Acoustically driven cortical delta oscillations underpin perceptual chunking

Johanna M. Rimmele*[1], David Poeppel[1,2], and Oded Ghitza[1,3]

[1] Department of Neuroscience, Max-Planck-Institut für empirische Ästhetik, Frankfurt/Main
[2] Department of Psychology, New York University
[3] Department of Biomedical Engineering, Boston University & Center of Hearing Research, Boston University

Max Planck Institute for Empirical Aesthetics

Introduction | Background

Oscillation-based models of speech perception postulate that decoding is guided by a cascade of oscillators. Based on behavioral data (Ghitza, 2017) it was proposed that phrasal chunking is derived by an oscillator in the delta range (0.5–2 Hz). Thereby, intelligibility is impaired when the ability of this oscillator to synchronize to the chunking structure is impaired.

Here we describe an MEG study, which addresses the following questions:

(i) does chunk intelligibility correlate with the presence of delta brain waves?

(ii) is the brain delta activity acoustic- or top-down driven?

(iii) where are the delta sources located?

Paradigm

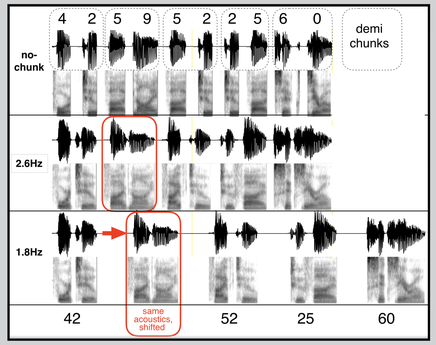

Fig. 1 Paradigm. Chunking patterns and rates for a 10-digit sequence. Chunks digitized as 2-digit unit. Chunk acoustics are equal in the 2.6Hz and 1.8Hz condition. The chunk rate is generated by inserting gaps.

2.6Hz condition: chunk rate "outside" of the delta range

1.8Hz condition: chunk rate inside of the delta range

No-chunk condition: No acoustic chunking cues, top-down instructions (demi-chunking: telling participants that they always hear 2-digit chunks)

- Participants (N =19)

- Instructions: Listen to sequences of chunks of 2 digits (top-down cue). After each sequence a 2-digit target is presented. Participants indicate whether the target was present in the sequence.

Results | Behavior

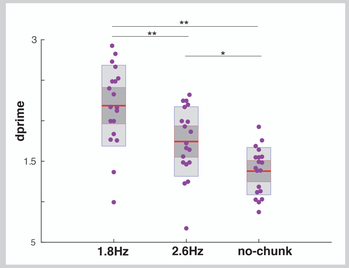

Fig.2 Behavioral performance. Increased performance when chunks are presented in the delta-range compared to higher frequencies (condition 1.8Hz chunked vs. 2.6Hz chunked, p = .0036 vs. no-chunk, p = .0006), particularly without bottom-up cues (condition 2.6 Hz vs. no-chunk, p = 0.031).

The findings replicate Ghitza (2017) and show the advantage of bottom-up vs. top-down cues.

Analysis | MEG

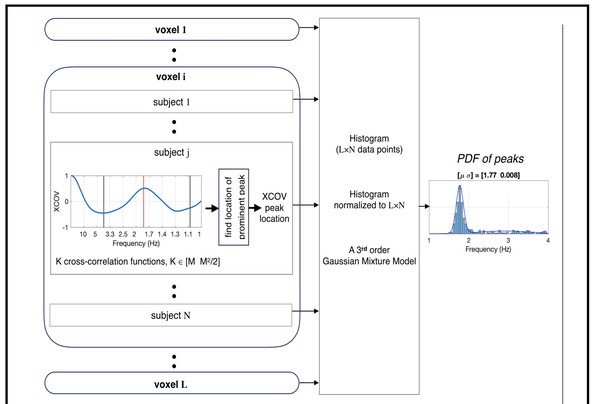

Fig. 3 Aggregated cross-correlation analysis (xcov). The cross-correlation was computed and aggregated across trials. The probability density function (PDF) was computed for the periodicities within a particular ROI, condition and response class. (L voxels, N subjects, and M trials).The "goodness" of the periodicity is quantified by the mean and variance of the prominent Gaussian component of a 3rd order Ggaussian Mixture Model.

Results | MEG

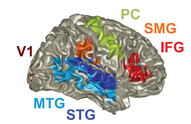

Fig. 4 Cortical regions of interest (ROIs). The AAL Atlas was used to define ROIs in left and right auditory cortex (STG), the ventral (MTG) and the dorsal (IFG, PC, SMG) auditory stream. V1 was used as control ROI.

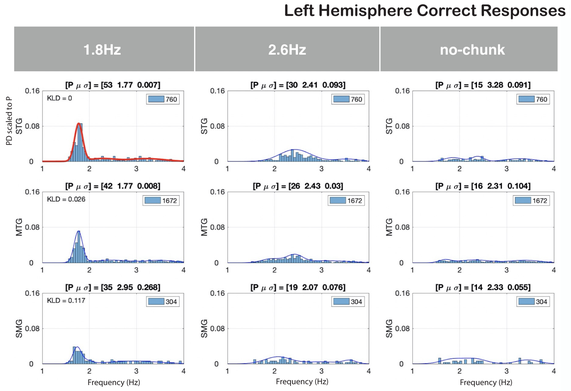

Fig.5 Delta periodicities for Correct responses in the left hemisphere. The periodicity PDFs are displayed (Rows: regions of interest, ROIs; columns: chunking conditions). Legend: total number of data points; P, percentage datapoints inside the frequency range, mean μ, variance σ of prominent Gaussian component. The results show:
1.8Hz condition: strong periodicities at 1.8 Hz chunk rate
2.6Hz condition: weaker periodicities at 2.6Hz chunk rate
No-chunk condition: no periodicities

The Kullback-Leibler Divergence (KLD) at all ROIs compared to the STG ROI (red) suggests two periodicity patterns:

ventral stream areas (STG and MTG ROIs): periodicities narrowly distributed at 1.8Hz
dorsal stream areas (IFG, SMG and PC ROIs): periodicities wider distributed at 1.8Hz, with less periodicities present

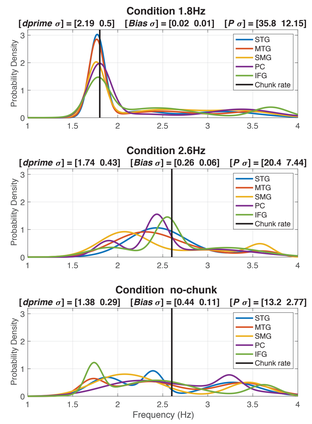

Fig.6 Behavioral vs. electrophysiological responses. The GMMs are displayed for all ROIs (left hemisphere, correct responses), along with the dprime values. The Bias indicates the variance of periodicities across ROIs. Small variance in periodicities is accompanied by higher performance (d-prime values).

Discussion

- MEG support for Ghitza (2017): digit chunk recognition is improved for chunk rates in the delta frequency range compared to faster chunk rates.
- Strong periodicities were elicited by acoustic-driven chunk rates inside of delta in superior and middle temporal and speech-motor integration areas
- Top-down grouping not strong enough to elicit delta periodicities
- Ventral and dorsal stream show distinct periodicity patterns
- Phrasal chunking correlated with acoustic-driven oscillations

→ Cortical computational principle at the phrasal level

Contact Dr. Johanna Rimmele | johanna.rimmele@ae.mpg.de | https://www.aesthetics.mpg.de/ | +49 69 8300479 323

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References:
Ghitza et al., 2017. Acoustic-driven delta rhythms as acoustic markers. Language, Cognition and Neuroscience, 32, 545-561.

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