Left Temporal Alpha-Band Power Predicts Single Word Intelligibility

Robert Becker[1], Maria Pefkou[2], Christoph M Michel[1], Alexis Hervais-Adelman[2]

[1]Functional Brain mapping Lab, University of Geneva
[2] Brain and Language Lab, Unviersity of Geneva

Introduction:

Investigations of the electroencephalographic (EEG) correlates of degraded speech perception have often been inconclusive as to whether observed differences in brain responses between conditions result from different acoustic properties of more or less intelligible stimuli or whether they relate to cognitive processes implicated in comprehending challenging stimuli[1].

We used noise vocoding to spectrally degrade monosyllabic words, and spectral rotation to generate incomprehensible control conditions matched in terms of spectral detail. We recorded EEG from 14 volunteers who listened to a series of noise-vocoded (NV) and noise-vocoded spectrally-rotated (rNV) words, while they carried out a detection task.

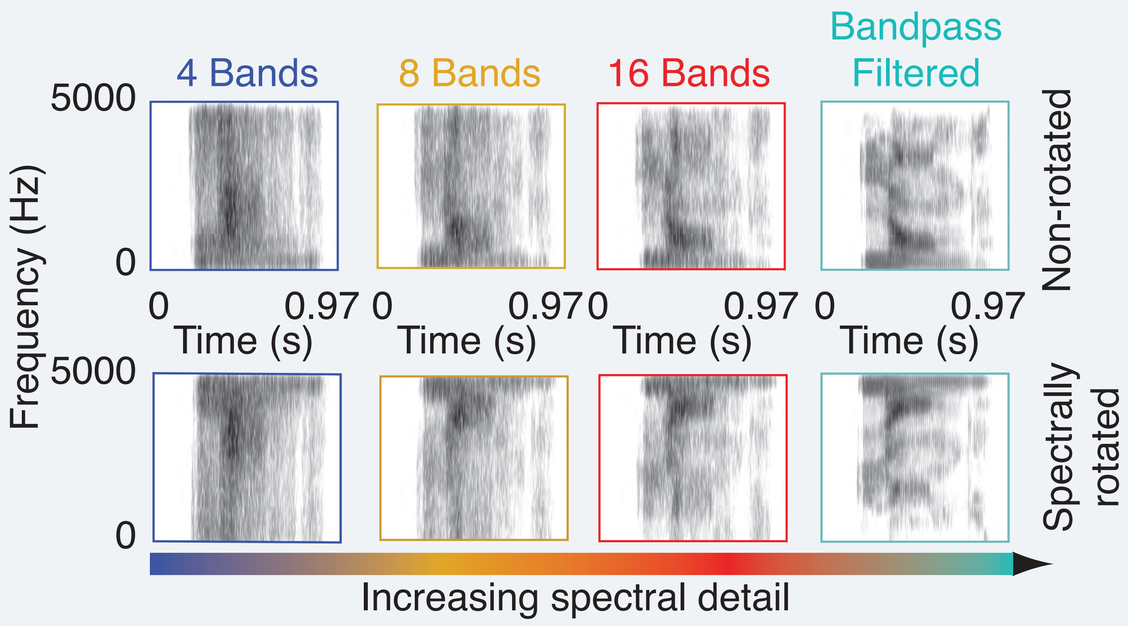
We specifically sought components of the EEG response that showed an interaction between spectral rotation and spectral degradation. This reflects aspects of the EEG response that are related to intelligibility of acoustically degraded monosyllabic words, while controlling for spectral detail.

Methods:

Participants: 14 monolingual right-handed French-speakers (2 male), with no history of hearing- or visual-impairment.

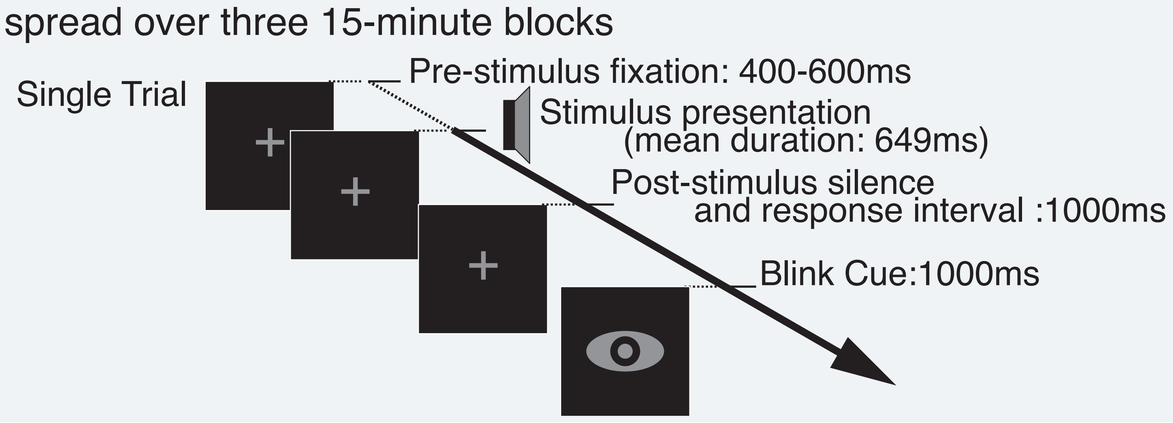
Materials: 360 monosyllabic high-frequency (29.25/million) concrete nouns, recorded by a male native-speaker of standard French. 36 animal names were included as targets for detection task.

Signal Processing: Band-pass filtering (50Hz-5kHz), noise-vocoding[2] (4-,8-,16-band, Greenwood-spaced filters, envelope extracted with 30Hz low-pass filter) and spectral rotation[3,4] (about 2.5kHz).

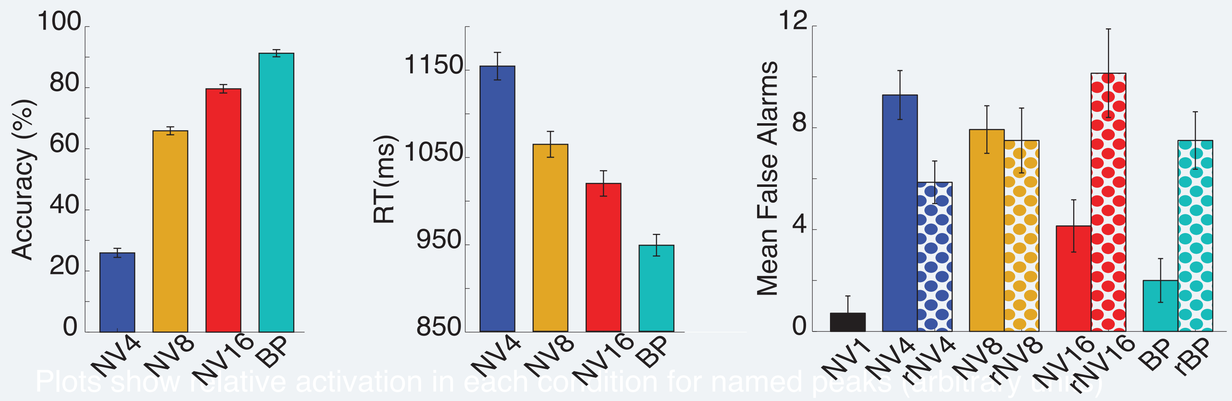


EEG Recording: 256-channel EGI Hydrocel net, 1000Hz sampling, 400Hz low-pass software anti-aliasing filter

Procedure: 81 stimuli per condition presented in random order, evenly spread over three 15-minute blocks



Results I: Detection Task



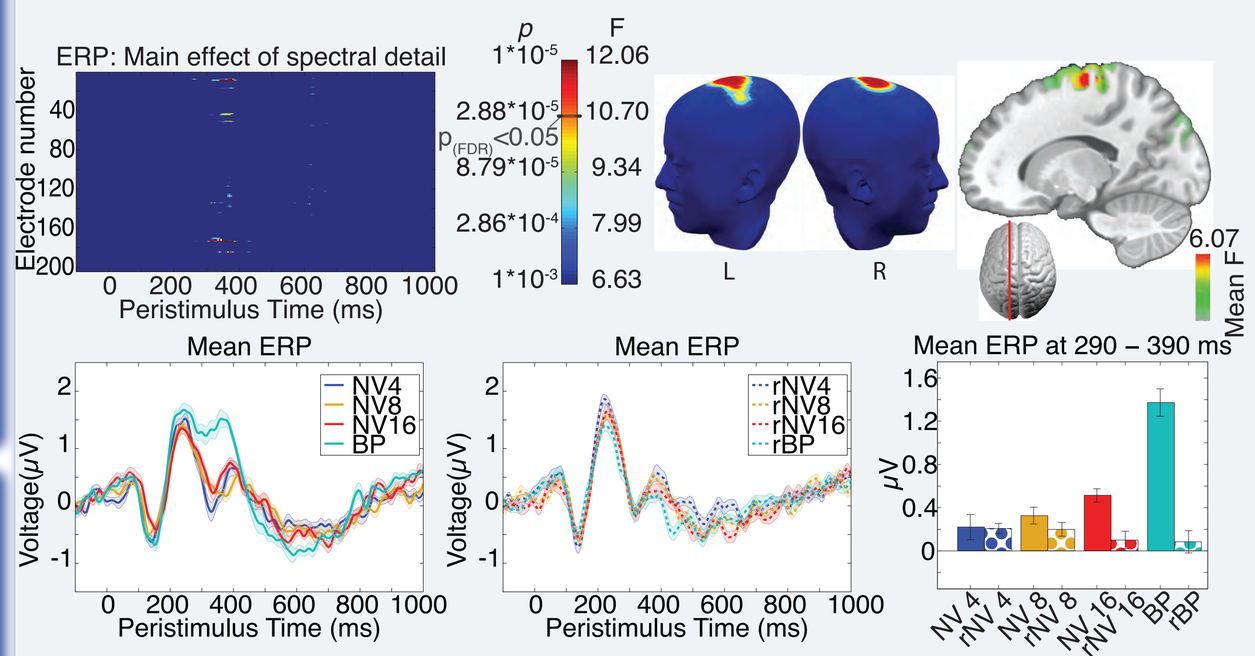
Plots show relative activation in each condition for named peaks (arbitrary units)

Results I: Detection Task

Significant main-effect of number of bands (Accuracy: $F_{(3,39)}$=339.931, $p<10^{-6}$, partial-η^2 =0.96); RTs: $F_{(3,39)}$=26.531, p<0.001, partial-η^2 =0.67, FAs: $F_{(3,19)}$=5.037, p=0.021, partial-η^2=0.279)

Results II: ERPs

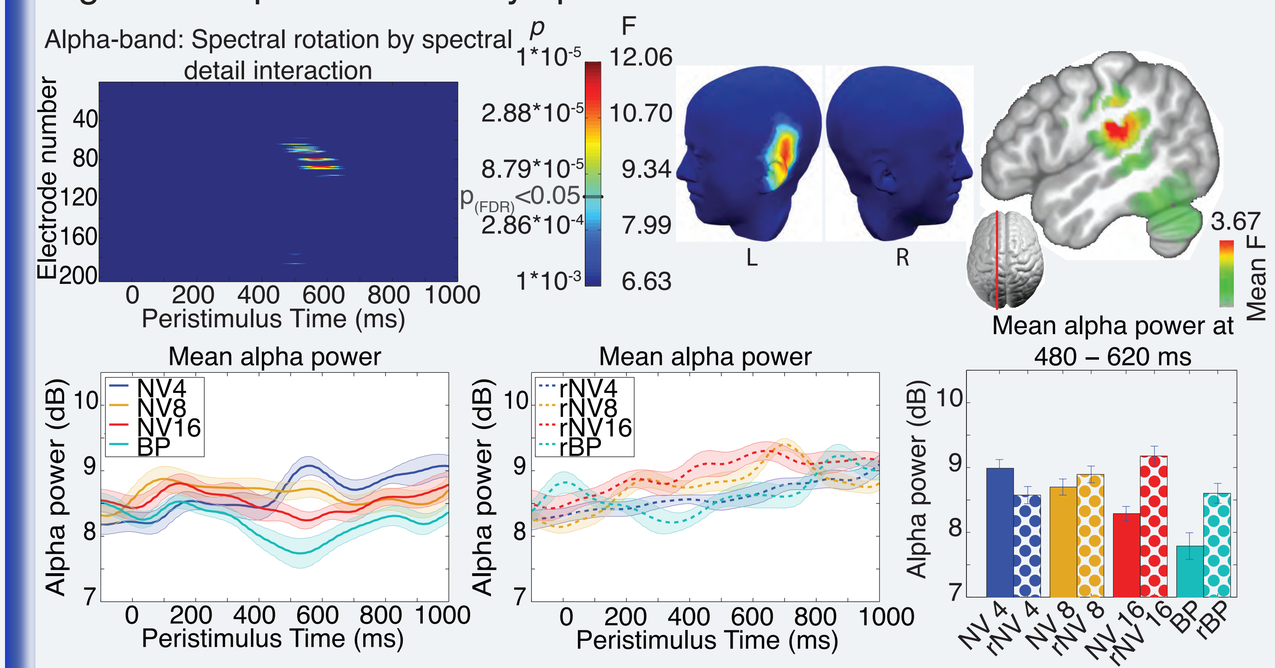
Significant main effect of spectral detail at 290-390ms



P300-like effect, as participants detect infrequent (11% clear stimuli)

Results III: Induced responses

Significant spectral detail by spectral rotation interaction at 480-620ms



Left temporal alpha-band descynchronisation increases with increased spectral detail in vocoded but not spectrally-rotated vocoded conditions, possibly revealing a suppression mechanism

Conclusions:

The auditory system rapidly distinguishes easily-comprehensible speech (approximately 300ms after stimulus onset) from degraded speech. Potentially-comprehensible degraded speech begins to be processed differently to incomprehensible speech at around 480ms after stimulus onset.

Alpha-band power in the left temporal lobe is modulated by stimulus intelligibility, but only for potentially-comprehensible conditons.

This may reveal a mechanism that compensates for acoustical degradation by suppressing recognition processes that ordinarily take place rapidly and automatically, thereby permitting additional processing to be carried out on the degraded signal.

References: 1.Obleser, J. & Weisz, N. Suppressed alpha oscillations predict intelligibility of speech and its acoustic details. Cereb Cortex 22, 2466-2477, doi:10.1093/cercor/bhr325 (2012). 2.Shannon, R. V., Zeng, F. G., Kamath, V., Wygonski, J. & Ekelid, M. Speech recognition with primarily temporal cues. Science 270, 303-304 (1995). 3.Blesser, B. Speech perception under conditions of spectral transformation. I. Phonetic characteristics. J. Speech Hear. Res. 15, 5-41 (1972). 4.Scott, S. K., Blank, C. C., Rosen, S. & Wise, R. J. S. Identification of a pathway for intelligible speech in the left temporal lobe. Brain 123, 2400-2406 (2000).

Acknowledgements: Work supported by a Marie Curie fellowship to RB with funding from the EU Seventh Framework Programme (FP7/2007-2013) under grant agreement n° 267171. CMM is supported by the Swiss National Science Foundation (Grant No. 310030_132952). AH-A and MP supported by the Swiss National Science Foundation (Grant No. 320030_122085 awarded to Professor Narly Golestani). EEG equipment and Cartool software supported by the Center for Biomedical Imagin, Geneva and Lausanne, Switzerland.