Cortical Processing of Arithmetic and Simple Sentences, in an Auditory Attention Task

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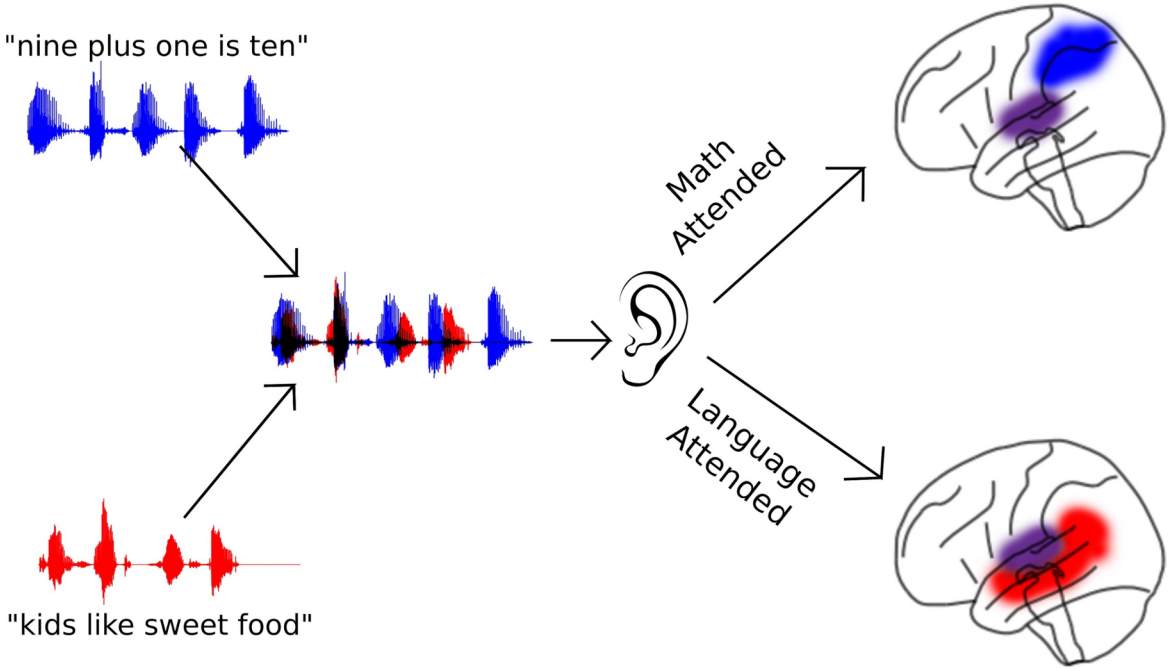
Computational Sensorimotor Systems Lab

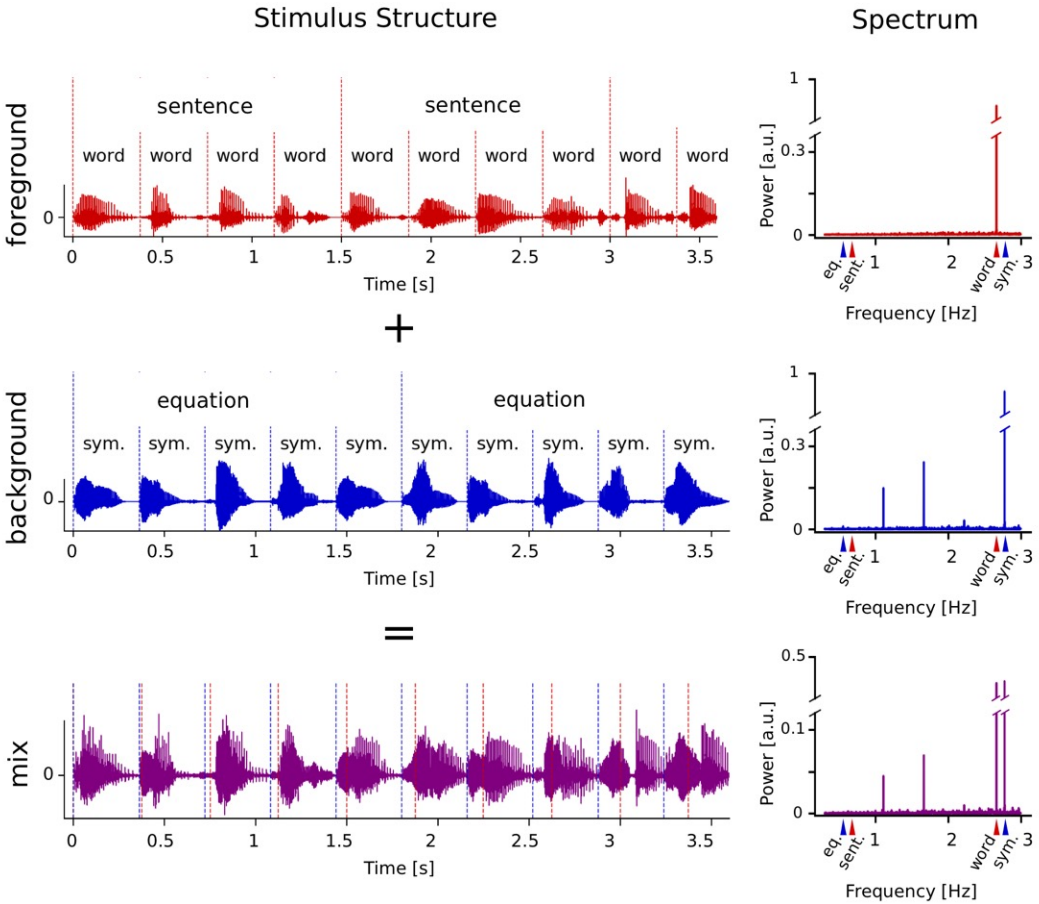
- What are the cortical areas and dynamics involved in neural processing of spoken arithmetic and language?
- What is the impact of selective attention?

Investigate MEG responses of 22 young subjects in a cocktail party paradigm



Methods: Stimuli

- Synthesized male and female speakers.
- Isochronous speech paradigm (Ding et. al. 2016)
- Language stimuli:
  - 4 word sentences.
  - Word rate **2.67 Hz**
  - Sentence rate **0.67 Hz**
- Arithmetic stimuli:
  - 5 symbol equations.
  - Symbol rate **2.78 Hz**
  - Equation rate **0.56 Hz**



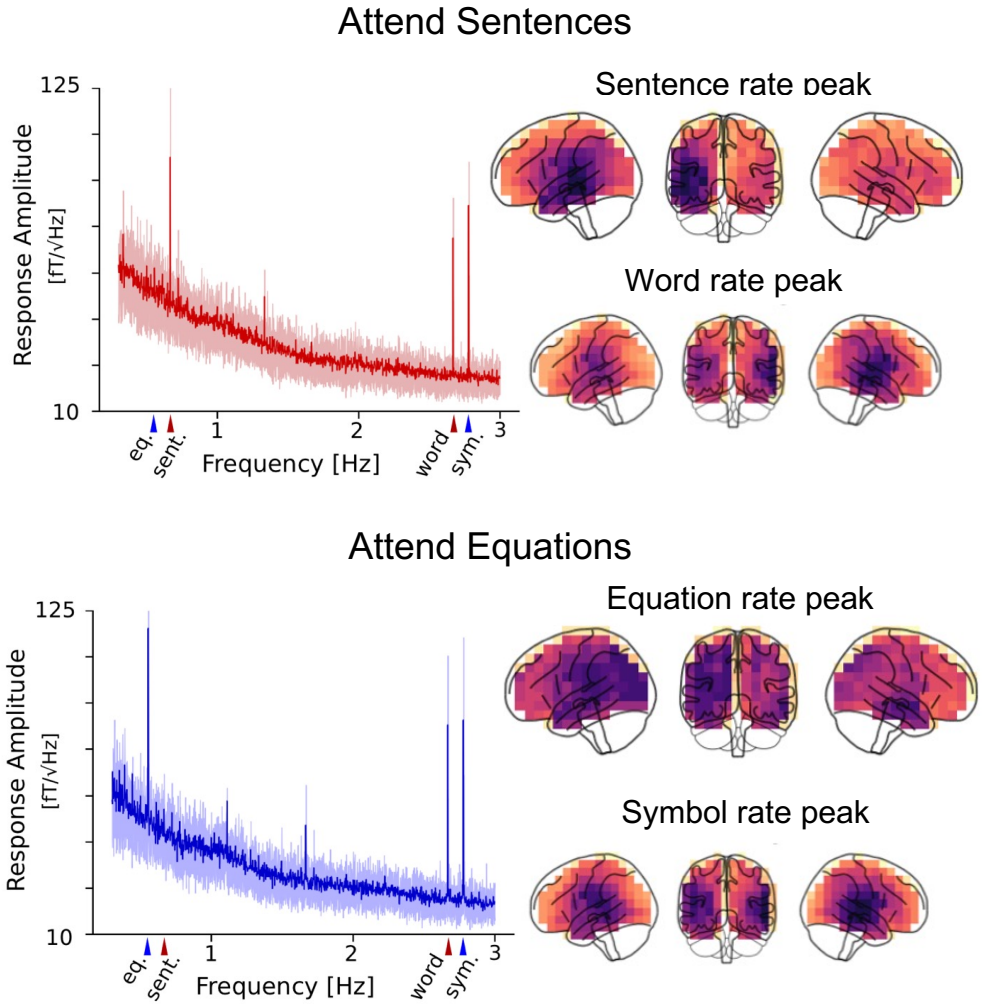
Neural Frequency Spectra

Acoustic Rate Peaks
- For both attended and unattended speech
- Bilateral auditory areas

Sentence Rate Peak (0.67 Hz)
- Only for attended speech
- Left temporal areas linked to language

Equation Rate Peak (0.56 Hz)
- Only for attended speech
- Parietal and occipital areas linked to arithmetic

Distinct networks for higher-level sentence and equation processing



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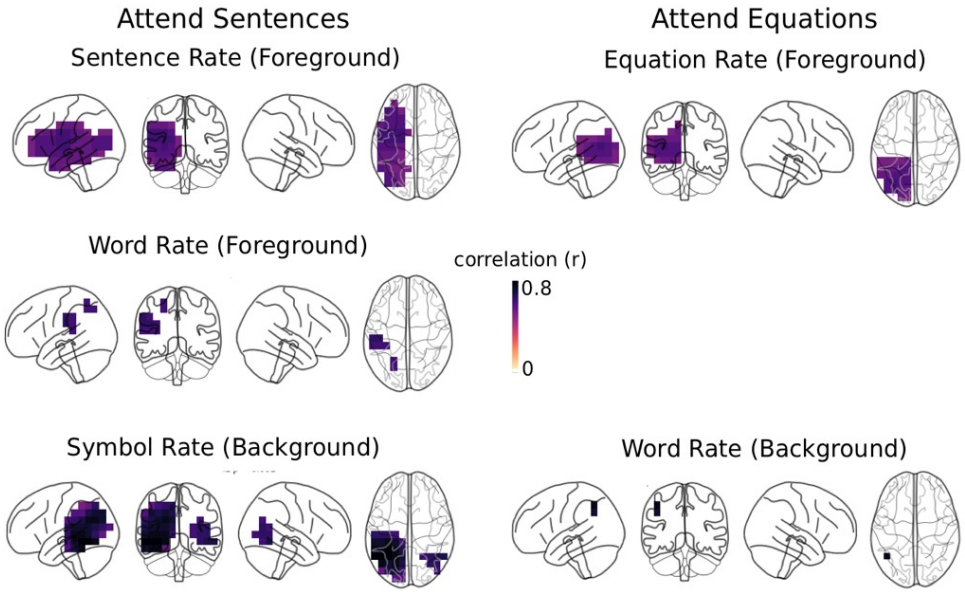
Behavior Correlates with Neural Responses

Behavior: deviant detection task

- Mathematically incorrect equations (‘one plus one is ten’)
- Semantically meaningless sentences (‘big boats eat cake’)

Attended sentence and equation rate peaks are correlated with behavioral accuracy

These neural responses may be linked to comprehension or correct calculations



Dynamics of Cortical Processing: Temporal Response Functions (TRFs)

Temporal Response Functions (TRFs)

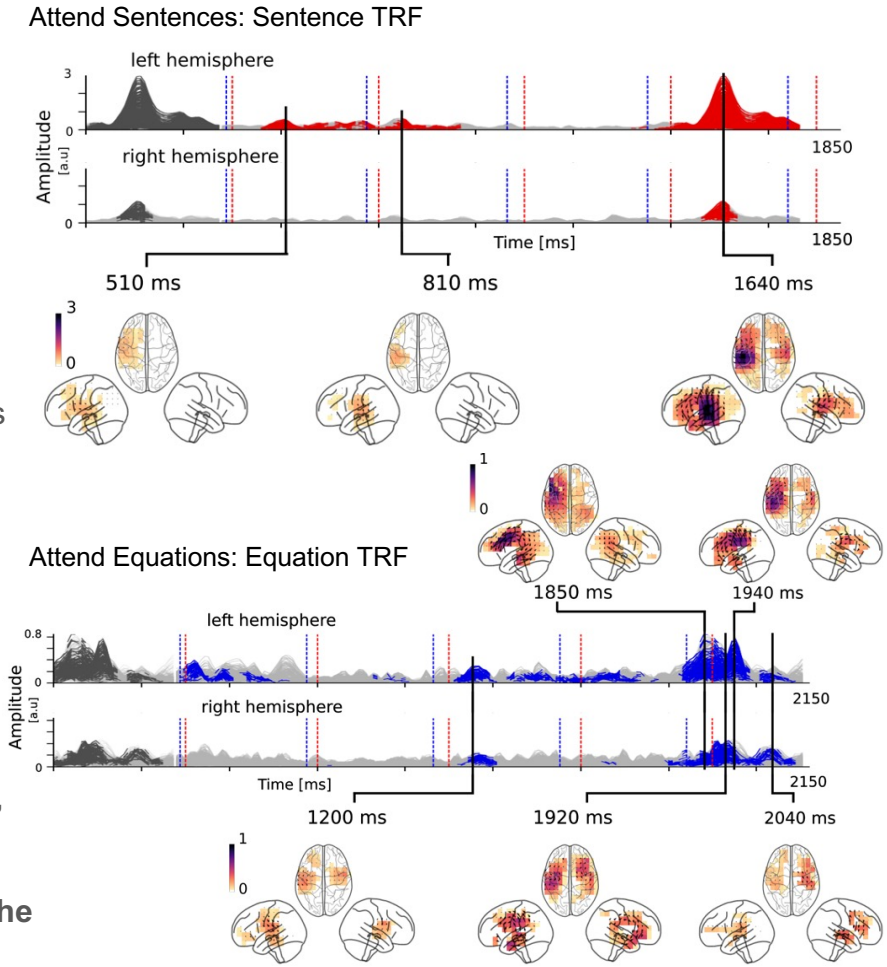
$$response = TRF * predictor + noise$$

- Linear model that estimates the impulse response of the neural system to continuous stimuli
- TRFs for:
  - speech envelopes
  - word and symbol onsets
  - sentence and equation onsets
- Regress out low-level processing

Sentence TRF peak: left temporal areas

Equation TRF peaks: bilateral temporal, parietal, motor areas

Selective attention and TRF analysis reveal the dynamics of the underlying networks



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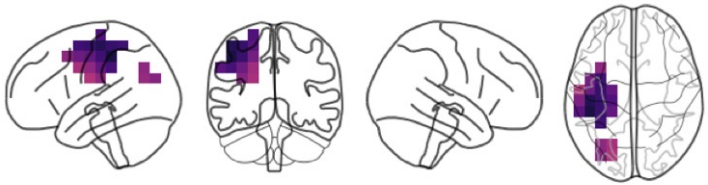
Decoder Analysis

Decoding based on the dynamics at each cortical voxel

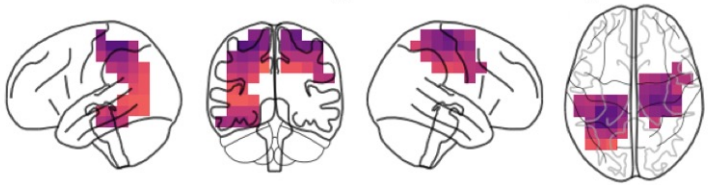
Attention to math vs. language could be reliably decoded

Attend-language and attend-math during cocktail party could be reliably decoded.

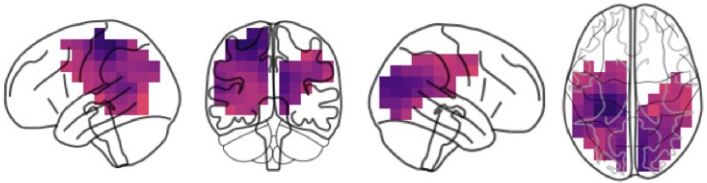
Math vs. Language



Sentences Foreground vs. Background



Equations Foreground vs. Background



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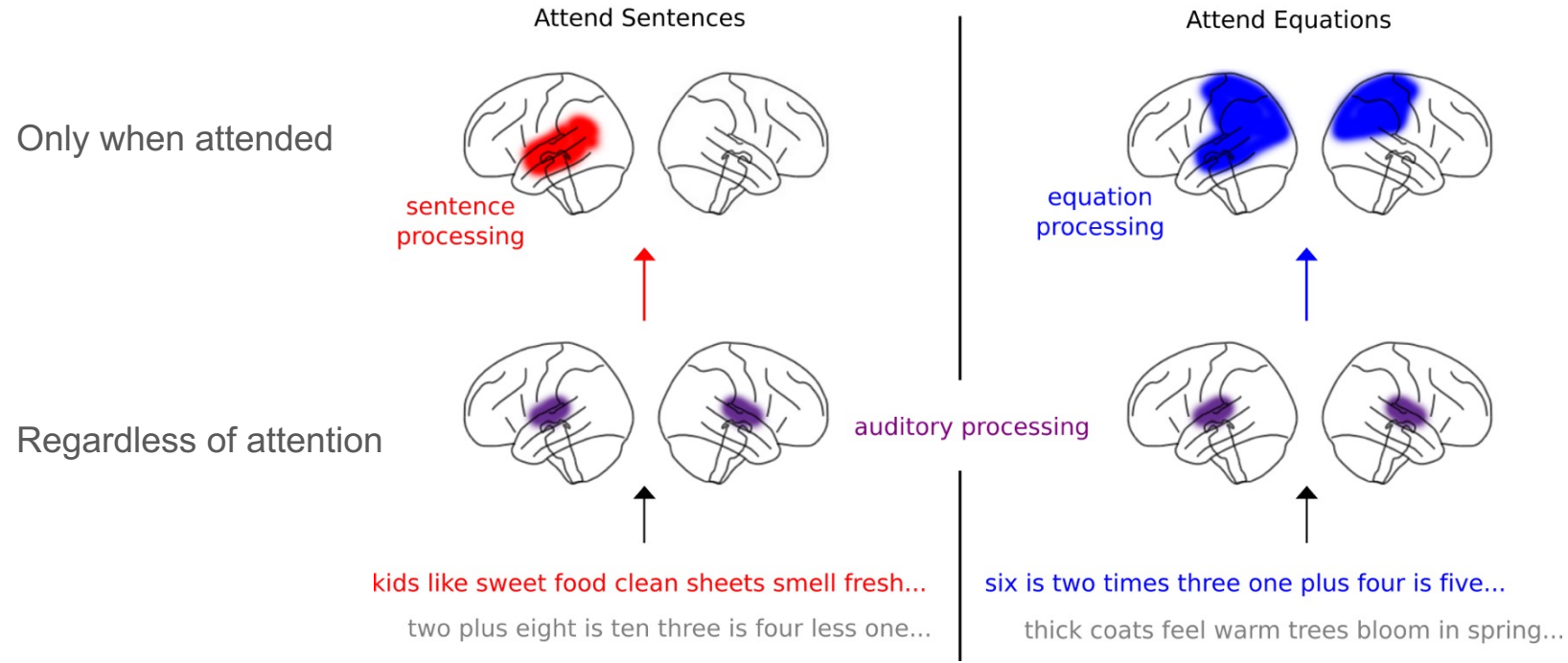
Summary



Underlying networks are well segregated during the cocktail party task

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Thank You

This work has been recently published:

Kulasingham, J.P., Joshi, N.H., Rezaeizadeh, M., Simon, J.Z., 2021. Cortical Processing of Arithmetic and Simple Sentences in an Auditory Attention Task. J. Neurosci. 41, 8023–8039. https://doi.org/10.1523/JNEUROSCI.0269-21.2021

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