Differential processing of sounds with varying spectral and temporal complexity in bilateral temporal cortex

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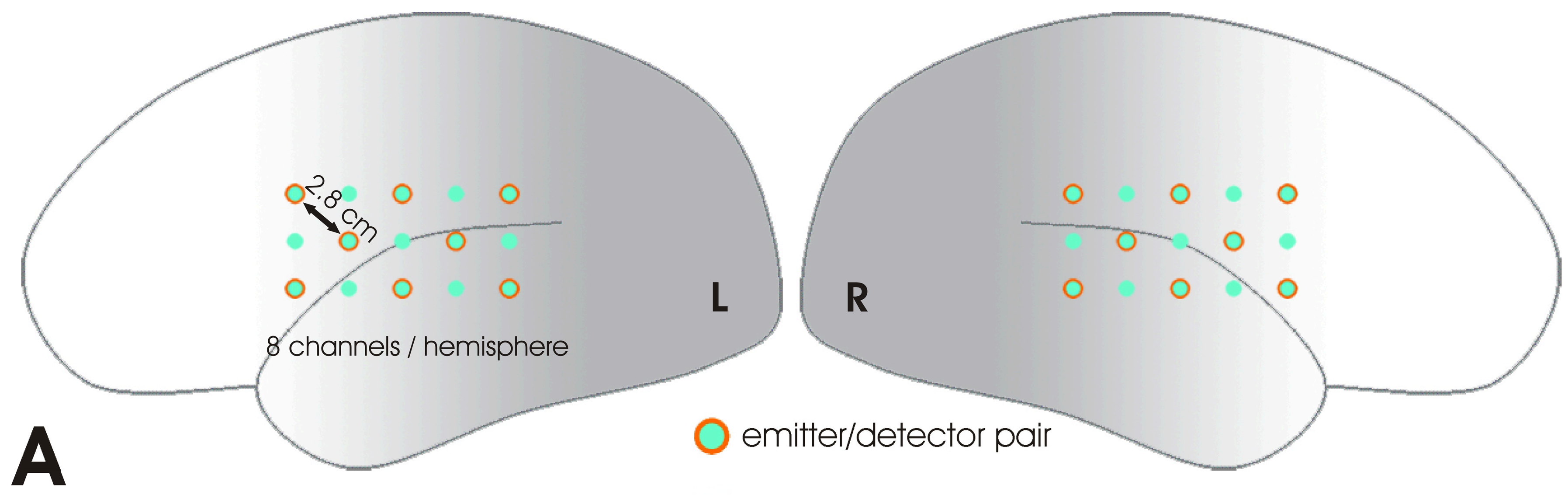
Introduction

- analysis and decoding of spectral and temporal information is a prerequisite for the extraction of linguistic content from acoustic signals
- recent theories suggest a lateralized specificity of the auditory cortices to spectral and/or temporal information[1-3]
- we aimed to characterize the cerebral basis of processing temporal and spectral modulations in the acoustic input signal by presenting noise-like stimuli containing different grades of temporal or spectral complexity (described in Schönwiesner et al., 2005) while measuring the cerebral oxygenation changes using Near-Infrared Spectroscopy (NIRS)
- based on recent fMRI findings we hypothesized hemispheric asymmetries and parametric modulations of the cortical oxygenation levels to vary parametrically in either the number of spectral components or the temporal modulation rate

A



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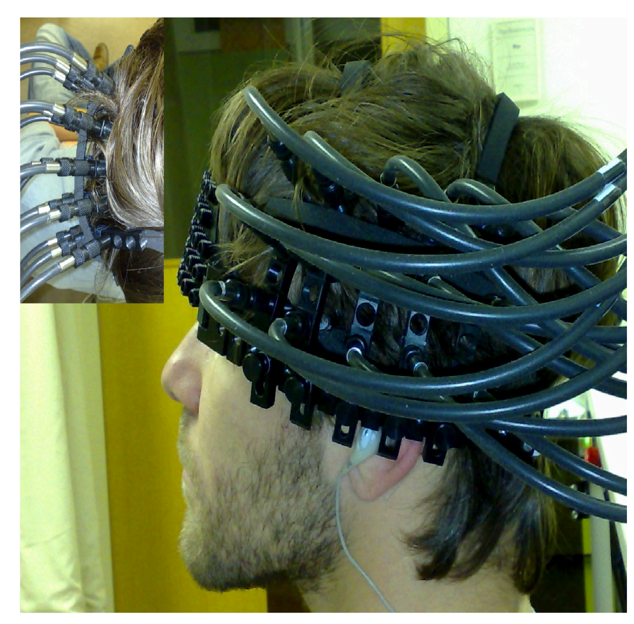

Figure 1: A) schematic display of emitter and detector pairs, B) NIRS-setup from lateral view (big photo) and from behind (small photo)

Methods

Subjects

23 healthy, right-handed adults (15 female)

Material

10 noise-like stimulus conditions (duration 3s), 20 stimuli per condition, pseudorandomized, silent ISI 3-12s (mean 5.5s), including:

- 5 stimulus conditions: variation of temporal complexity: 2, 5, 14, 30, or 40 Hz, all with 3 spectra
- 5 stimulus conditions: variation of spectral complexity: 4, 6, 8, 12, or 16 spectral components, all at 3 Hz

Task

one-back comparison: is the current stimulus the same as the stimulus before?

Data acqusition and analysis

- NIRS imaging system (DYNOT 232 by NIRx Medizintechnik GmbH, Berlin, Germany) using wavelengths of 760 nm and 830 nm
- 16 emitting and 30 detecting fiber optic probes (optodes) over left and right hemispheric temporo-parietal cortices
- modified Beer–Lambert law to convert attenuation changes into changes of [oxy]-Hb and [deoxy]-Hb[4]
- GLM analysis was performed

Results

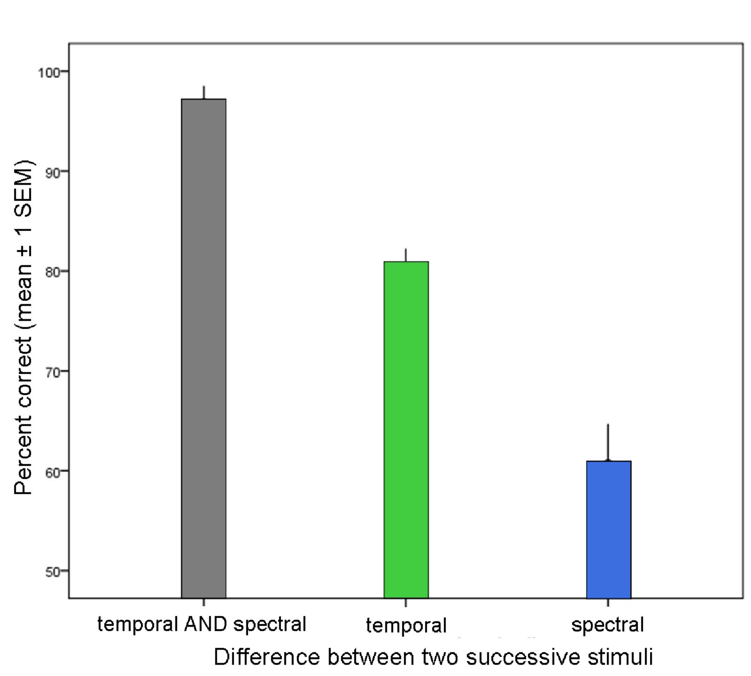

Figure 2: Behavioral results: percentage of correctly identified similarity of successive stimulus pairs:
Judging the identity of two successive stimuli was more difficult when stimuli differed in spectral complexity than in temporal complexity than in combined spectral-temporal complexity.

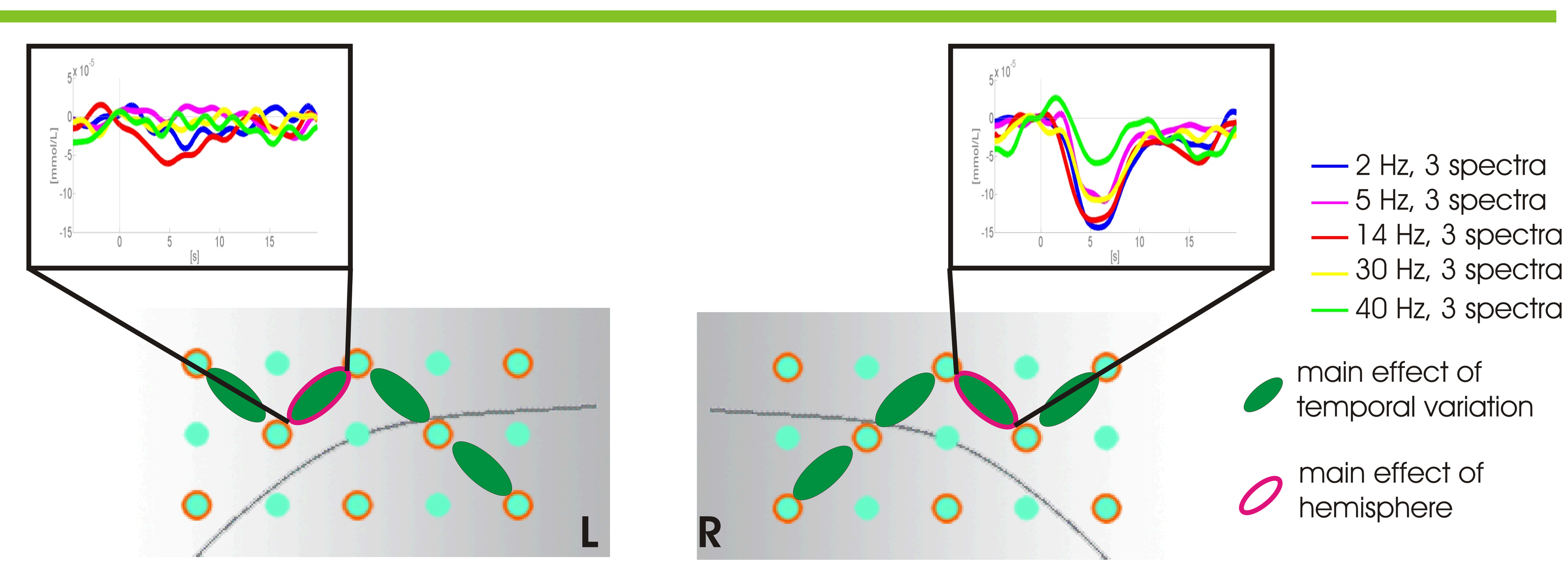

Figure 4: ANOVA main effects for temporal variation and hemisphere:
In the right hemisphere the slowest sound leads to higher activation than faster sounds.

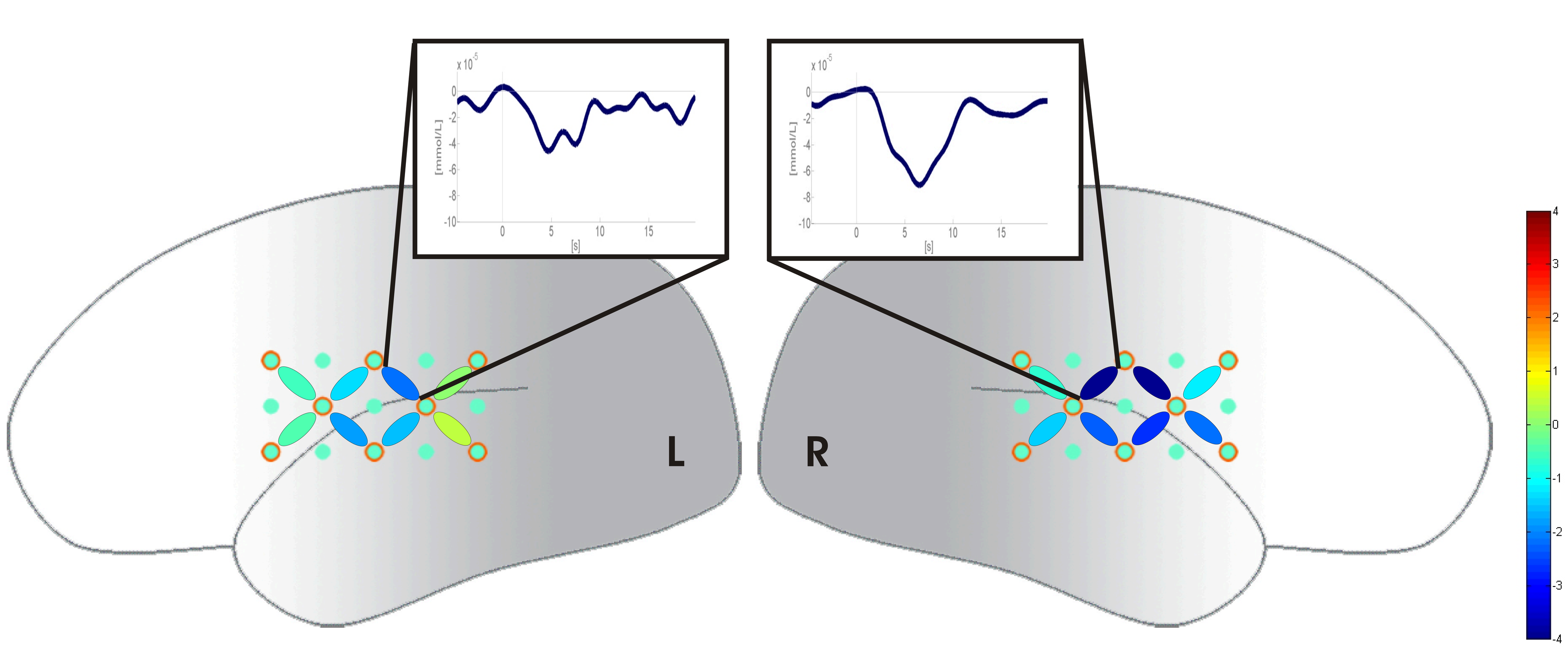

Figure 3: T-values of activation patterns for all stimuli combined. Deep blue color indicates most significant changes in [deoxy]-Hb:
Time courses indicate greater activation in the right hemisphere.

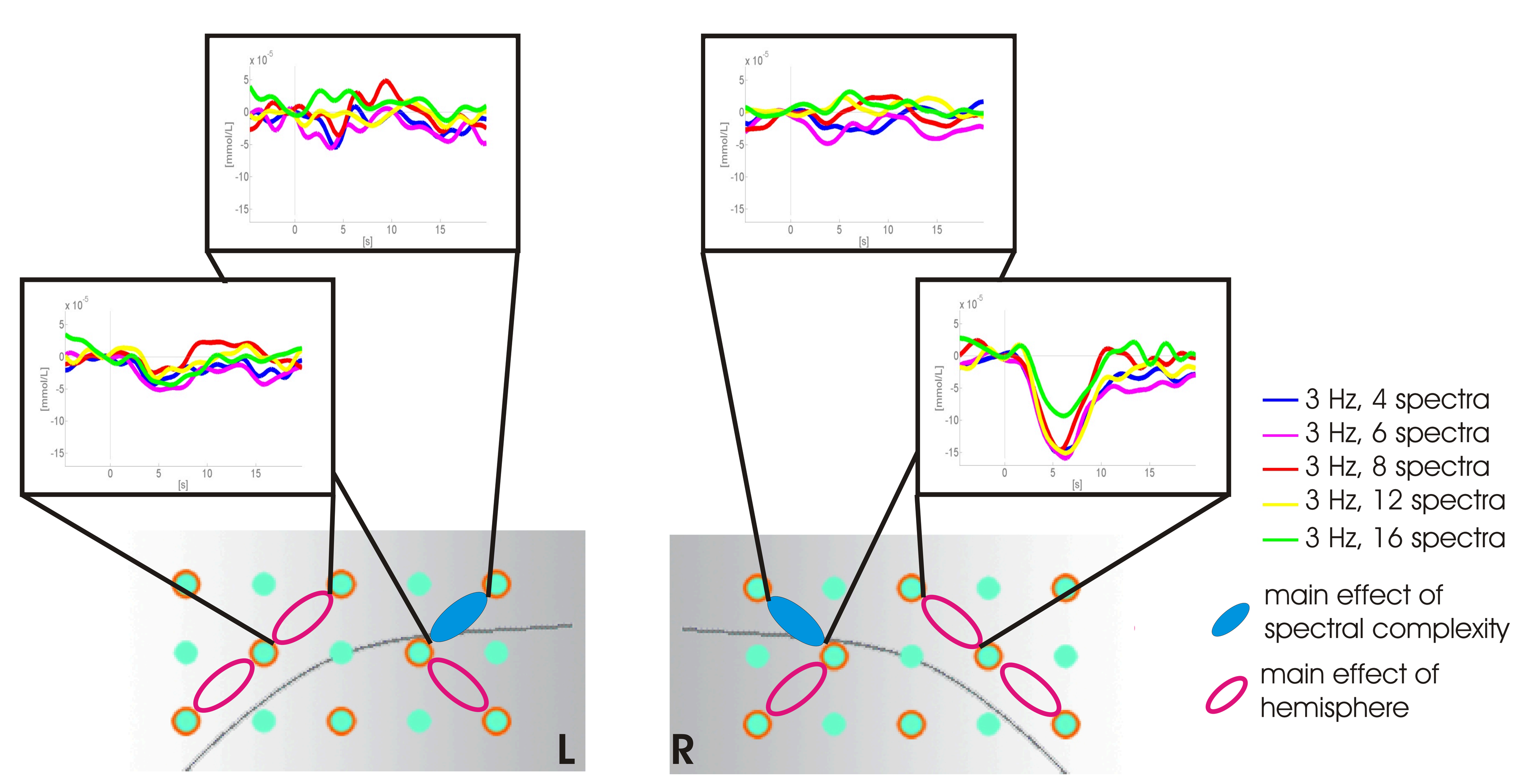

Figure 5: ANOVA main effects for spectral variation and hemisphere:
Time courses show activations but no parametric increase for spectral complexity.

Summary and Discussion

Our data shows that the modulation of temporal and spectral complexity in noise-like stimuli, which are parametrically varied with respect to their spectral and temporal complexity, elicits a focal hemodynamic response. This response is reflected by oxygenation changes in temporal cortices as detected by NIRS. Data show a dominant response in the right hemisphere across all stimulus conditions probably due to the noise-like nature of the stimuli. However, some focal brain regions are modulated by either temporal or spectral complexity. Thus, we found a distributed network subserving the analysis of specific acoustic properties but didn't find the expected lateralized modulation of the left hemisphere by temporal variation or of the right hemisphere for spectral modulation as it was shown for the antero-lateral belt using fMRI[2].

References

1 Hickok, G. & Poeppel, D. (2007), 'The cortical organization of speech processing'. Nature Reviews Neuroscience, vol. 8, no. 5, pp. 393-402.
2 Schönwiesner, M., Rübsamen, R., & von Cramon, D. Y. (2005), 'Spectral and Temporal Processing in the Human Auditory Cortex – Revisited'. Annals of the New York Academy of Sciences, vol. 1060, pp. 89-92.
3 Zatorre, R. J. & Belin, P. (2001), 'Spectral and temporal processing in human auditory cortex'. Cerebral Cortex, vol. 11, no. 10, pp. 946-953.
4 Cope, M. & Delpy, D. T. (1988), 'System for long-term measurement of cerebral blood and tissue oxygenation on newborn infants by near infra-red transillumination'. Medical & Biological Engineering & Computing, vol. 26, no. 3, pp. 289-294.

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