IMT SCHOOL FOR ADVANCED STUDIES LUCCA

UNIVERSITÀ DEGLI STUDI DI MILANO

SIPF 2023 Siena

XXXI CONGRESSO NAZIONALE SIPF

Past, Present and Future Brains

Siena 9-11 novembre 2023

Museo Santa Maria della Scala

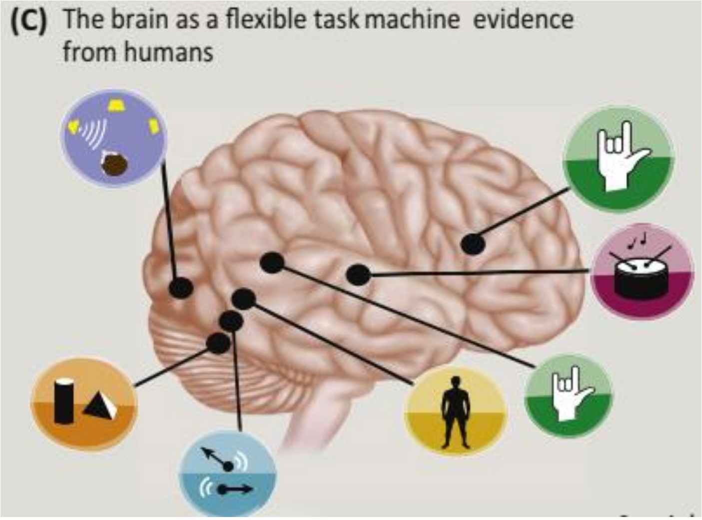
SALA SANT'ANSANO

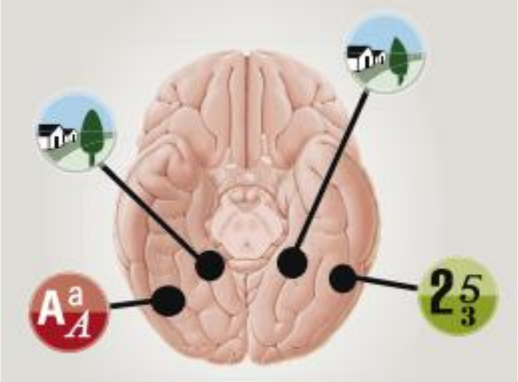
11.45 - 13.00 SIMPOSIO III

BEYOND SENSORY MODALITY AS THE PRIMARY ORGANIZING PRINCIPLE OF SENSORY CORTICES ARCHITECTURE

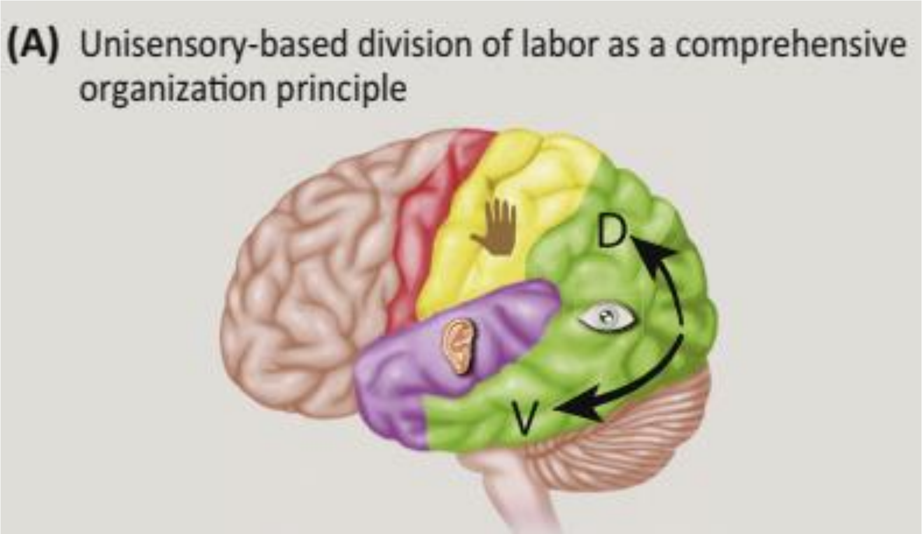
Sensory dependent vs. sensory-independent specializations

Task-anchored





Sensory-anchored



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Auditory features modelling demonstrates sound envelope representation in the striate cortex
Davide Bottari (Lucca)

Blindness affects occipital cortex reactivity: a TMS-EEG study
Gabriel Hassan (Milano)

Early cortical sensory responses in typical but not in blind and deaf individuals
Monica Gori (Genova)

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AUDITORY FEATURES MODELLING DEMONSTRATES SOUND ENVELOPE REPRESENTATION IN THE STRIATE CORTEX

Davide Bottari, PhD

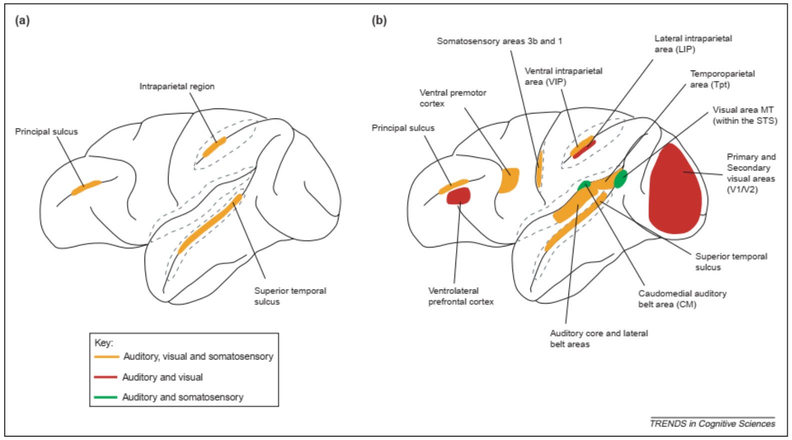
IMT School for Advanced Studies Lucca, Italy

Review
TRENDS in Cognitive Sciences Vol.10 No.6 June 2006
Full text provided by www.sciencedirect.com

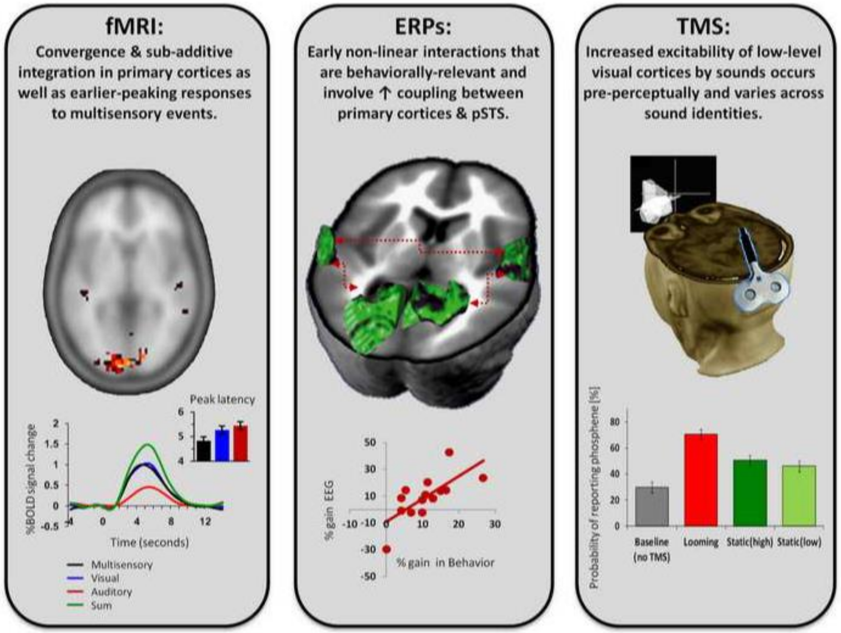
Is neocortex essentially multisensory?

Asif A. Ghazanfar[1] and Charles E. Schroeder[2]

[1]Program in Neuroscience, Department of Psychology, Green Hall, Princeton University, Princeton, New Jersey, 08540, USA
[2]Cognitive Neuroscience and Schizophrenia Program, Nathan S. Kline Institute for Psychiatric Research, 140 Old Orangeburg Rd, Orangeburg, New York, 10962, USA

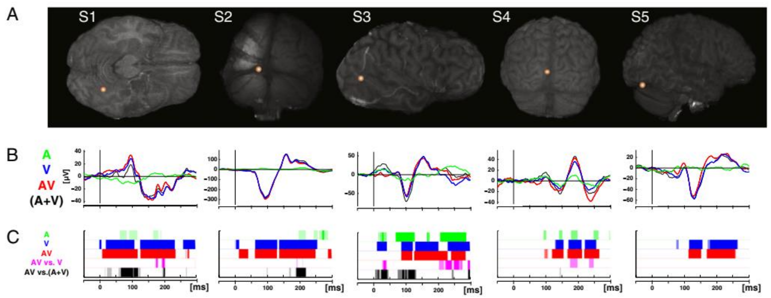


Audio-visual interactions occur in V1



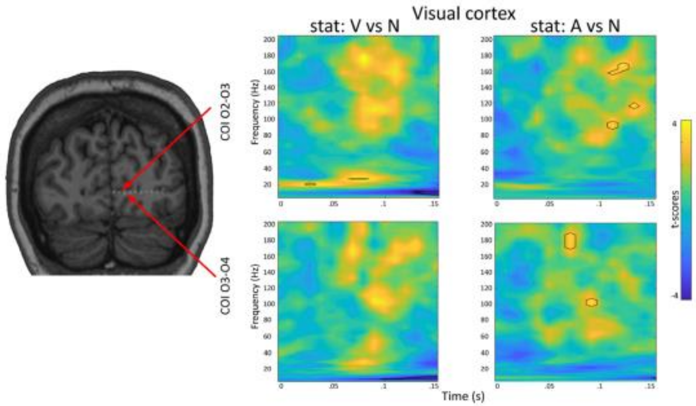
Adapted from Murray et al., 2016

Unimodal Auditory Responses in V1



Adapted from Mercier et al., 2013

Event Related Responses (ERPs) to a tone have been measured with intracranial recordings from V1 (ERPs Mercier et al., 2013).



Adapted from Ferraro et al., 2020

High gamma neural oscillations after white-noise bursts were measured in striate cortex (Ferraro et al., 2020).

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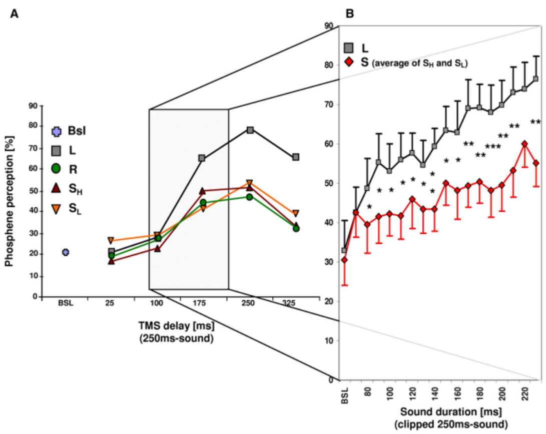
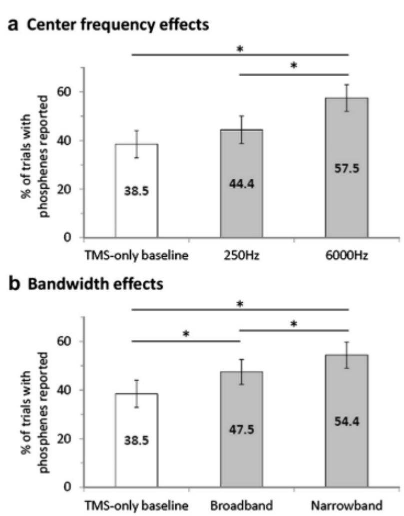
Not all sounds seem to exert the same effect on V1 (measured by phosphene perception)



Adapted from Romei et al., 2009

Looming sounds have been found more effective than static or receding sounds in enhancing visual cortex excitability (Romei et al., 2009).



Adapted from Spierer et al., 2013

High pitch and **narrowband** sounds elicit a greater increase of visual cortex excitability compared to lower pitch and broadband sounds, respectively (Spierer et al., 2013).

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Which sound properties are mapped in V1?

We investigated whether the **envelope of natural sounds** is mapped in V1

Why?

Natural sounds and vocalizations are characterized by high energy at slow temporal modulations

Intensity fluctuations match the neural coding selectivity of the auditory system (Hsu et al., 2004; Riecke, 1995)

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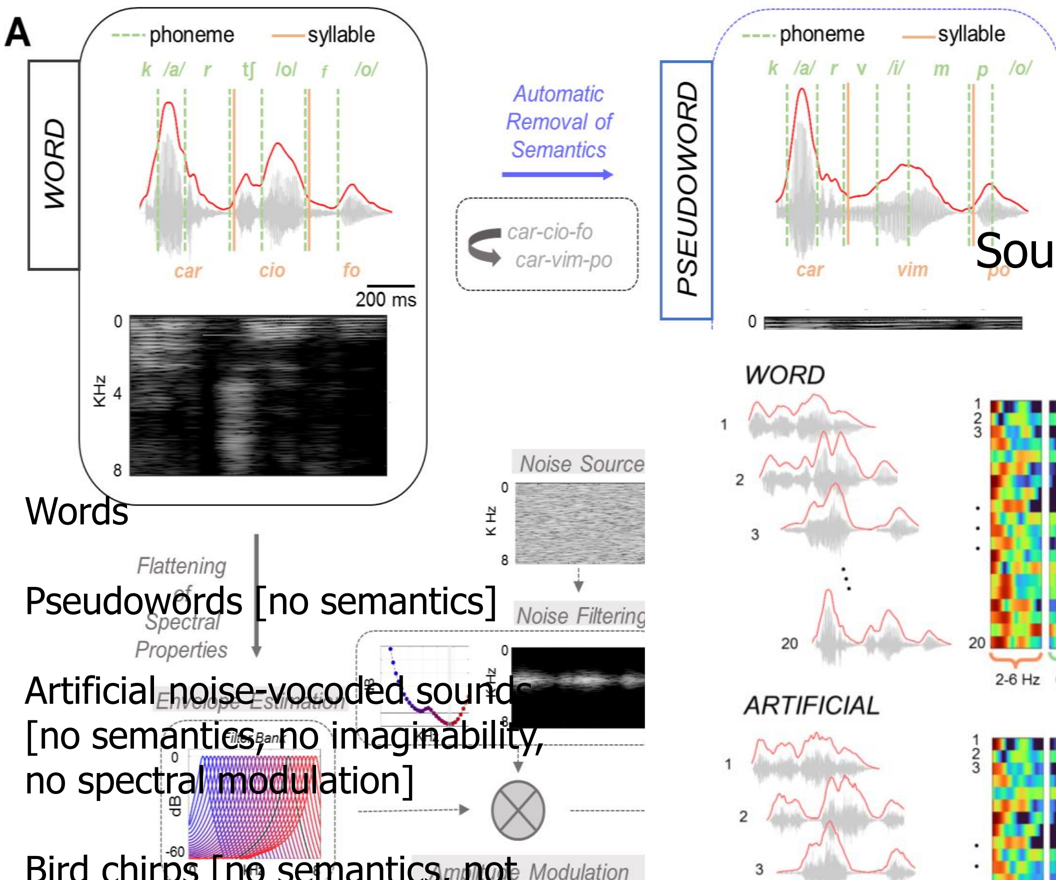
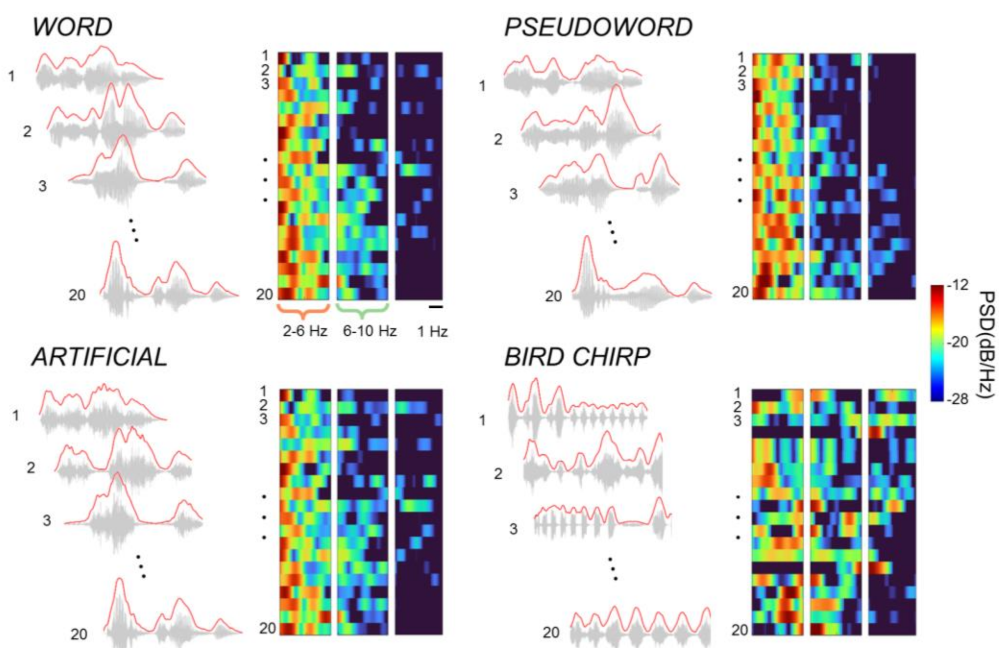
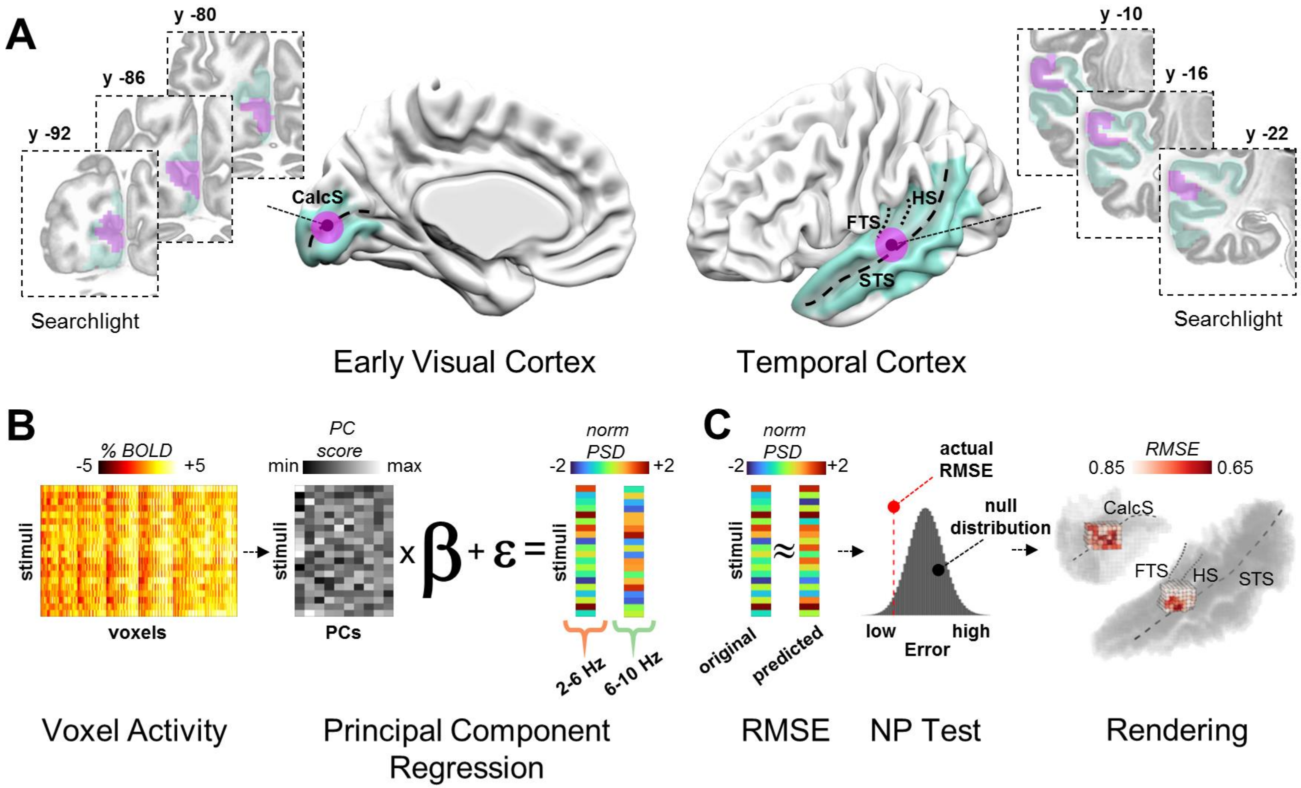
Sound Categories



- Words
- Pseudowords [no semantics]
- Artificial noise-vocoded sounds [no semantics, no imaginability, no spectral modulation]
- Bird chirps [no semantics, not language]



Analysis Pipeline



N=20, Blindfolded Participants

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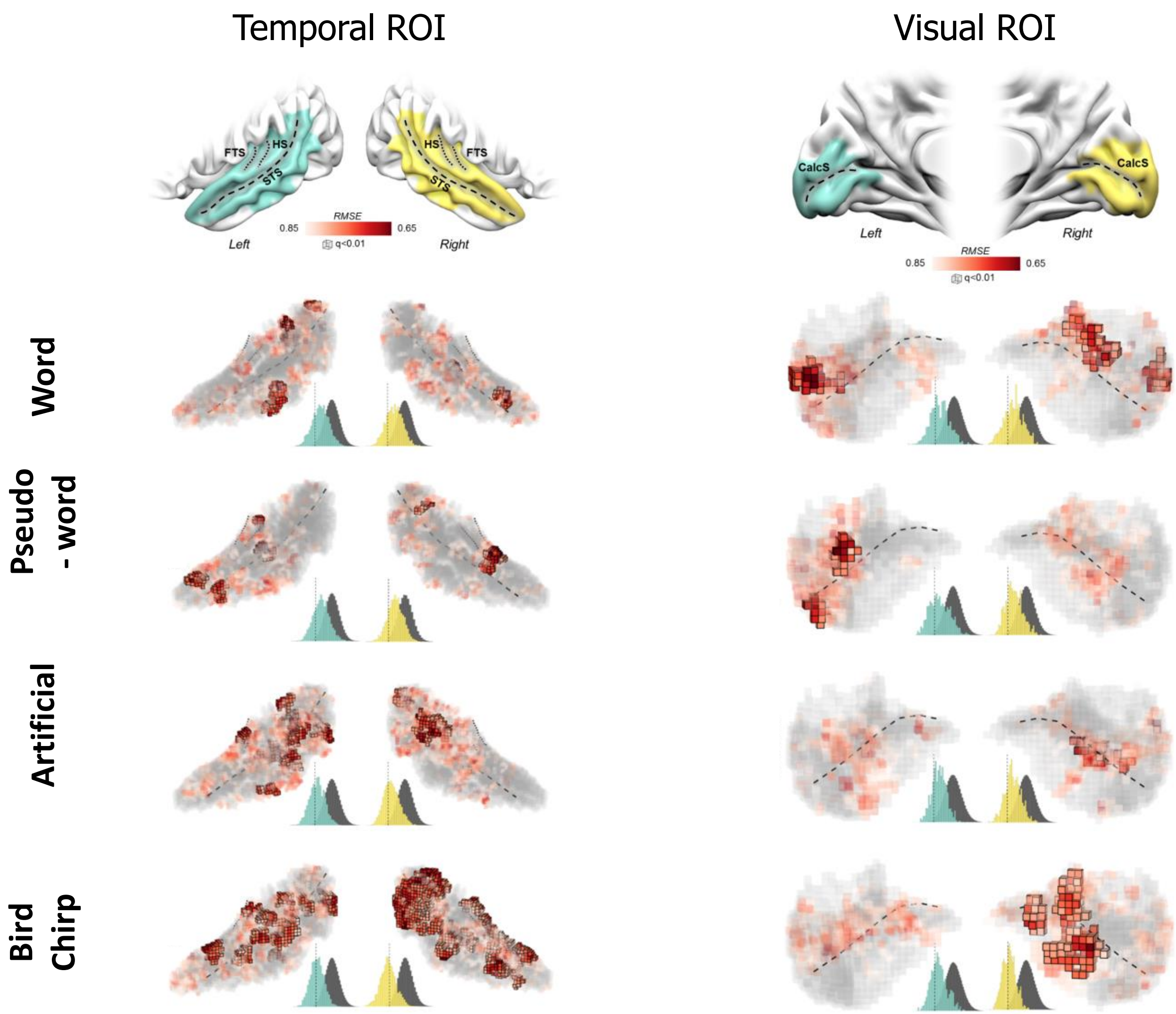
Reconstruction of the sound envelope power in the 6-10 Hz frequency range



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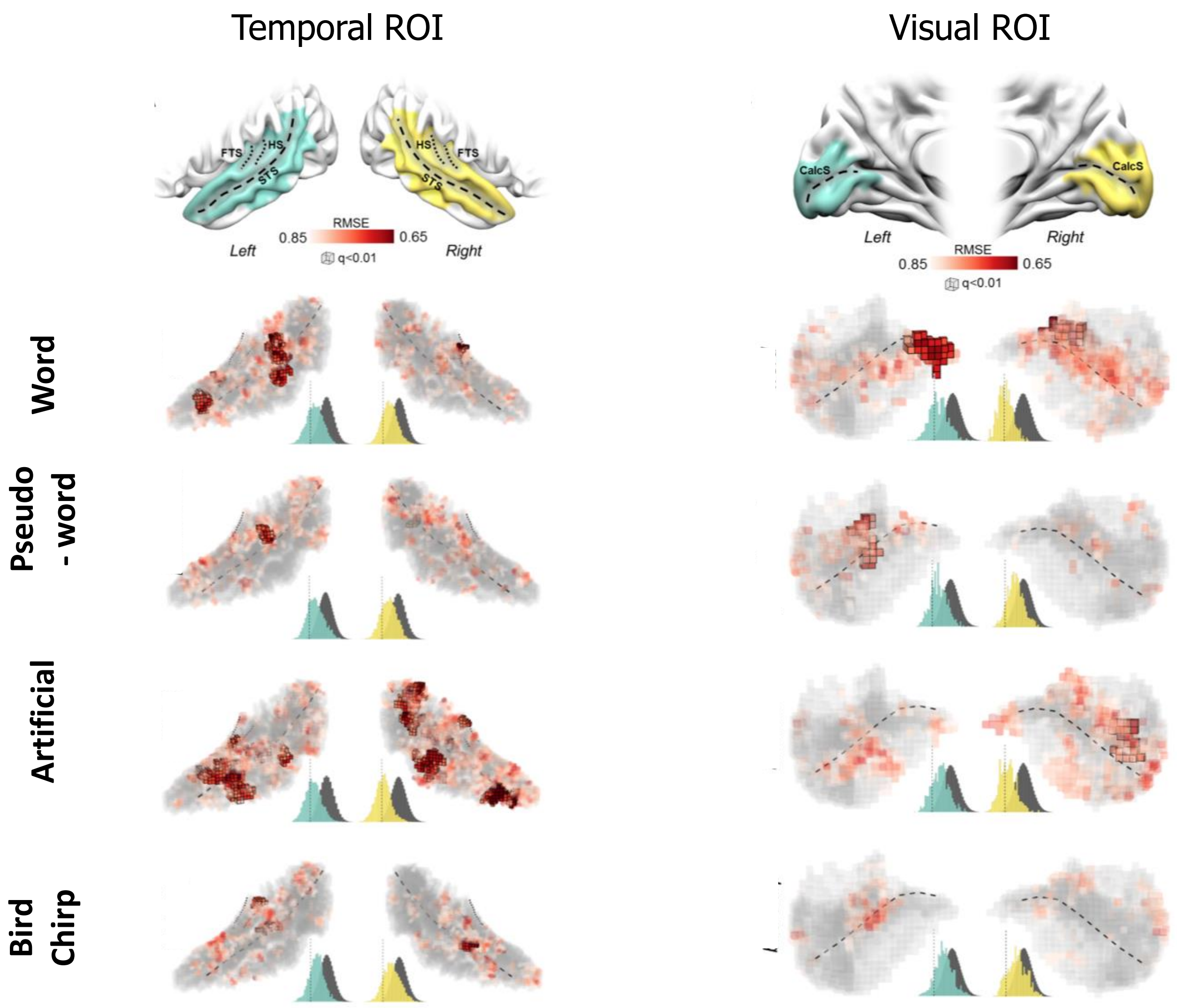
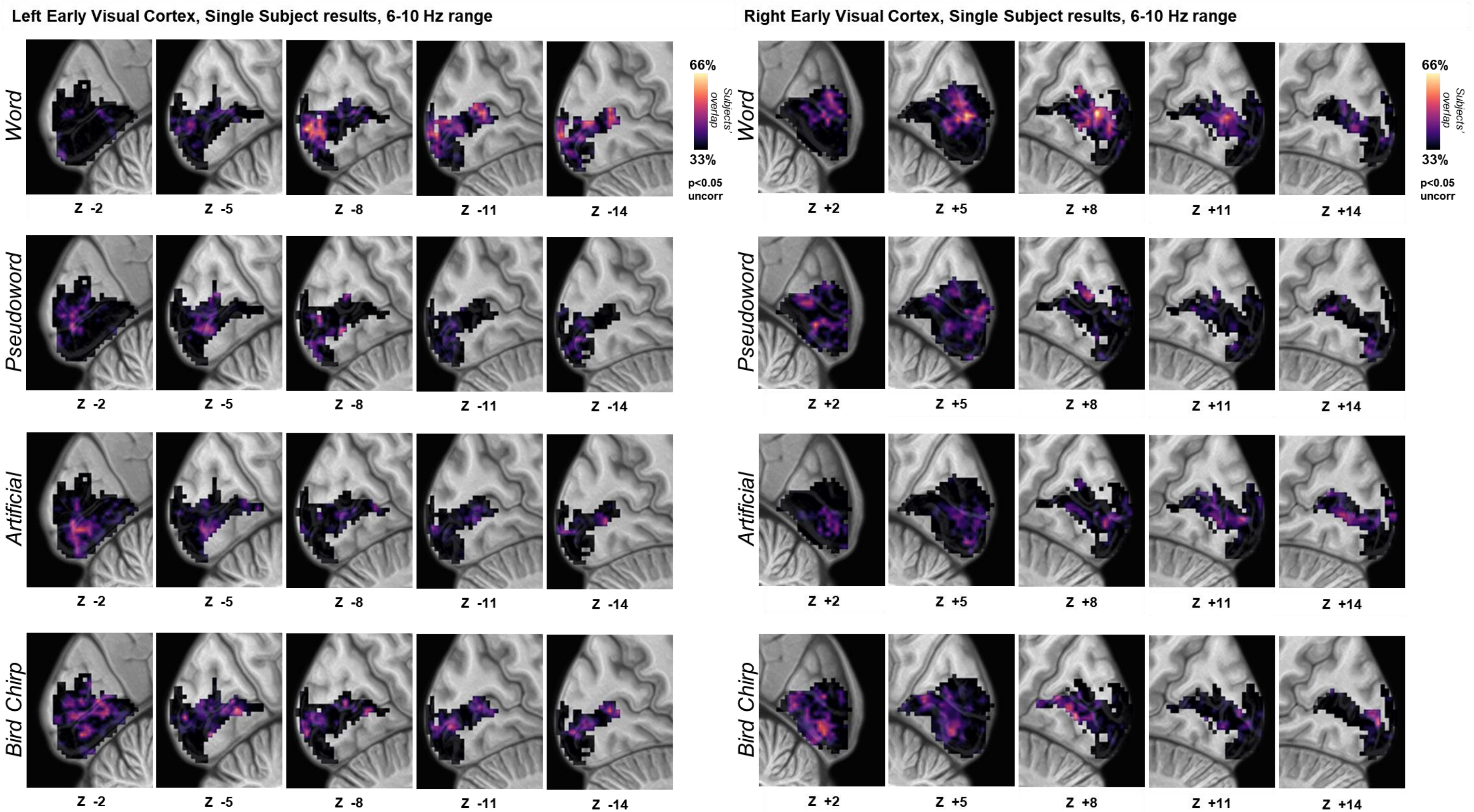
Reconstruction of the sound envelope power in the 2-6 Hz frequency range



Reconstruction of the sound envelope power in the 6-10 Hz frequency range in the Visual ROI.

Overlap across participants



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Interim results

The envelope of sounds was traceable in Temporal and in the Calcarine cortex:

Regressing out global signal (no arousal)

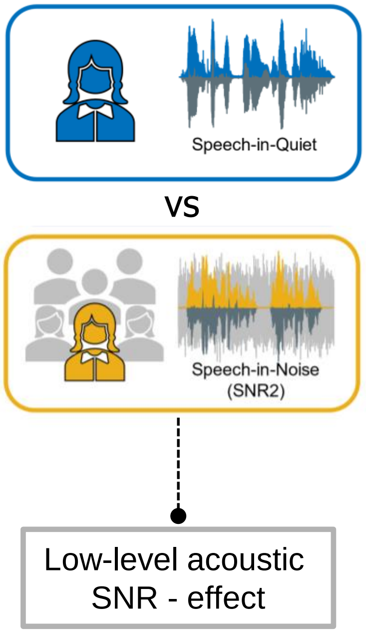
With non-imaginable sounds (*pseudowords* and *artificial sounds*)

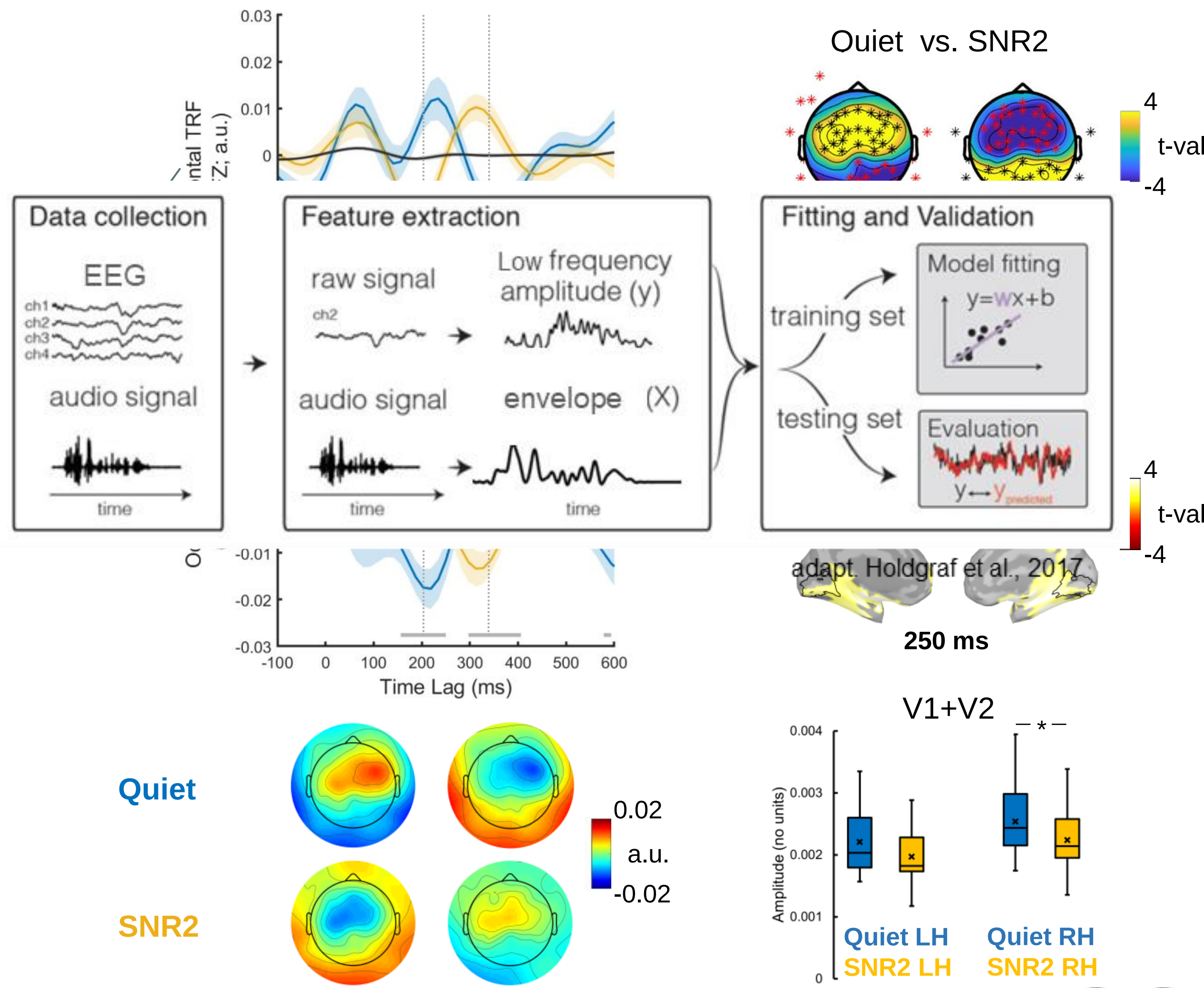
In the absence of spectral properties (*artificial sounds*)

The effect was not speech-specific (*bird chirps*)

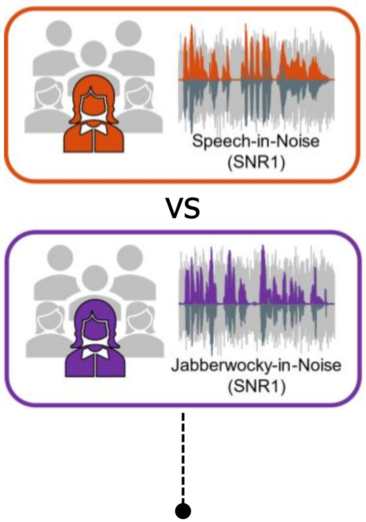
Which factors characterize the dynamic of this crossmodal response?

Auditory Attention?

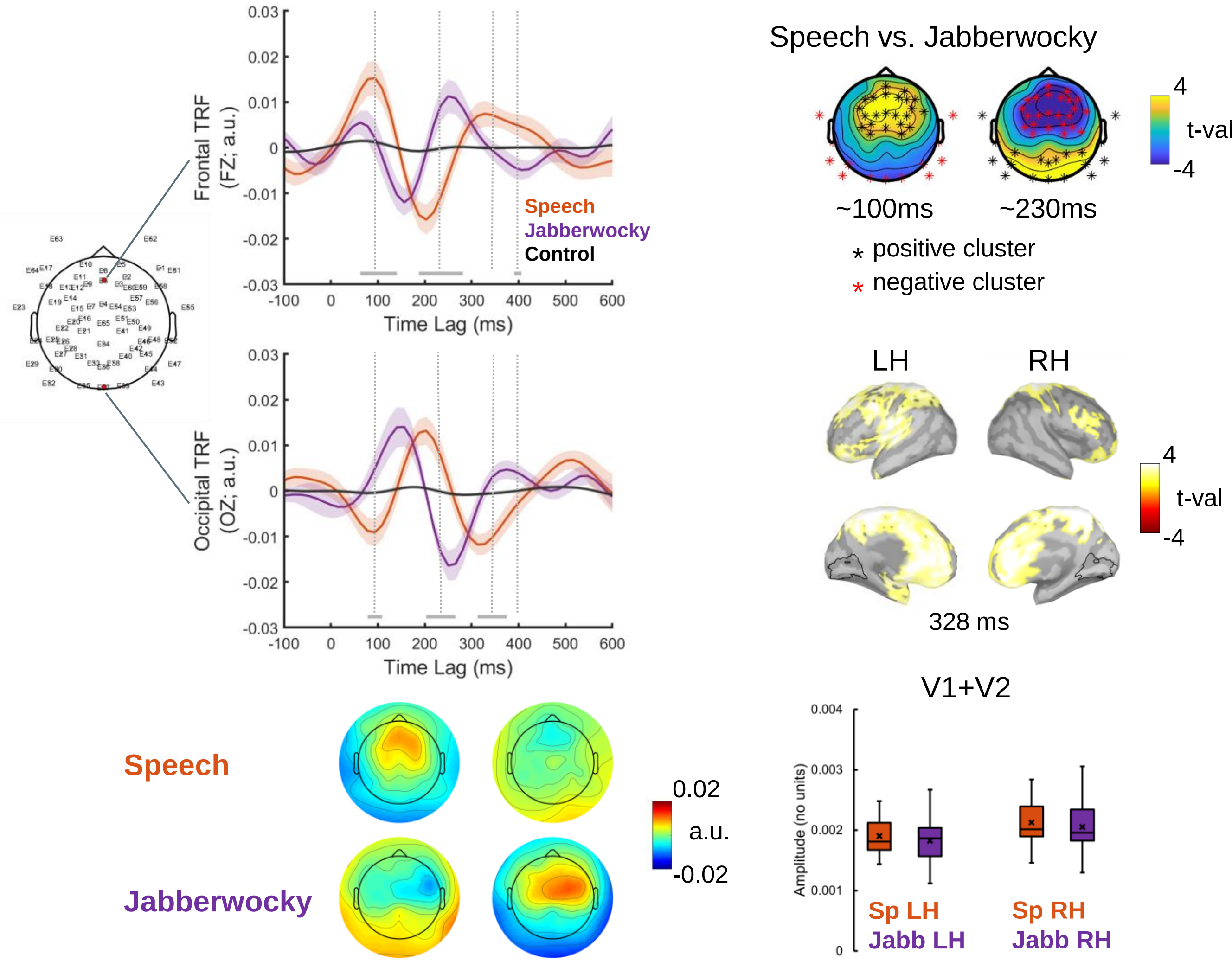




N=20, Blindfolded Participants



High-level linguistic
Semantic - effect



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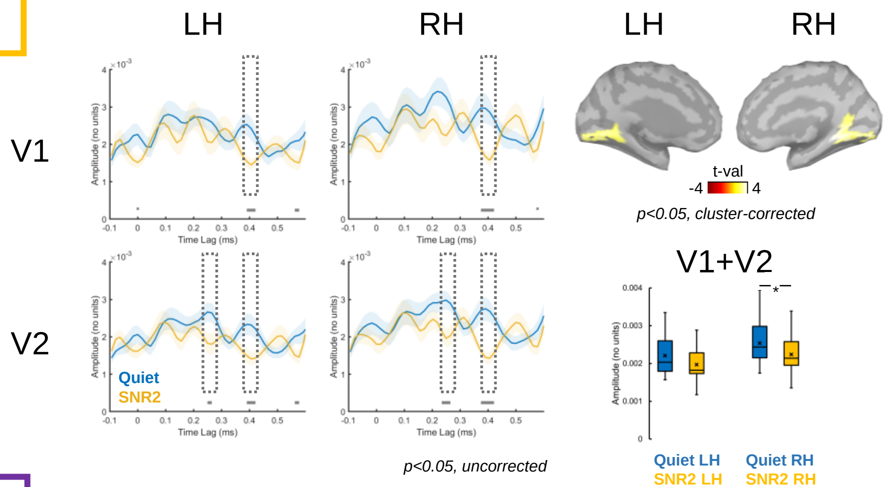
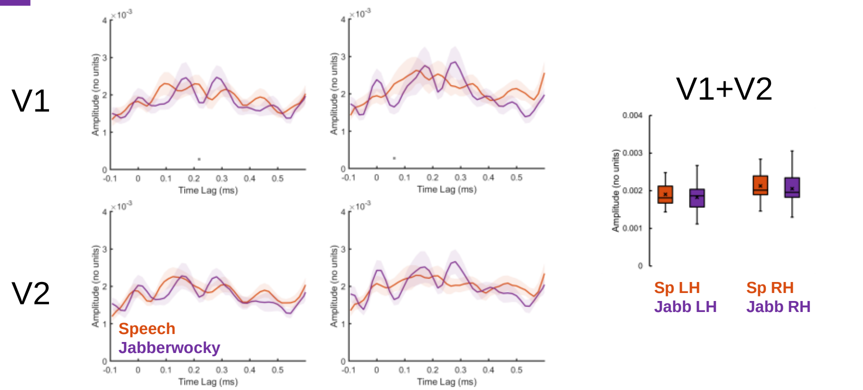
Low-level acoustic (SNR) effect



High-level linguistic (Semantic) effect



Discussion

Overall, results suggest that the early visual cortex maps sound envelope (irrespective of semantics, spectral content, and language). This input reaches the early visual cortex following auditory processing (>250-400ms).

When the task required extraction of sound from noise (i.e., was *strictly auditory),* crossmodal activity seemed reduced

Energetic variation in sounds (non-stationarity) could help drive multisensory integration

Overall, these results could help understand why in blind individuals, V1 is typically found to represent different sound categories (e.g., Vetter et al., 2020) and speech (Bedny et al., 2011).

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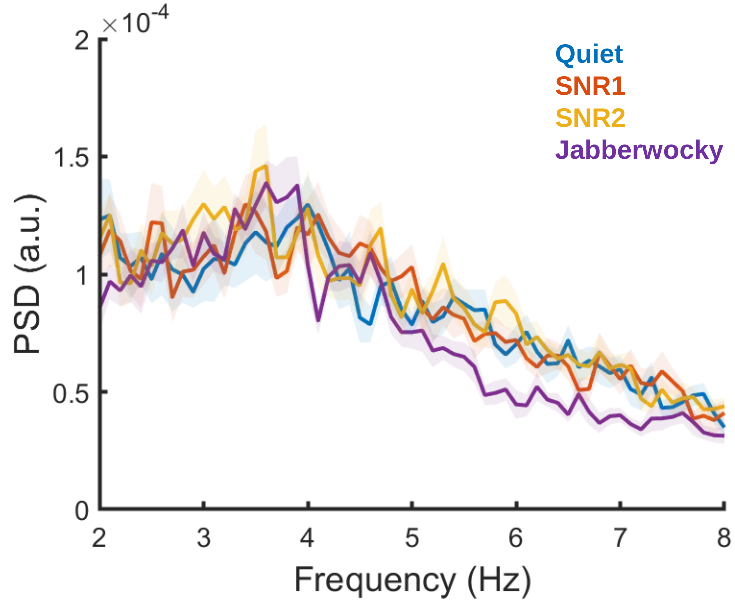
MOMILAB

SEED SENSORY EXPERIENCE DEPENDENT

Giacomo Handjaras | Alice Martinelli | Monica Betta | Pietro Pietrini | Emiliano Ricciardi

Evgenia Bednaya | Bojana Mirkovic | Alessandra Federici | Martina Berto | Stefan Debener

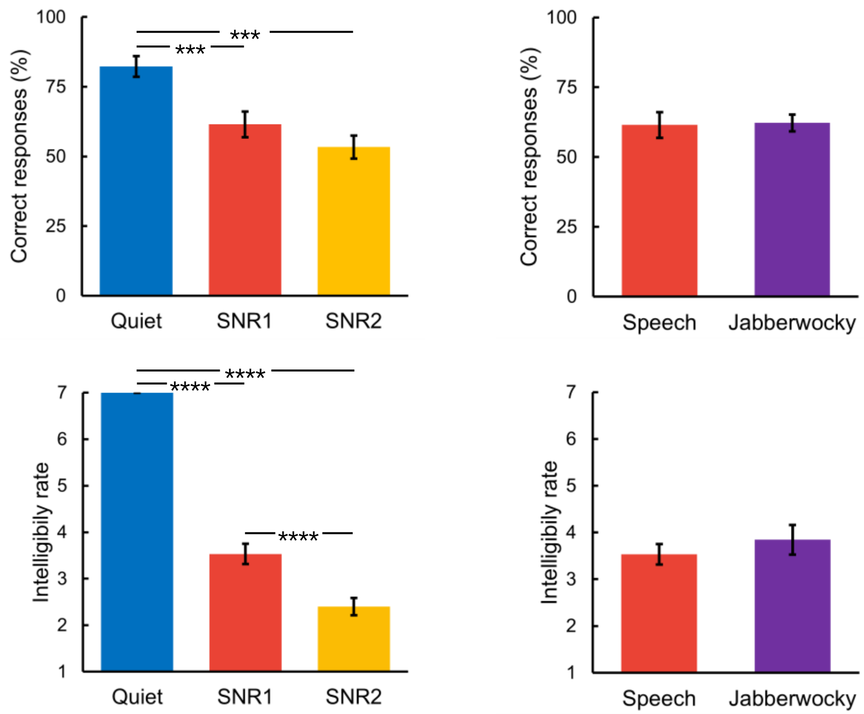
Carl von Ossietzky Universität Oldenburg



×10^-4
2
1.5
1
0.5
0
PSD (a.u.)
2
3
4
5
6
7
8
Frequency (Hz)
Quiet
SNR1
SNR2
Jabberwocky

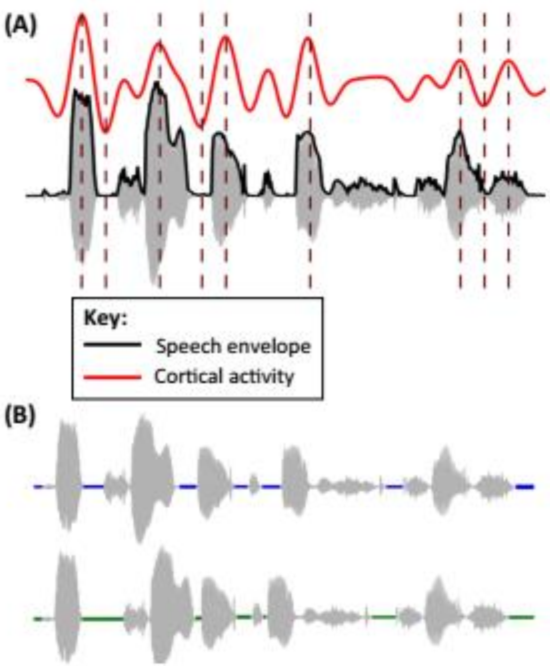
Low-level acoustic (SNR) effect

High-level linguistic (Semantic) effect

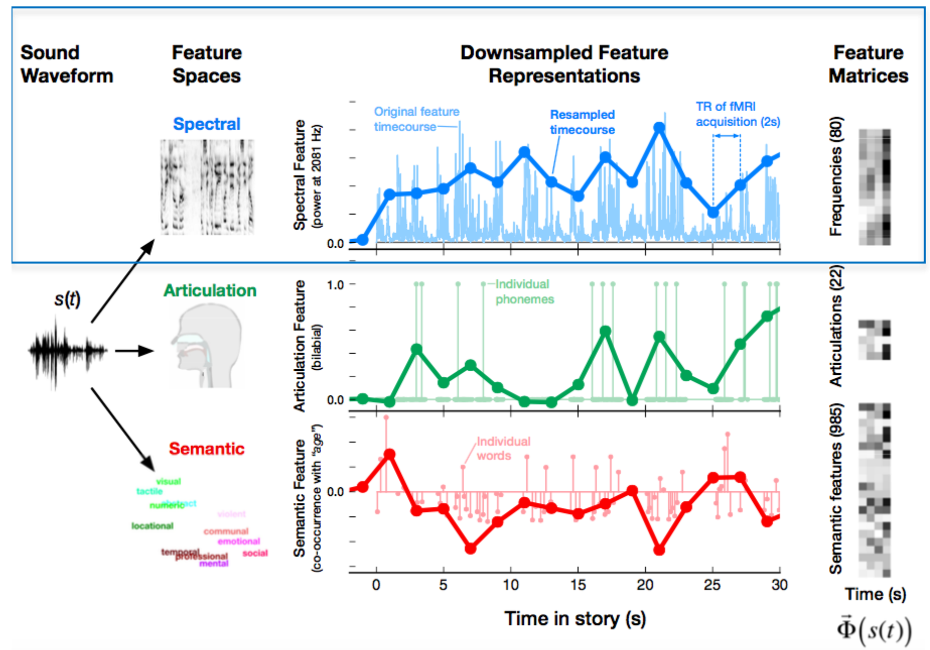


A methodological reference

- Most recent approaches of language processing link the analysis of acoustics features of speech and brain activity (Entrainment: e.g. Giraud and Poeppel, 2012 NN)
- Through voxelwise modeling we can determine which specific speech-related features (for instance amplitude modulations) are represented in each voxel

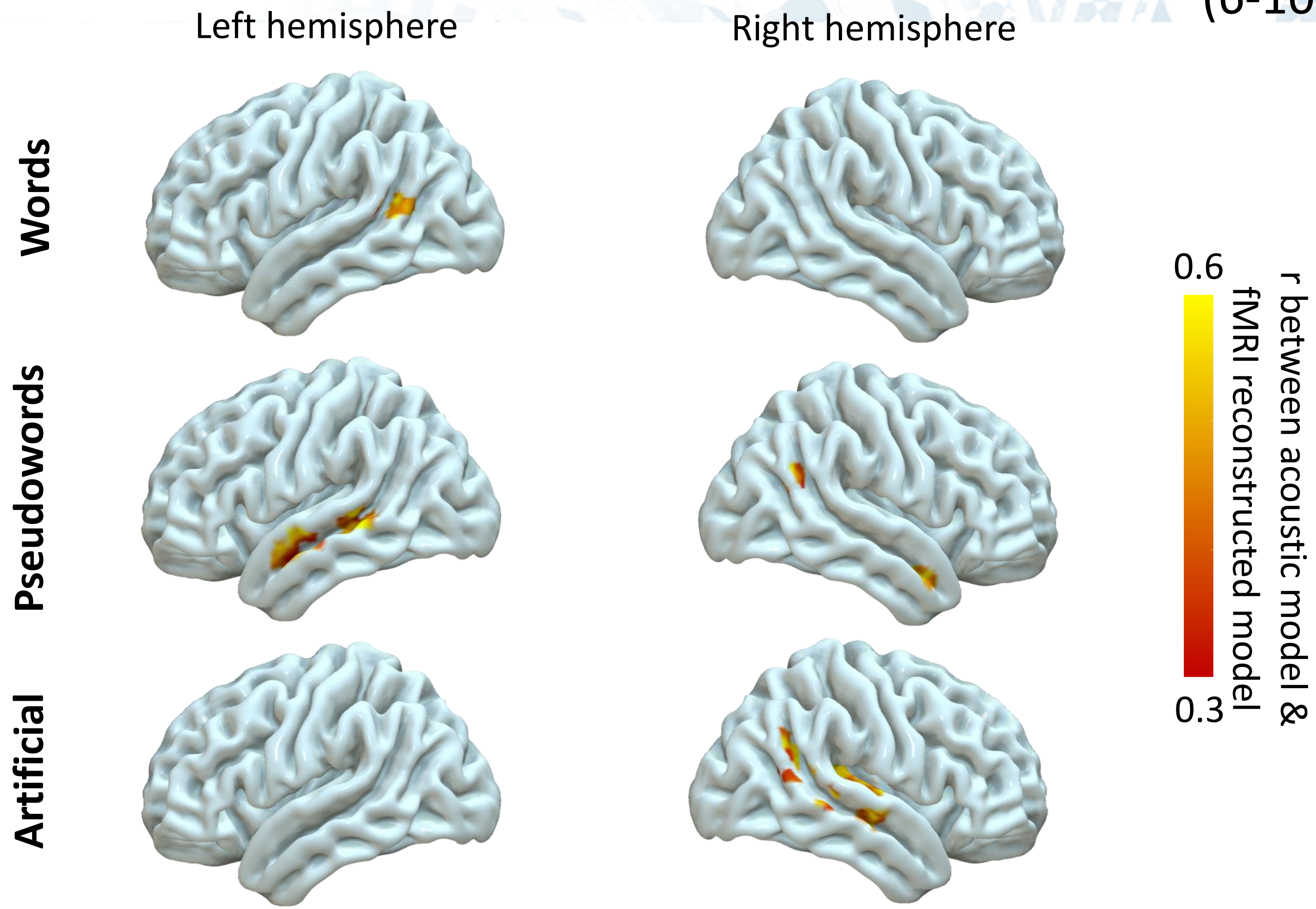


Ding et al., 2017 TiCS



De Heer et al., 2017 J of Neuro

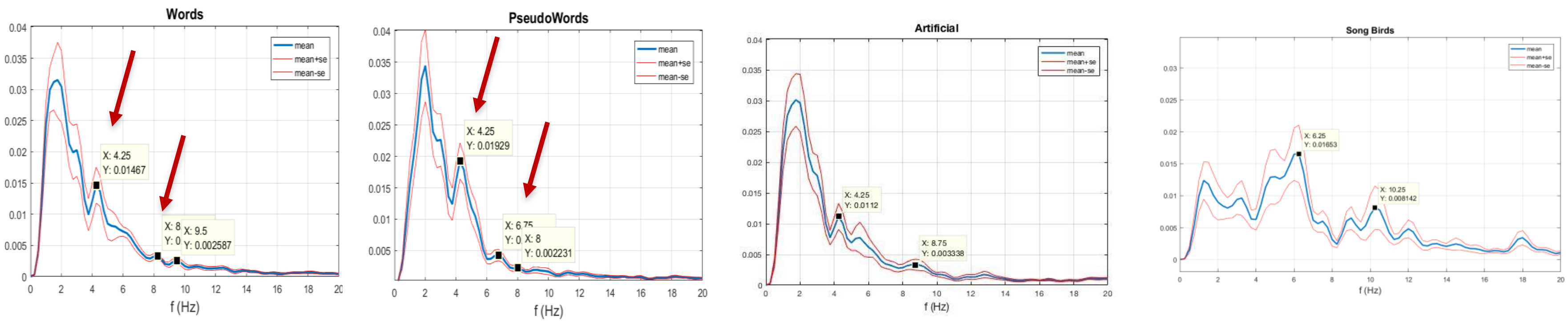
Encoding of envelope power in the *phomenic* range (6-10Hz)



p<0.05, α<0.05 (cluster corr.)

Envelope modulation

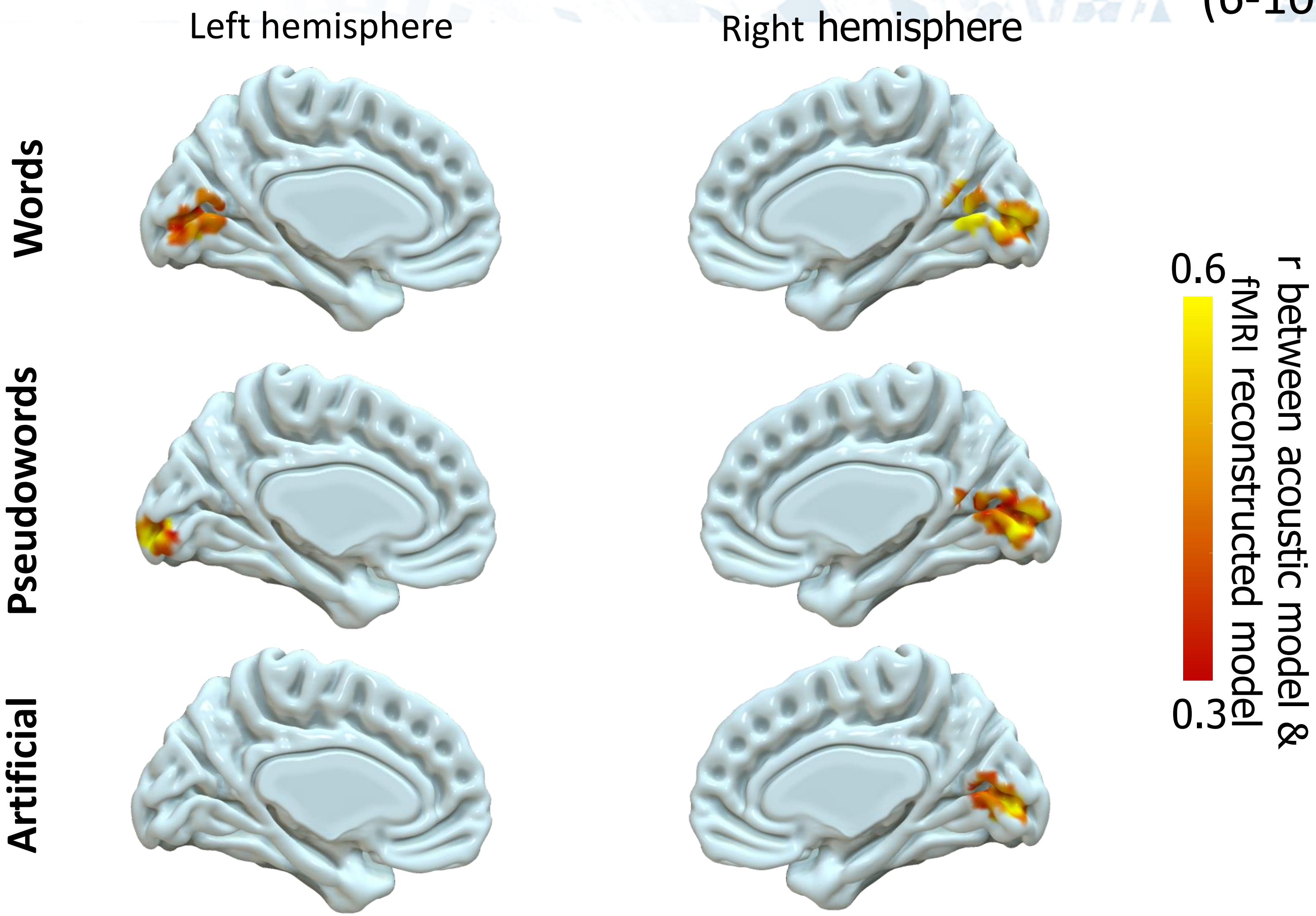
Entrainment is typically calculated at speech related rates (e.g. syllabic, phonemic)



Acoustic features: from the sound envelope (AM over time) syllabic and phonemic frequencies ~4 Hz and ~8 Hz respectively (e.g. Keitel, Gross & Kayser, 2018)

model: 2 normalized columns of power, one centered on the syllabic frequency (2-6 Hz), the other on the phonemic freq. (6-10 Hz) both for words, pseudowords and artificial noise vocoded sounds. The two frequency ranges were not collinear.

Encoding of envelope power in the *phomenic* range (6-10Hz)



$p<0.05$, $\alpha<0.05$ (cluster corr.)

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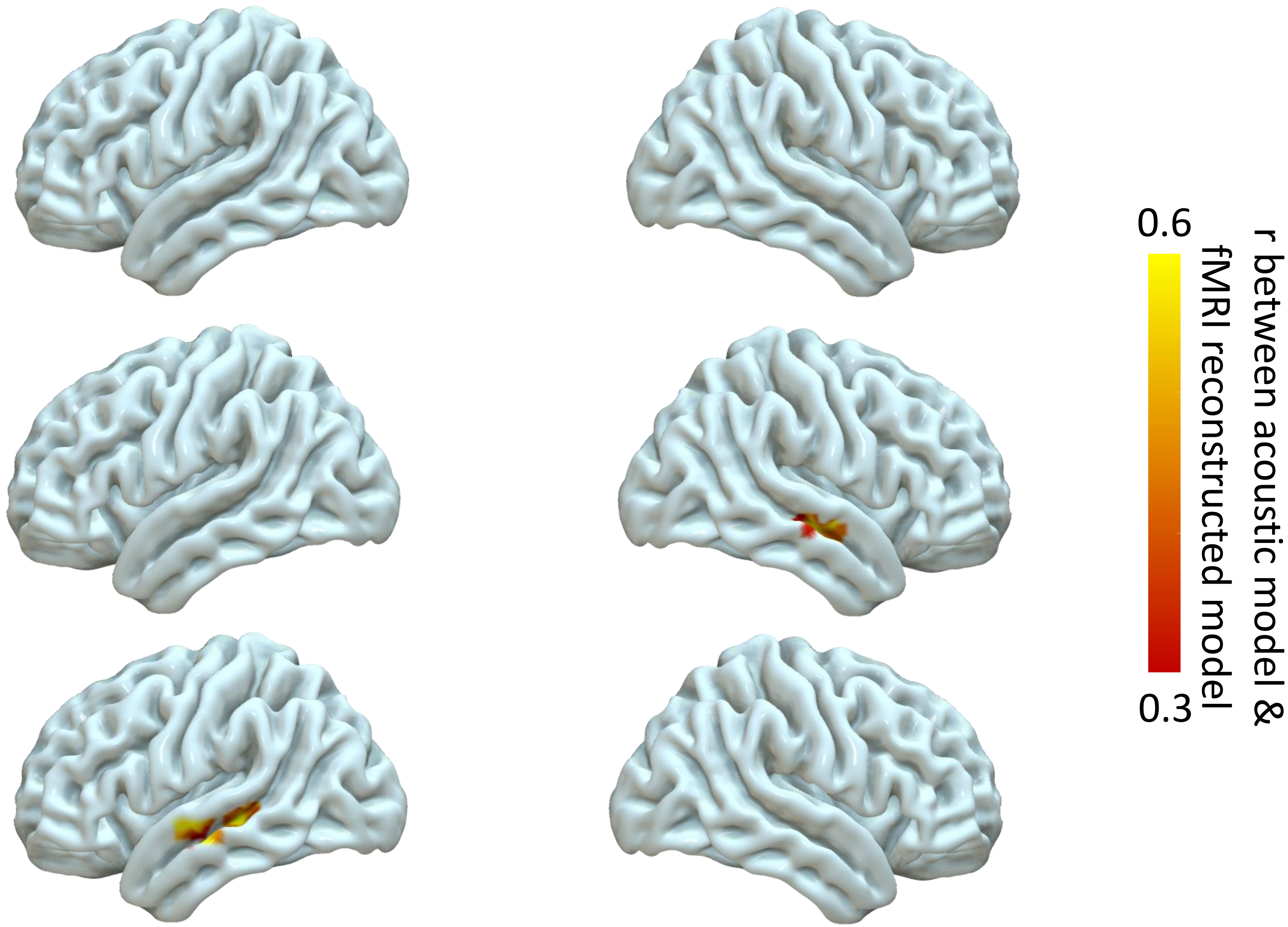
Encoding of envelope power in the *syllabic* range (2-6Hz)

Left hemisphere | Right hemisphere

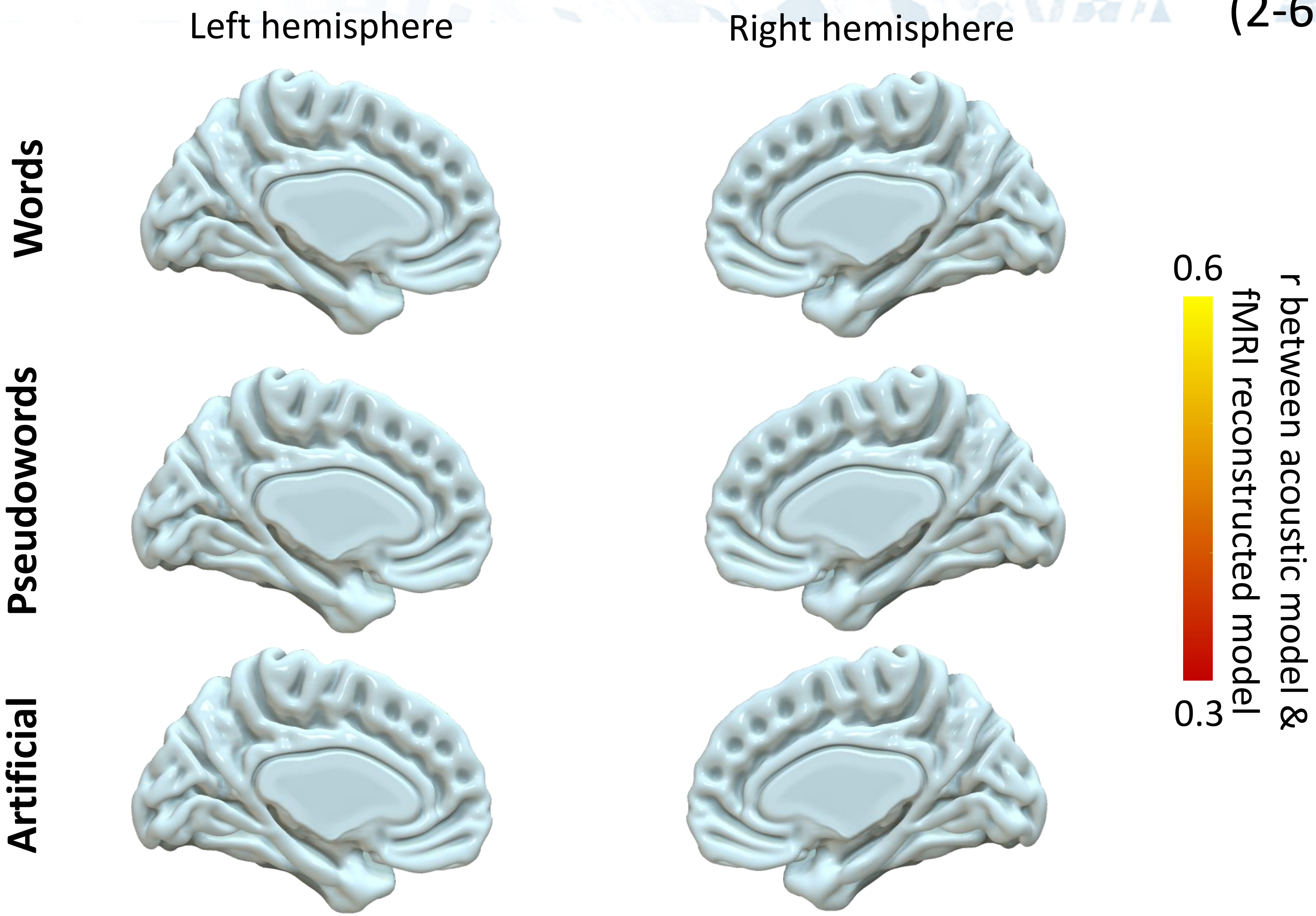
Words / Pseudowords / Artificial



p<0.05, α<0.05 (cluster corr.)

IMT SCHOOL FOR ADVANCED STUDIES LUCCA

Encoding of envelope power in the *syllabic* range (2-6Hz)



p<0.05, α<0.05 (cluster corr.)

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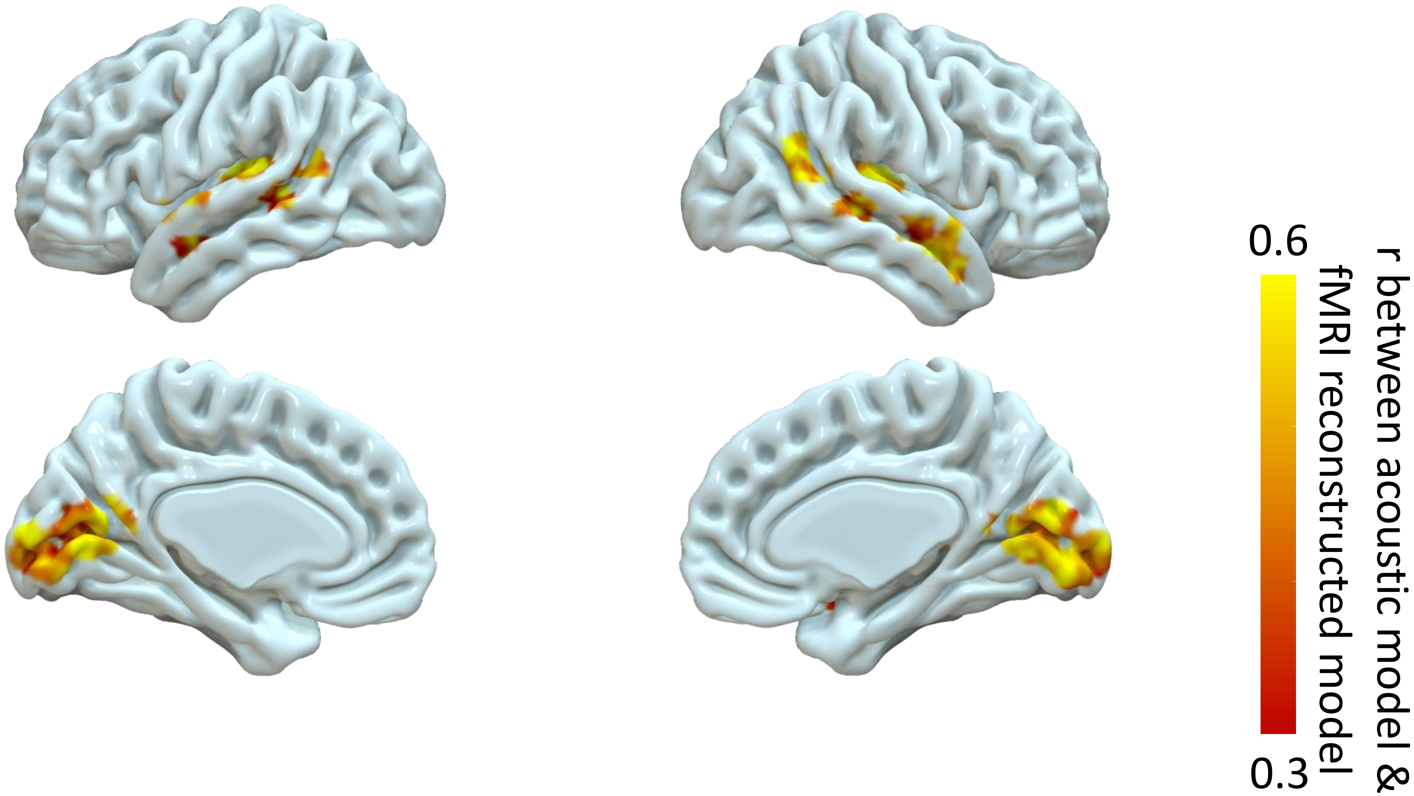
Encoding of envelope power in the *phomenic* range (6-10Hz)

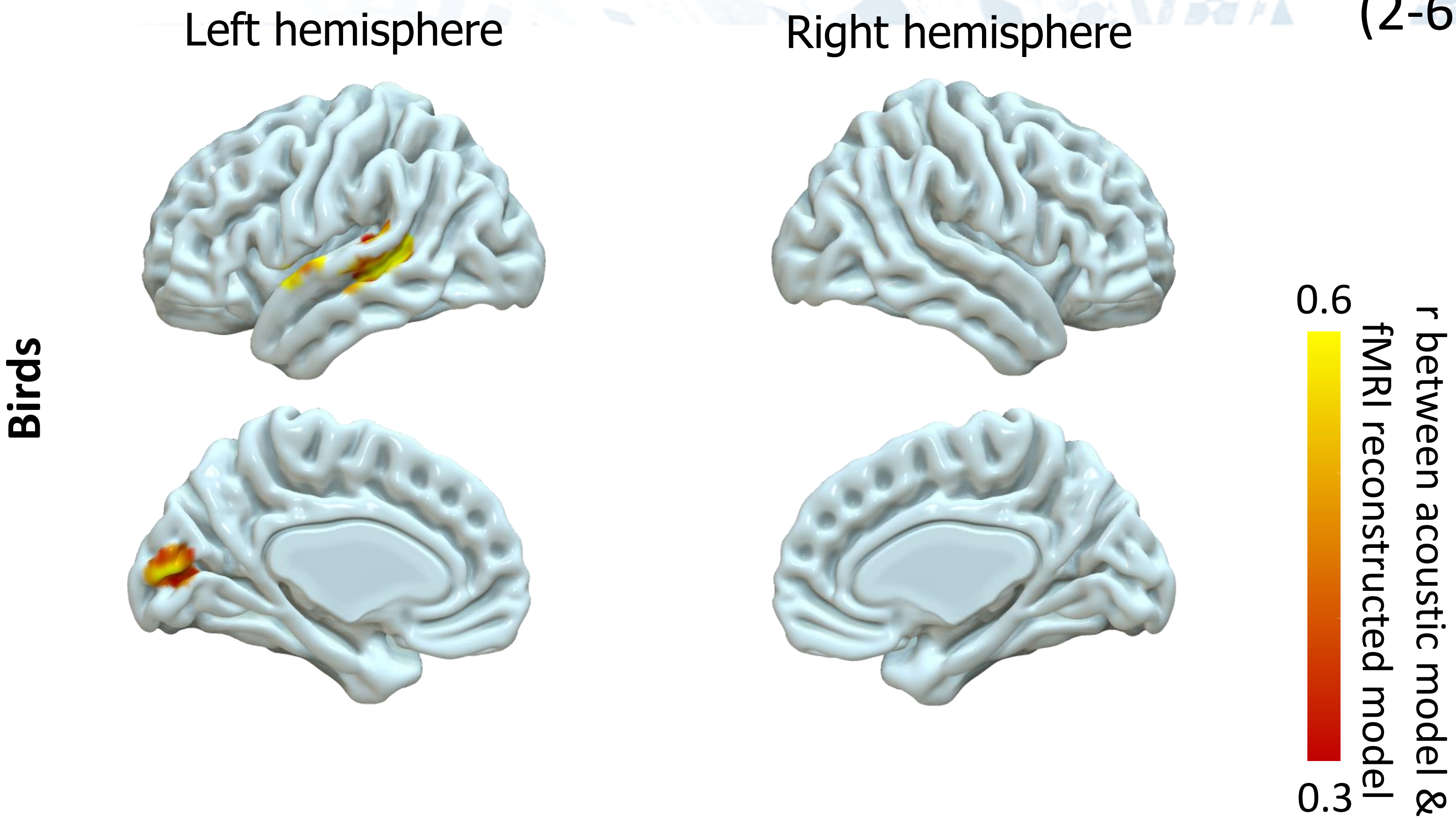
Left hemisphere   Right hemisphere

Birds



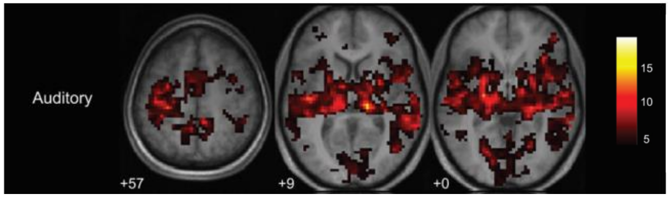
p<0.05, α<0.05 (cluster corr.)

Encoding of envelope power in the *syllabic* range (2-6Hz)



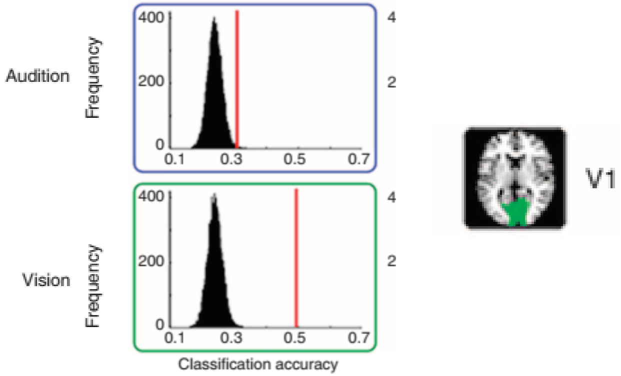
p<0.05, α<0.05 (cluster corr.)

Auditory modulation of early visual cortex activity



Adapted from Martuzzi et al., 2007

The primary visual cortex exhibited robust responsiveness to a noise burst (Martuzzi et al., 2007)



Adapted from Liang et al., 2013

MVPA of fMRI signals revealed that distinguishable spatial patterns of neuronal activities in response to a tone could be predicted not only in the primary auditory cortex, but in V1 as well (Liang et al., 2013)

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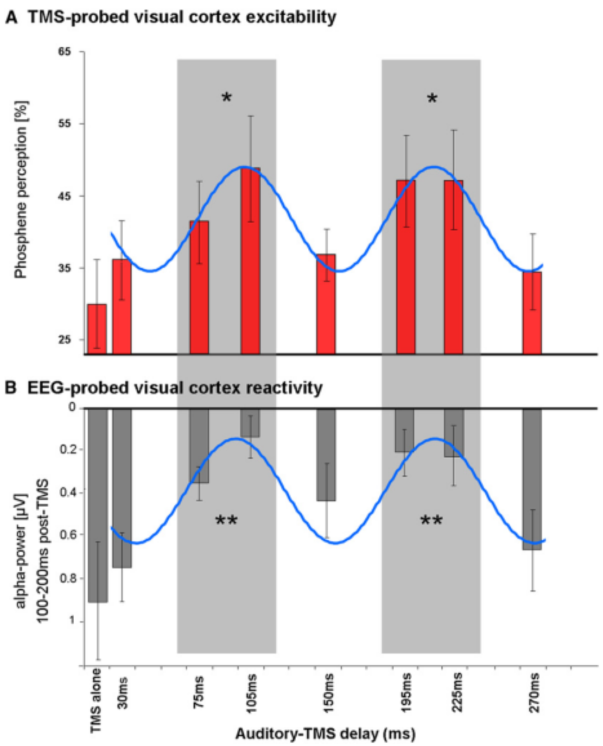
Auditory modulation of early visual cortex activity and consequences on behaviour



Adapted from Romei et al., 2012

In a combined EEG-TMS experiment, it was shown that a sound (pure tone) can phase lock alpha oscillations in human visual cortex, with direct consequences for perception (phosphene measure; Romei et al., 2012).

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Which sound properties are mapped in V1?

Responses to artificial sounds do not allow to exploit the richness of the population encoding properties.

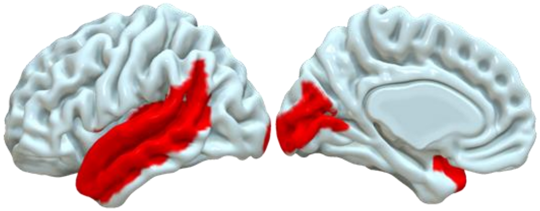
Natural sounds and vocalizations are characterized by profiles of high power at slow temporal amplitude modulations. The statistical structure of natural sounds, such as their characteristic intensity fluctuations, matches the neural coding selectivity of the auditory system (Hsu et al., 2004; Riecke, 1995).

We modelled the envelope power of natural sounds, starting from vocalizations, and specifically assessed whether this hallmark of neural representation of sounds is mapped in V1.

Methods

- 3T fMRI, TR= 2, 2x2x3 voxel size
- N = 20 sighted blindfolded participants (mean age 34.5y)
- Participants were asked to detect a rare deviant sound having 200 ms gap

- Global Signal Regression procedure (Aguirre, 1998; Macey et al., 2004)
- Searchlight approach (8 mm radius) in a large patch of cortex comprising the Lateral Sulcus, Superior Temporal Sulcus (AICHA atlas) and Calcarine Sulcus (probabilistic map by Wang et al., 2015) in the left and right hemispheres separately
- a Voxel-wise decoding on based on Principal Component Regression (PC) Analysis (Thirion et al., 2017) was employed. PC scores extracted from the fMRI data represented the independent variable and the power of Low (e.g., 2-6Hz) and High (e.g., 6-10Hz) modulation frequencies the dependent one
- Statistical analyses were performed by a cross-validation procedure (within subject) and by using a permutation tests (1000 iterations), results were FDR corrected (Benjamini and Yekutieli, 2001).



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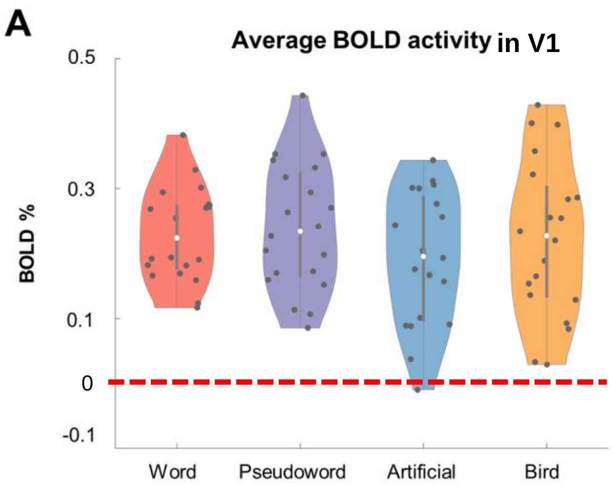
Sanity Check



A positive hemodynamic response for each sound categories was found in striate cortex (i.e., no deactivation)

- Continuous speech engages visual cortex in blind individuals (MEG, *Van Ackeren et al, 2017*).

-> **Data collection** from blind participants was not feasible due to the COVID19 pandemic! We changed perspectives:

- Visual cortex activation is associated to speech envelope even in **sighted blindfolded participants** (fMRI*: see Martinelli et al., 2020* - preprint from our group).

- Here we can use sighted blindfolded individuals as a model to investigate speech envelope tracking when visual input is lacking

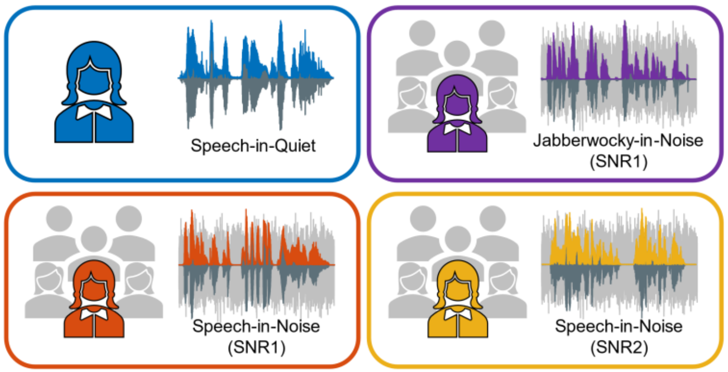
Aim: Investigate cortical entrainment to speech envelope in sighted blindfolded individuals

EEG recording: sighted blindfolded participants (N = 15; right-handed; IMT students);
64-channel EGI HydroCel GSN SensorNet; sampling rate 500Hz; reference electrode – Cz

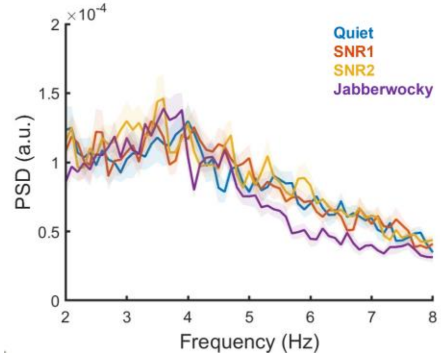
Stimuli: continuous stories (15 min per condition, divided in 5 min chunks) from an audiobook for children (‘*Polissena del Porcello*’, Italian); background if present 5-talker babble noise (Italian)

Behavioural responses: 3 very specific Yes/No questions for each part of a story; Intelligibility rating: 1-7 (completely unintelligible/very intelligible)

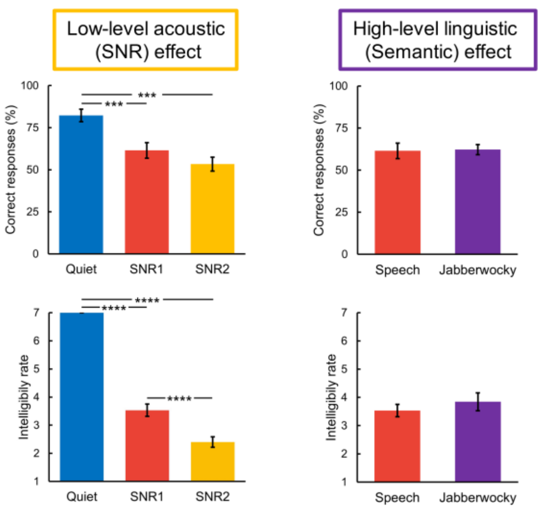
Stimuli



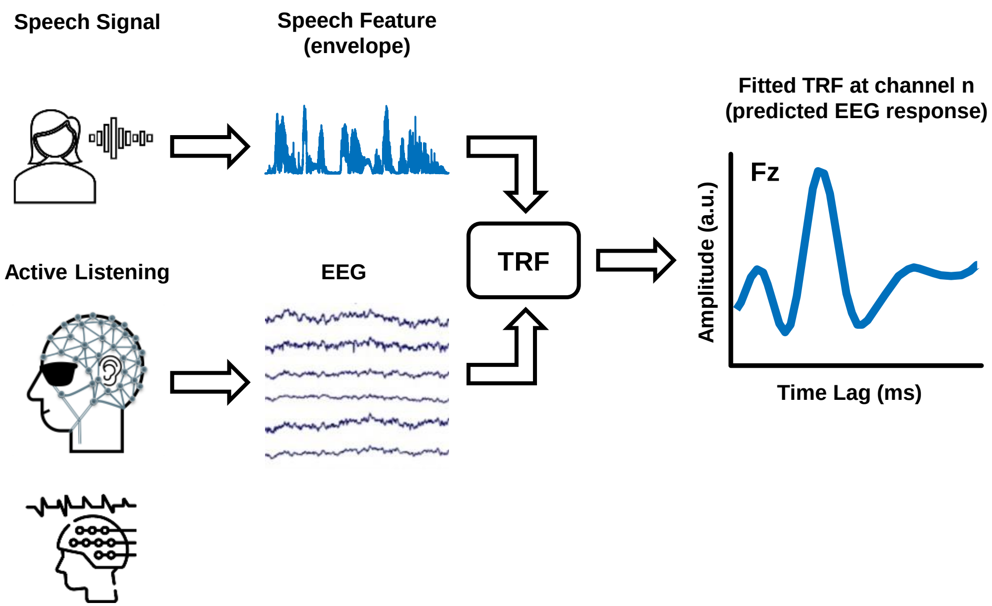
Stimuli PSD



Behavioral Responses



Analysis Approach



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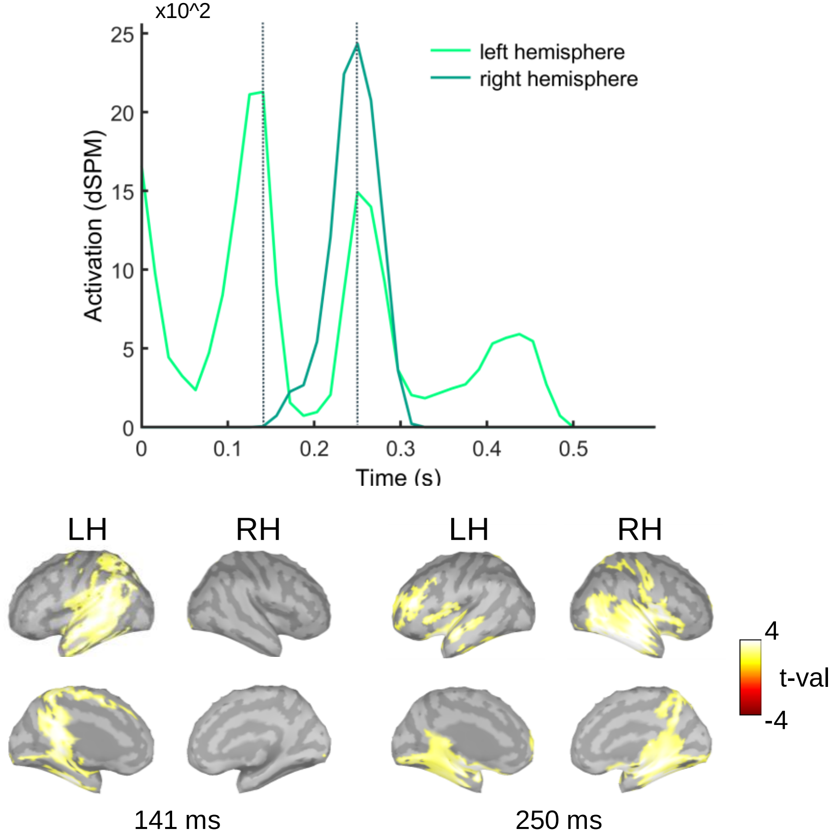
Low-level acoustic (SNR) effect

Temporal profile of significant clusters



High-level linguistic (Semantic) effect

Temporal profile of significant clusters