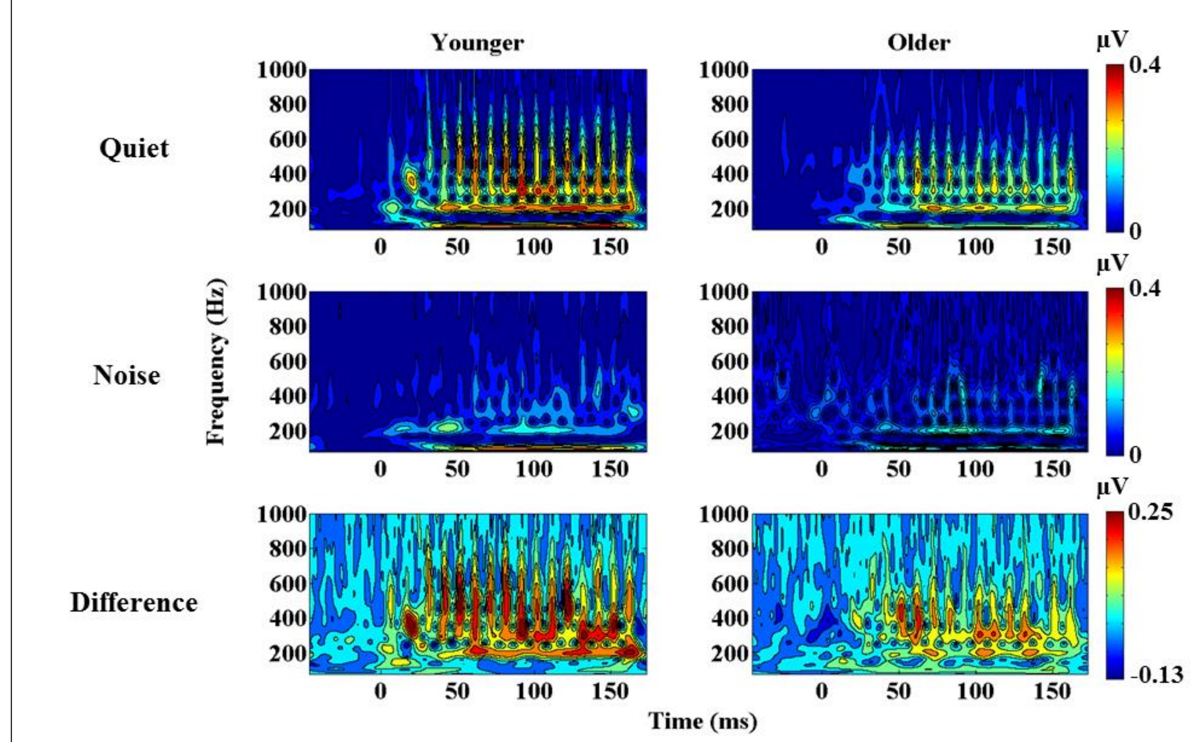

Fig.5 Time-Frequency representation of the grand average of the ENV of the 2 conditions (first 2 rows, quiet and noise respectively) for younger (first column) and older (second column) adults. The last row (difference) represents the difference in amplitude between quiet and noise. Note how differences are more pronounced in younger adults, particularly in the transition region.

Conclusions

- QuickSIN: significant differences between younger and older adults.
- RMS value
  - Transition region: RMS x group interaction effect.
  - Steady-state region: significant differences between quiet and noise in younger and older adults.
  - The correlation between the response of younger adults in quiet and noise is higher in younger adults throughout the whole response, suggesting that younger adults' temporal processing is robust to noise
- FFRs:
  - Transition region: significant differences between quiet and noise in younger and older adults in the fundamental frequency and in the second and third harmonics.
  - Steady-state region: significant differences between quiet and noise in younger adults only in the second and third harmonic, while older adults showed significant differences even at the fundamental frequency.
- Time-frequency representation: stronger differences between quiet and noise in younger adults, particularly in the transition region.
- Altogether our findings suggest the envelope of younger adults is more robust to noise than the one of older adults, probably because of a loss of temporal precision in older adults. This may, at least in part, account for their difficulties in understanding speech in noise.

References

1. Gordon-Salant et al. (2006). **Age-related differences in identification and discrimination of temporal cues in speech segments**. *J. Acoust. Soc. Am., 119(4), 2455-2466.*
2. Anderson et al. (2012) **Aging affects neural precision of speech encoding** *J Neurosci, 32(41):14156-14164*
3. Anderson et al. (2013) **Auditory brainstem response to complex sounds predicts self-reported speech-in-noise performance** *J. Speech Lang. Hear. 56(1):31-43*
4. Zhu, J., Garcia, E. (1999). **The Wechsler Abbreviated Scale of Intelligence (WASI)**. *New York: Psychological Corporation*
5. Nasreddine, Z. S., Phillips, N. A., Bedirian, V., et al. (2005). **The Montreal Cognitive Assessment, MoCA: a brief screening tool for mild cognitive impairment**. *J Am Geriatr Soc, 53*, 695-699
6. Tallon-Baudry et al. (1996) Oscillatory g-Band (30 –70 Hz) **Activity Induced by a Visual Search Task in Humans** *J Neurosci* 17(2):722-734

Acknowledgements

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