Preserved Temporal Fine Structure Facilitates Cognitive Operations on the Speech Signal

Malte Wöstmann[1,2] and Jonas Obleser[1]

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

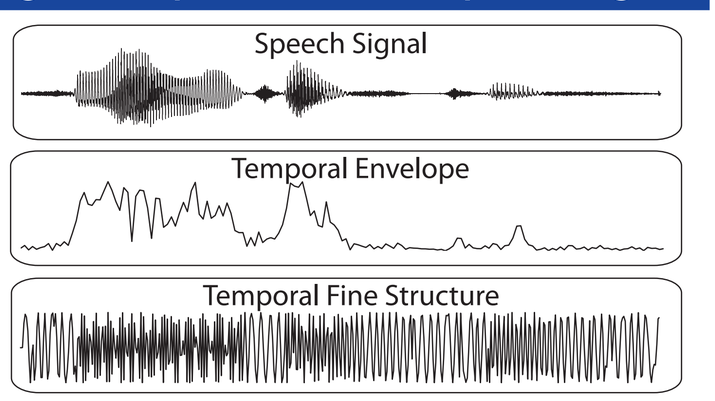
[2]International Max Planck Research School on Neuroscience of Communication, Leipzig, Germany

woestmann@cbs.mpg.de

Introduction

- The speech signal in each frequency band can be divided into two components ([1]; Fig 1):
  1) slowly fluctuating **Temporal Envelope**
  2) fast carrier signal (**Temporal Fine Structure; TFS**).
- TFS has proven beneficial for speech perception in the presence of a **fluctuating masker** [2].
- Prior studies suggest that sensitivity to TFS might decline with **age** [3,4].
- In an **electroencephalography** (EEG) study, we investigated the **neural mechanisms** sensitive to manipulations of TFS in speech for young and old listeners.

Fig 1. Components of the Speech Signal



Methods

- Twenty **young** (20-30 years) and 20 **old** (60-70 years) subjects performed a masker-obliterated **auditory number comparison** task.
- Materials: Two **spoken numerals** (*signal*) embedded in a **distracting speech masker** (*background*; Fig 5)
- Task: Indicate whether the second numeral was smaller or larger than the first.
- Manipulation: Replace TFS in frequency bands above a cutoff value by an envelope-modulated sine-tone and preserve TFS below cutoff (Fig 2; [1]).
- Adaptive tracking: Determine subject-specific **Signal-to-Background Ratio** (*SBR*; Fig 3) for 70% correct performance on materials without TFS.
- Experiment: Materials were presented at individual **SBR**. Materials were amplified and equalised to adapt to **audiometric thresholds** using the *CAMEQ* procedure [5].

Fig 2. Temporal Fine Structure Manipulation

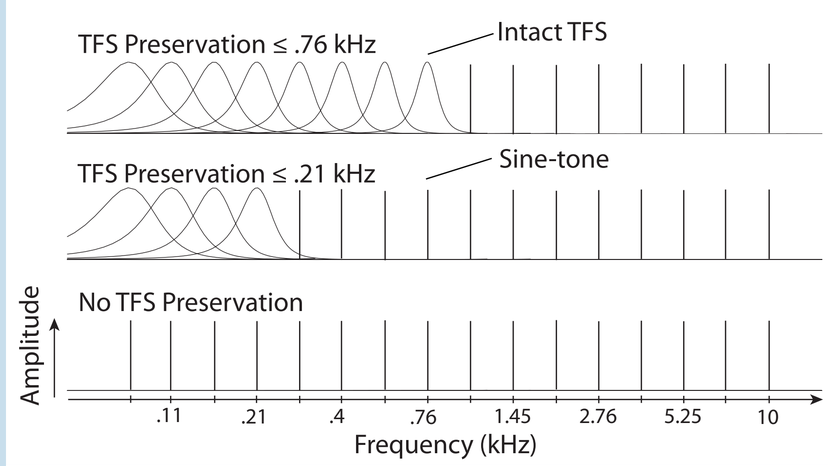
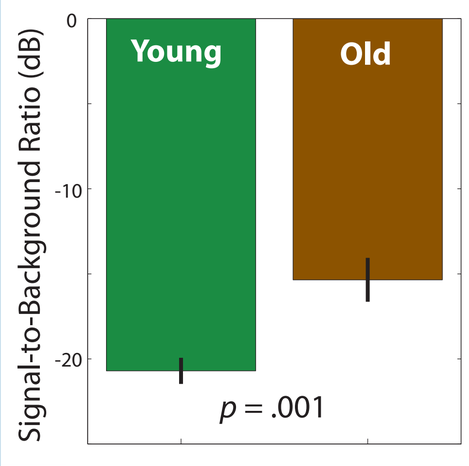


Fig 3. SBR



Results

Fig 4. Behavioral Results

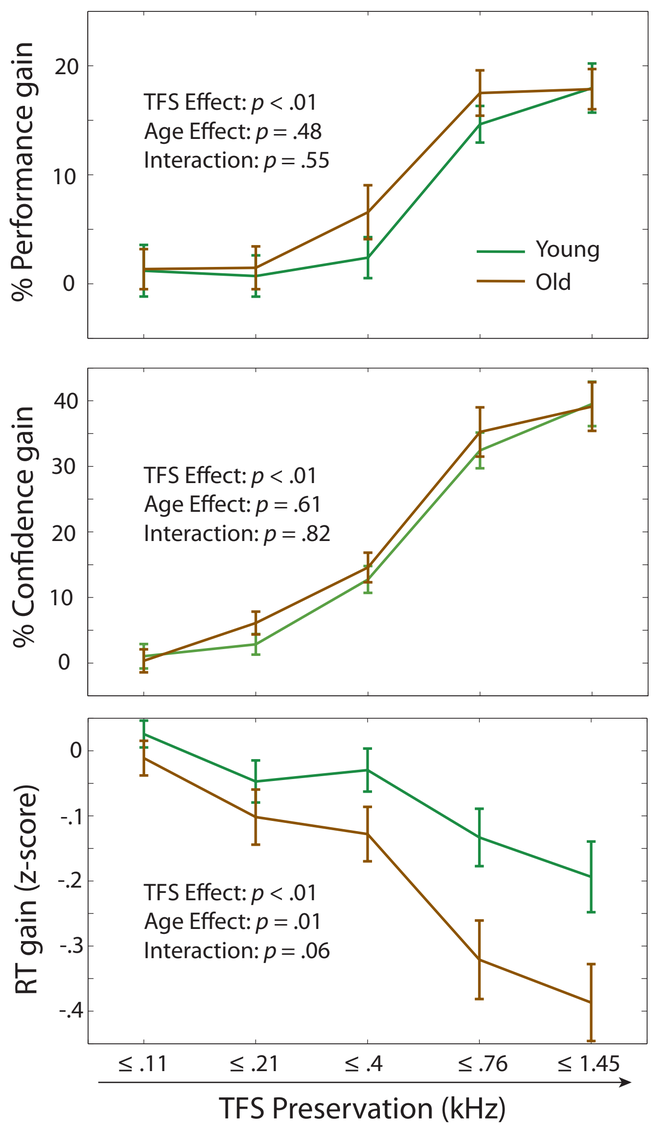
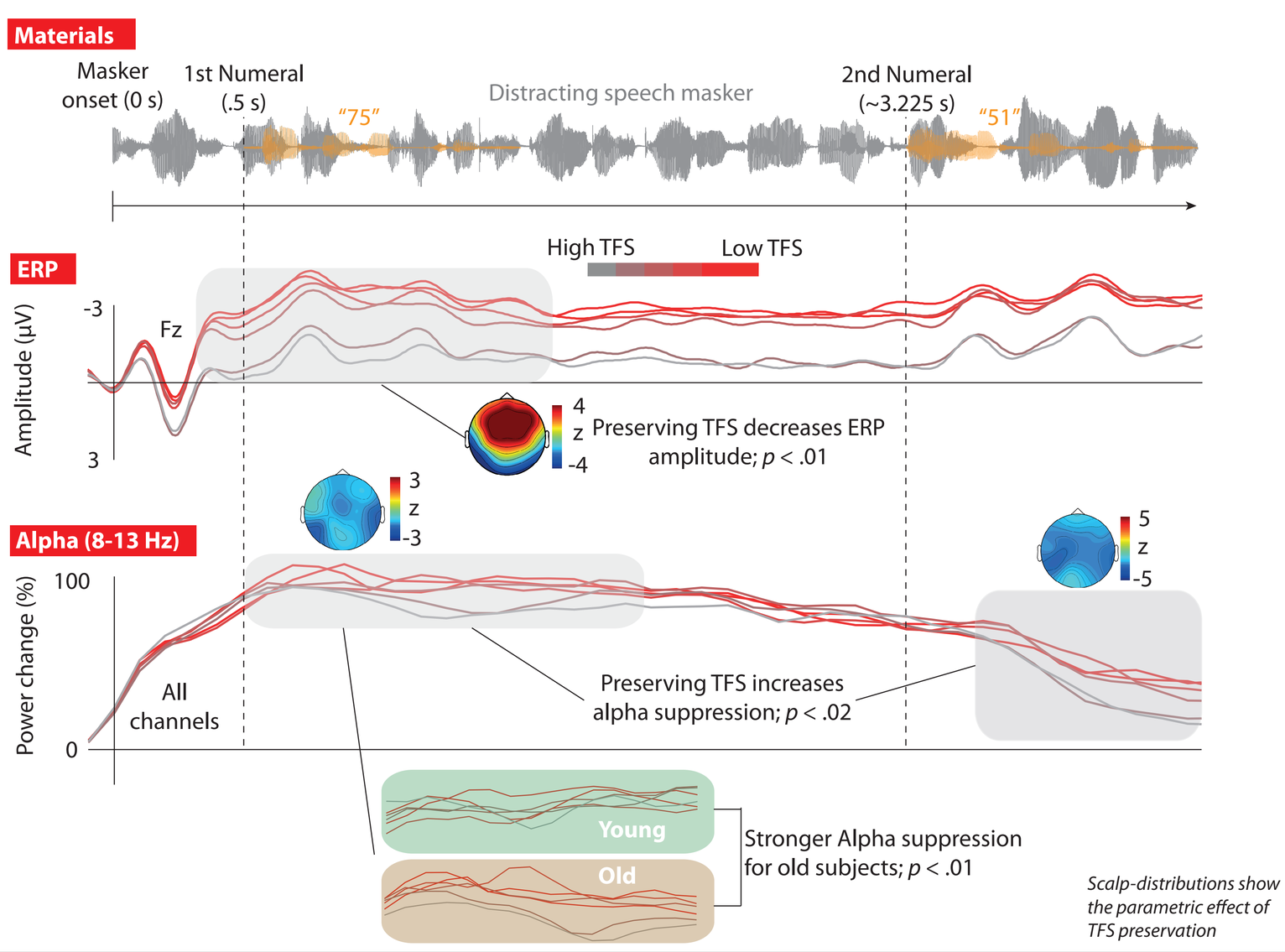


Fig 5. EEG Results



Discussion

General Results

- Preserving TFS in signal and masker **increased performance** (Fig 4).
- TFS is beneficial for **speech perception against fluctuating masker** [cf. 2].

- The ERP showed a sustained **contingent negative variation** (CNV) after masker onset (Fig 5). CNV amplitude decreased when TFS was preserved.
- Reduced CNV when preserving TFS indicates decreased **selective attention** [6] and **cortical arousal** [7].

- Preserving TFS increased the **alpha (8-13 Hz) suppression** after onset of first and second numeral (Fig 5).
- Alpha suppression might index enhanced **downstream auditory processing** and **facilitation of speech perception** [8].

Age-Specific Results

- Old subjects required a significantly **better SBR** (Fig 3).
- Old subjects' **reaction times** were more strongly modulated by preserving TFS (Fig 4).
- Effect of TFS preservation on **alpha suppression** after first numeral was stronger for old subjects (Fig 5).
- Old subjects' speech processing mechanisms are more strongly bottom-up driven by **TFS manipulations** [cf. 9].

Conclusions

- Preserving TFS in speech...
  ... **increases intelligibility,**
  ... reduces the need for **selective attention,**
  ... facilitates **cognitive operations** performed on the speech signal.

References

[1]Hopkins, K., Moore, B. C. J., & Stone, M. (2008). *JASA*, 123(2).

[2]Hopkins, K. & Moore, B. C. J. (2009). *JASA*, 125(1).

[3]Grose, J. H., & Mamo, S. K. (2010). *Ear Hear*, 31(6).

[4]Moore, B. C. J., Glasberg, B. R., Stoev, M., Füllgrabe, C., & Hopkins, K. (2012). *JASA*, 131(2).

[5]Moore, B. C. J., Alcántara, J. I., & Glasberg, B. R. (1998). *Br J Audiol*, 32(3).

[6]Wilkinson, R. T. & Ashby, S. M. (1974). *Bio Psych*, 1(3).

[7]Nagai, Y., Critchley, H. D., Featherstone, E., Fenwick, P. B. C., Trimble, M. R., & Dolan, R. J. (2003). *NeuroImage*, 21(4).

[8]Obleser, J. & Weisz, N. (2012). *Cereb Cortex*, 22(11).

[9]Passow, S., Westerhausen, R., Wartenburger, I., Hugdahl, K., Heekeren, H. R., Lindenberger, U., & Li, S.-C. (2012). *Psychol & Aging*, 27(1).