

Linguistic speech tracking by the brain



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TEST BATTERY



Pure tone audiometry

- » raise your hand whenever you hear a tone

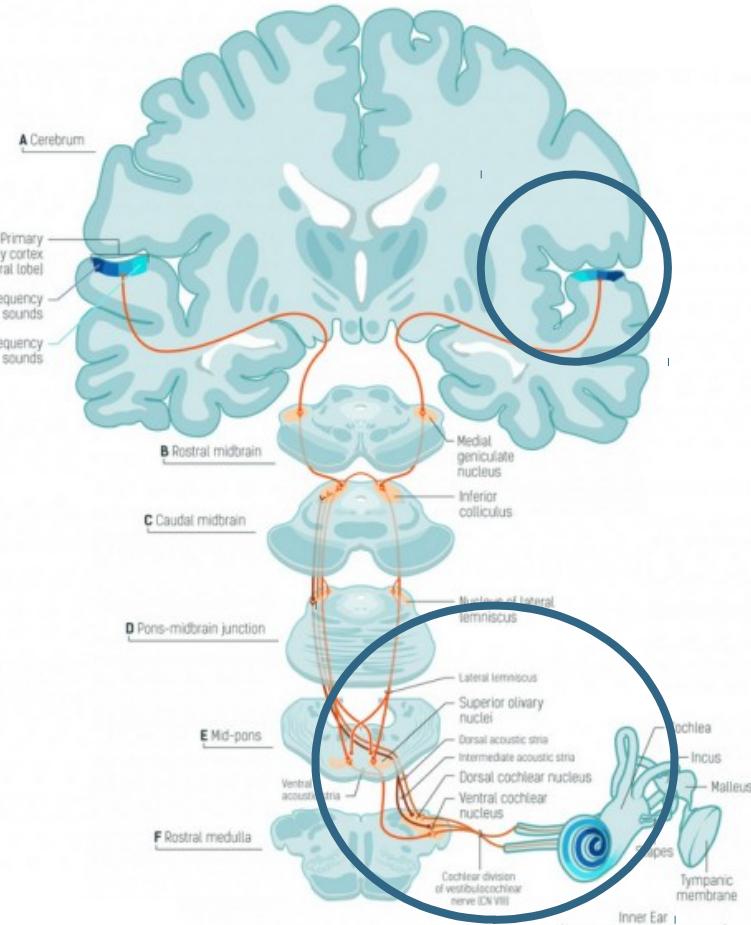
Sentence recall tasks

- » recall the sentence you heard which is embedded in noise

...

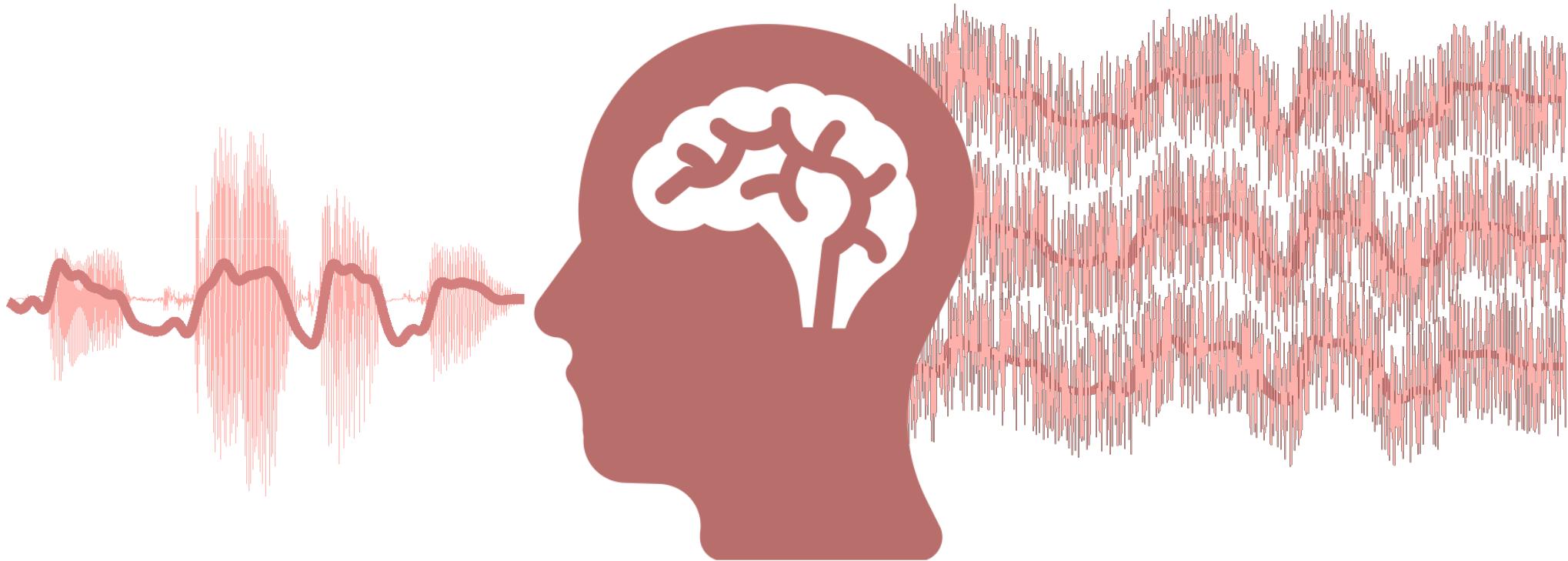
**BUT THESE TONES AND STAND-ALONE SENTENCES
ARE NOTHING LIKE
“REAL” LISTENING ENVIRONMENTS**

WHAT IS CAUSING THE SPEECH UNDERSTANDING DEFICIT?



WHAT IF THE PATIENT CANNOT DO THE TASKS?

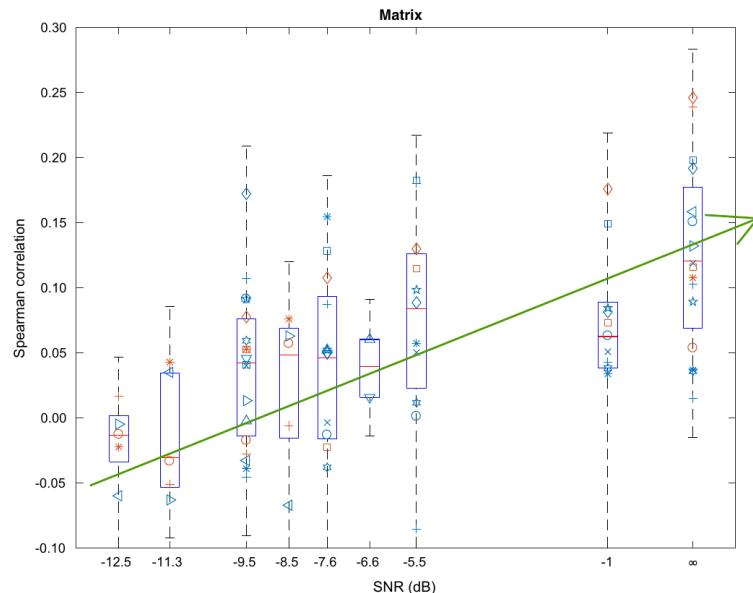
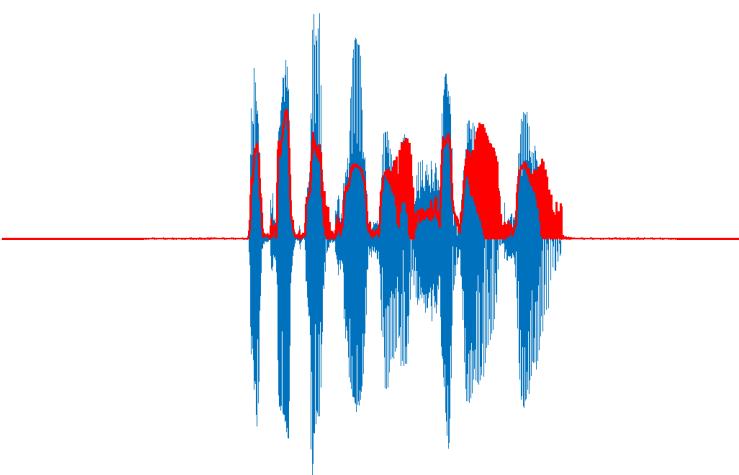




What is known?

Speech Intelligibility Predicted from Neural Entrainment of the Speech Envelope

JONAS VANTHORNHOUT,¹  LIEN DECRUY,¹ JAN WOUTERS,¹ JONATHAN Z. SIMON,^{2,3,4} AND TOM FRANCART¹

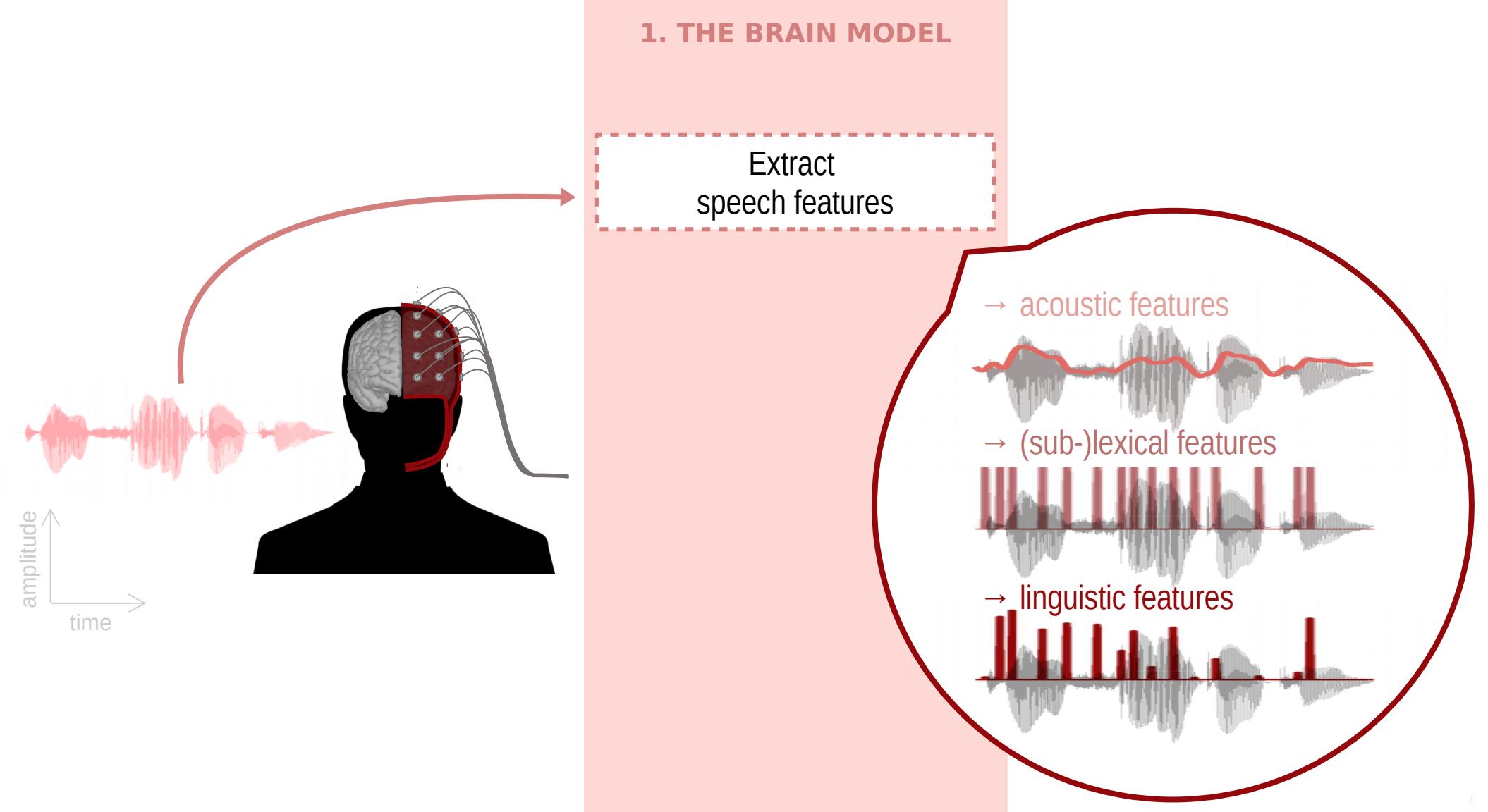


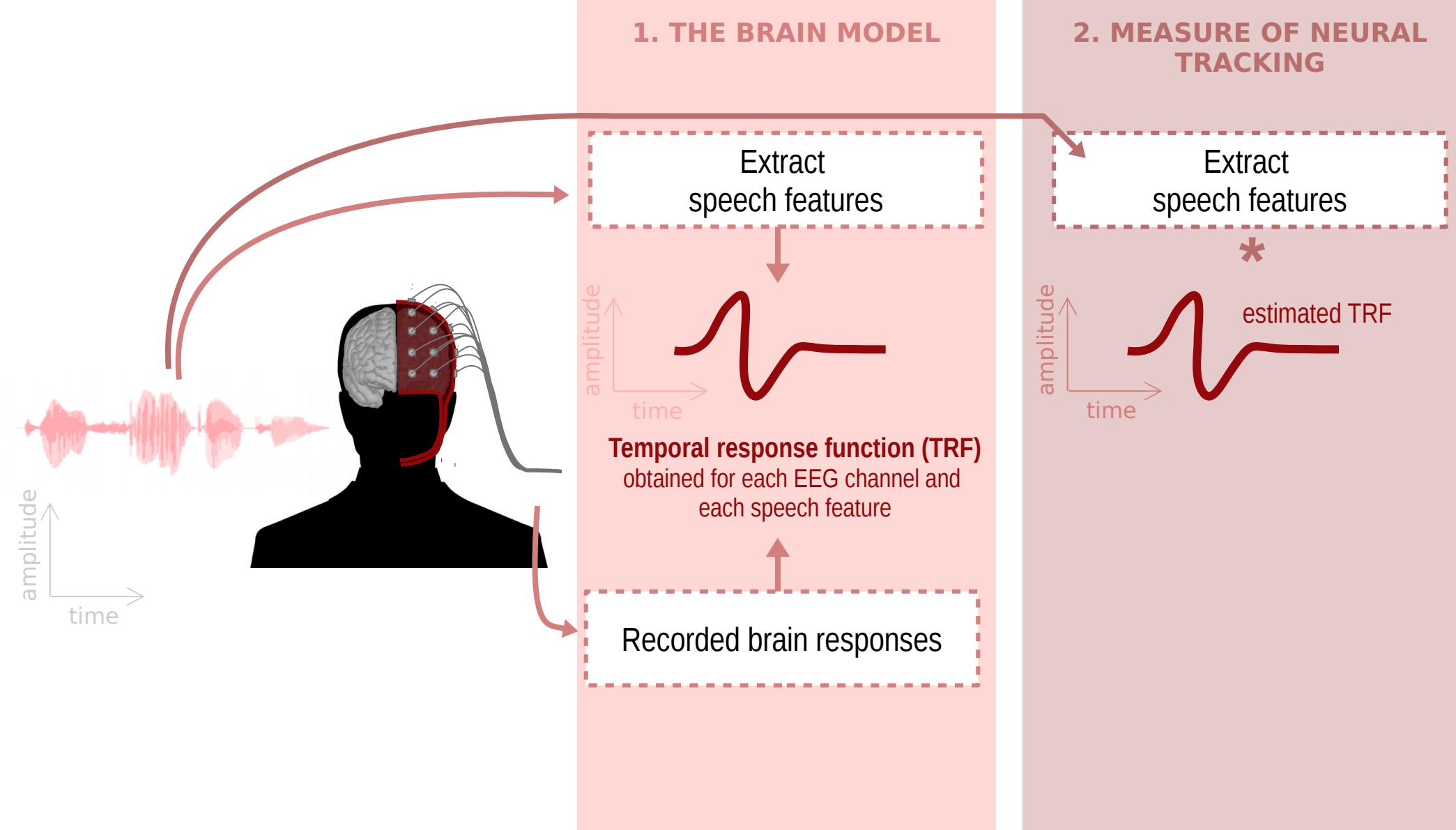
Increased neural tracking ~ increased speech understanding?

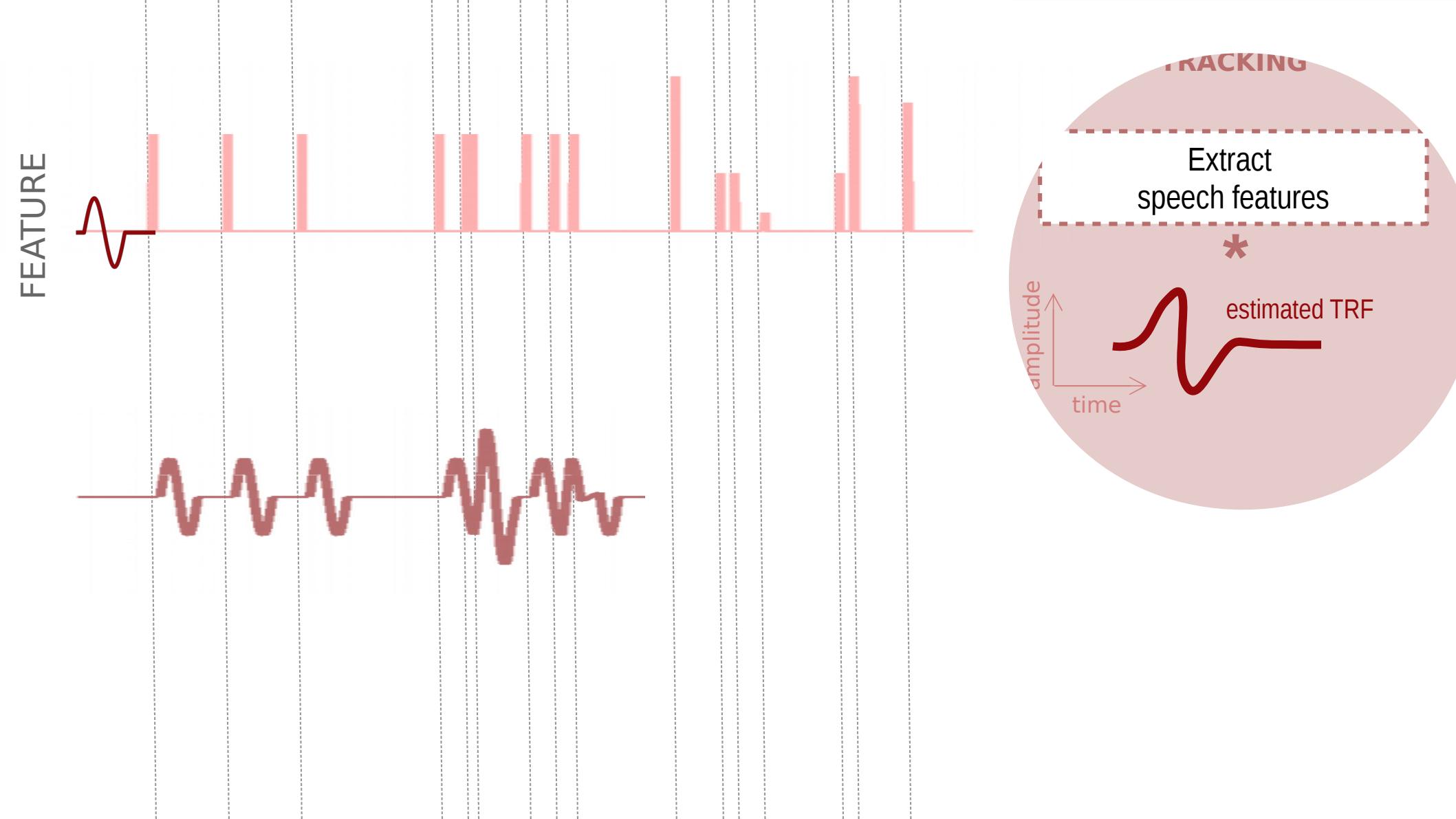
NOT PERSE

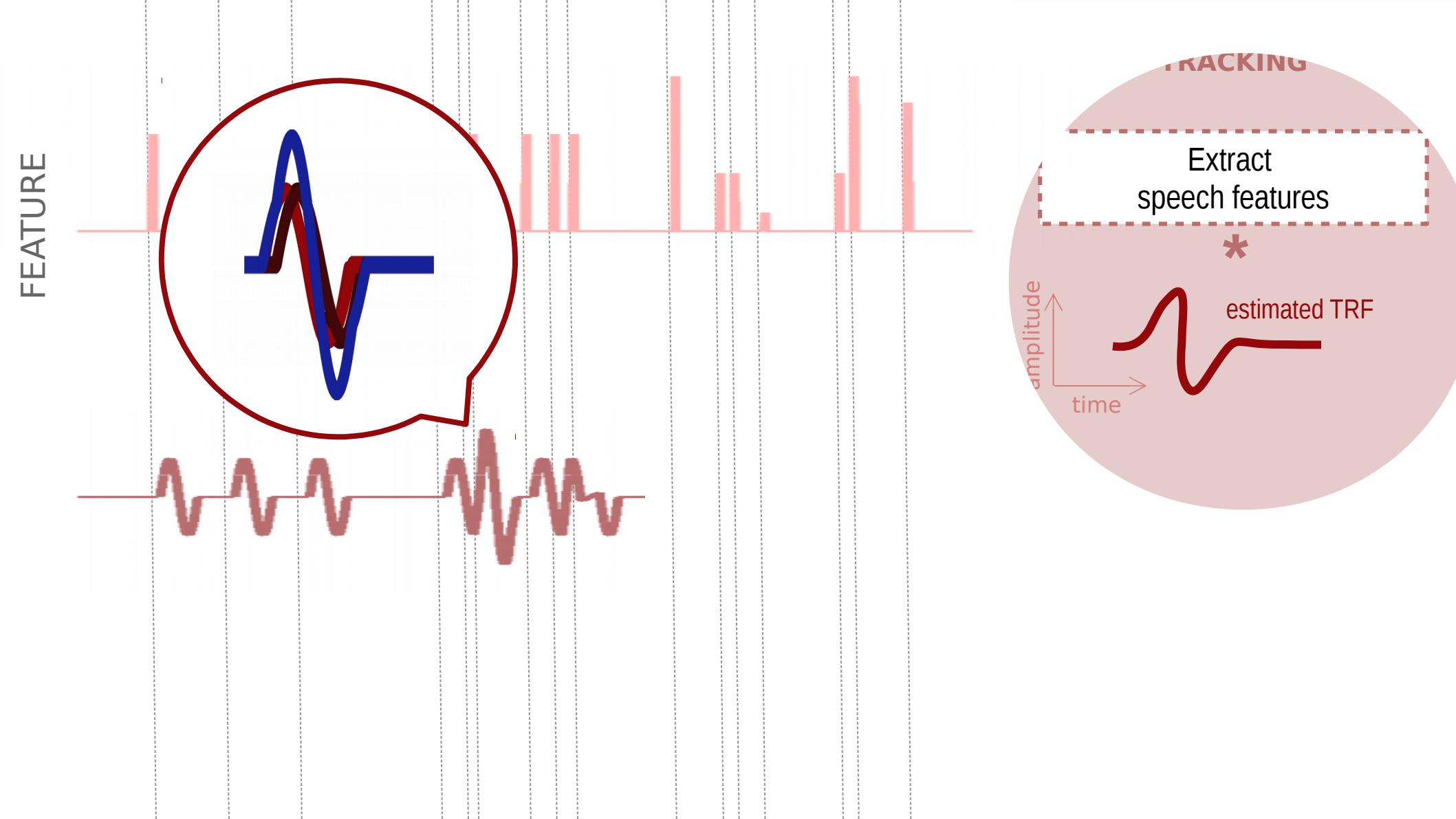
Neural tracking is also observed to music

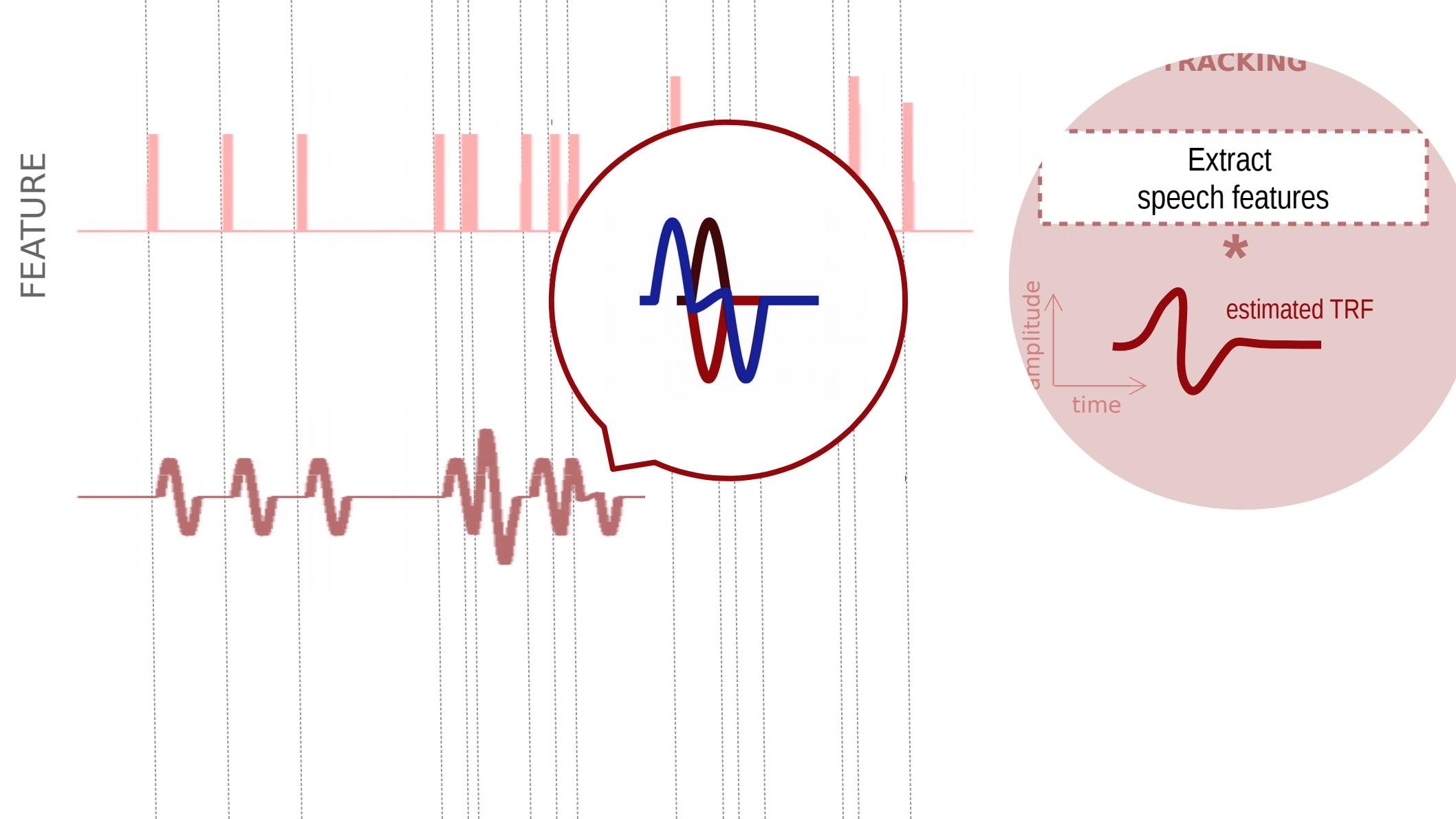
Neural tracking is also observed to the ignored talker
in a cocktail paradigm



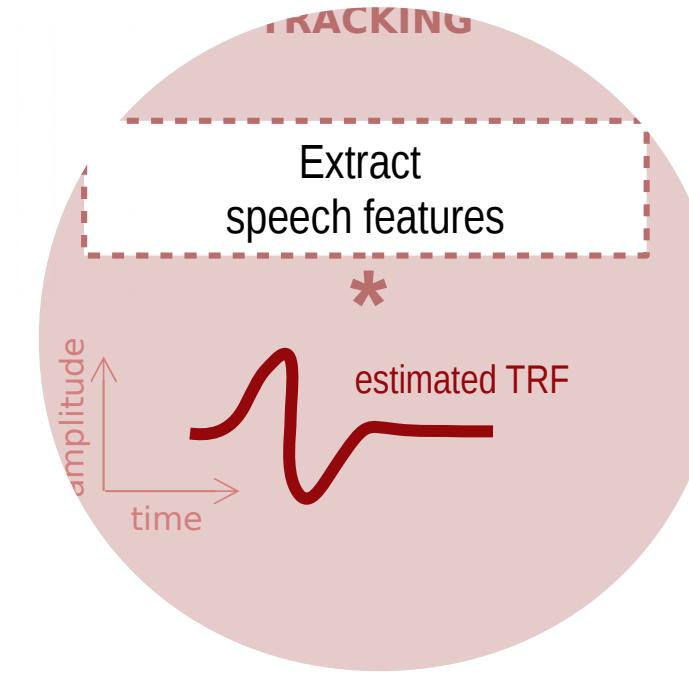
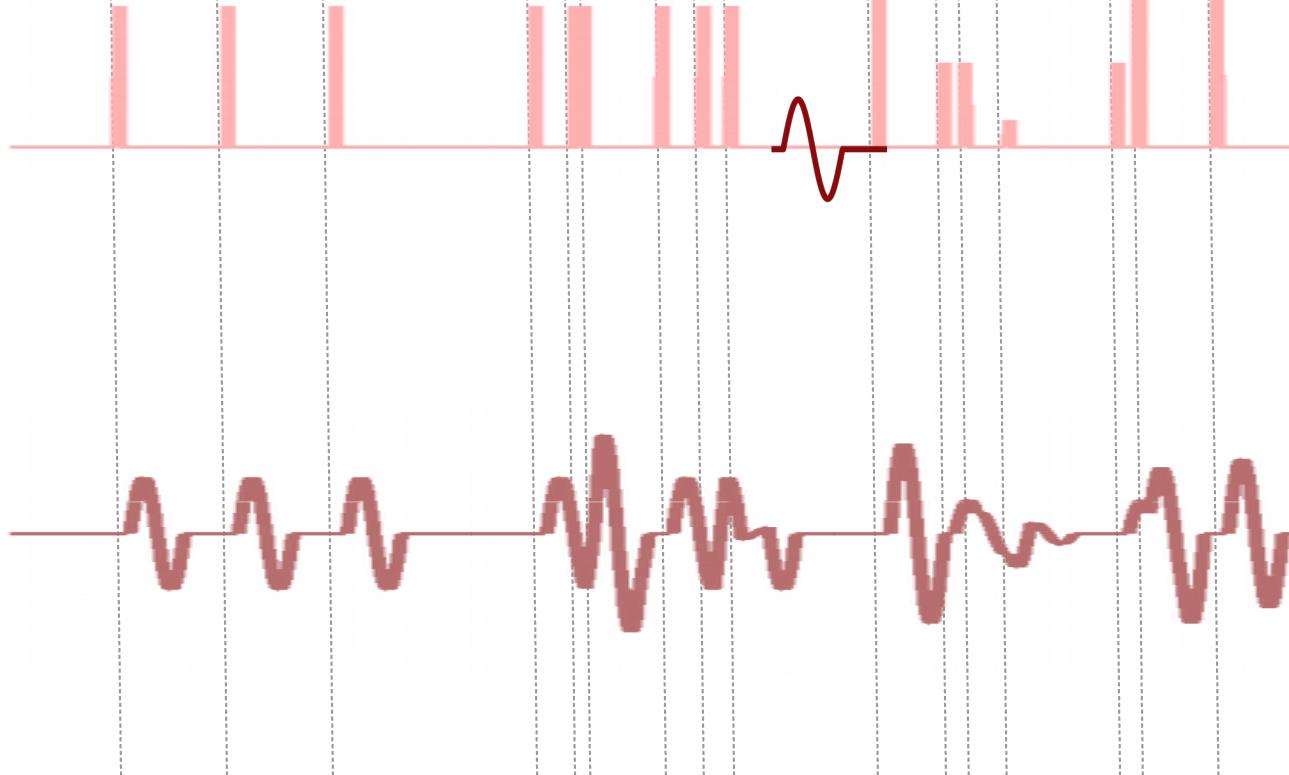


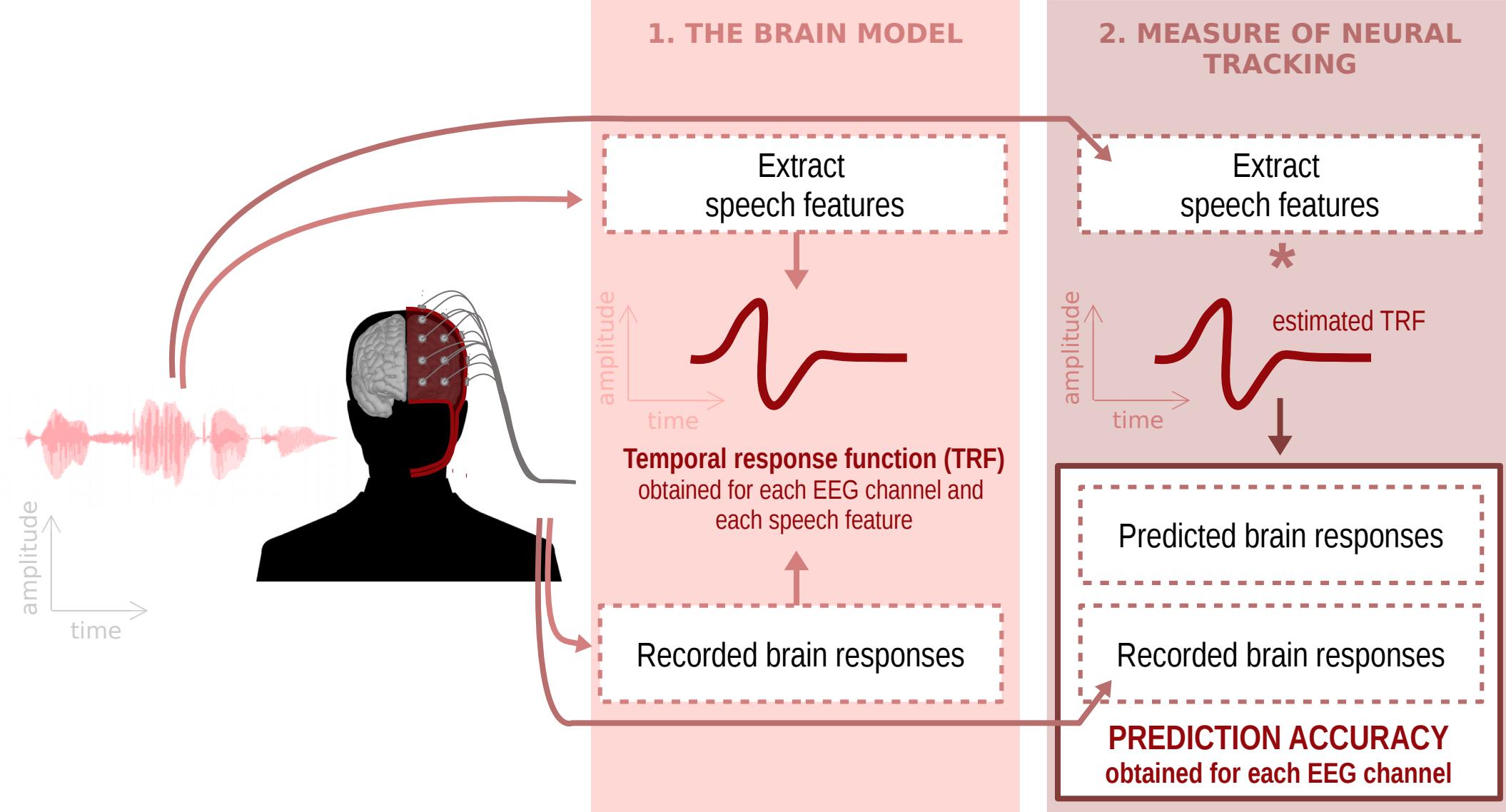




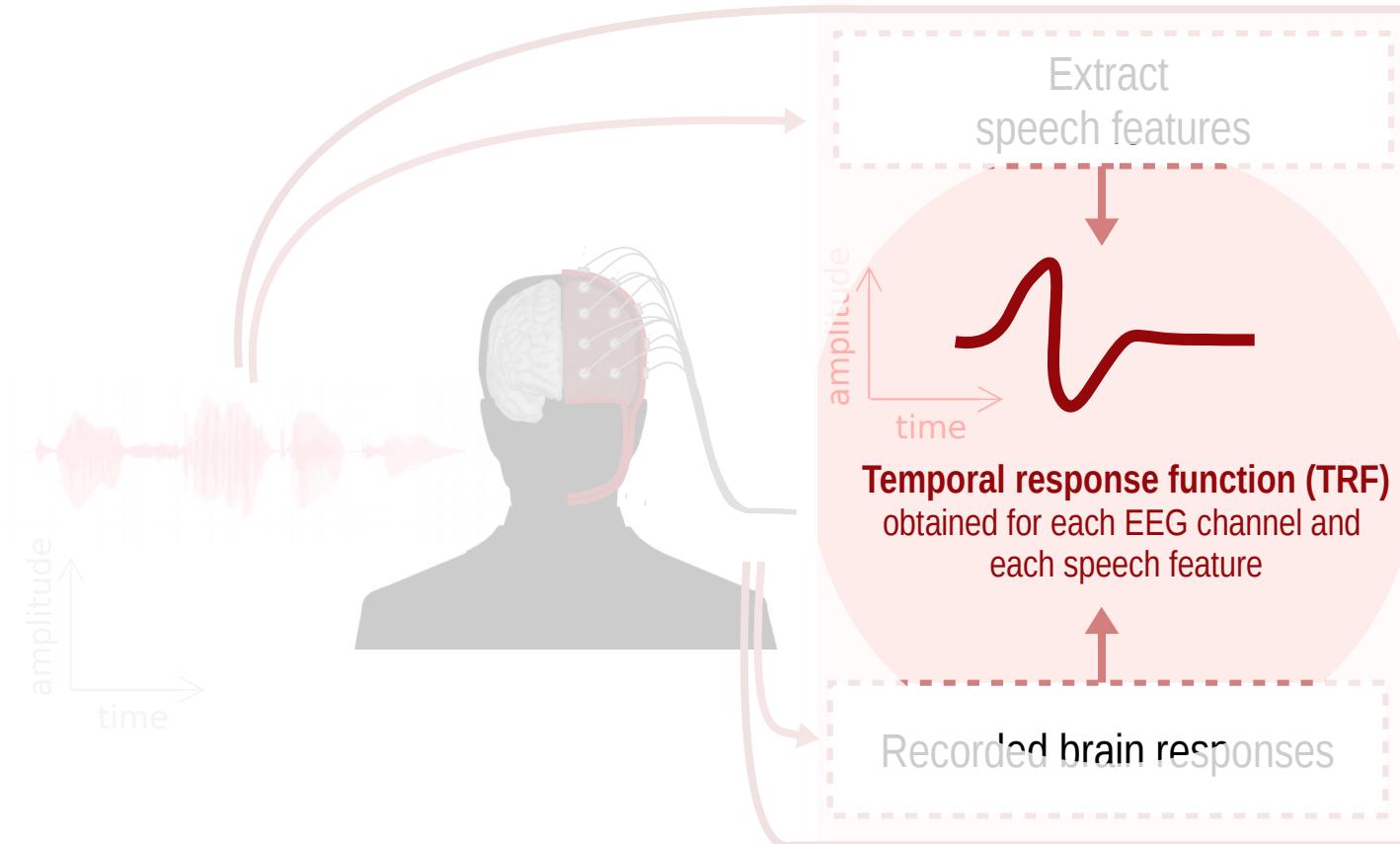


FEATURE

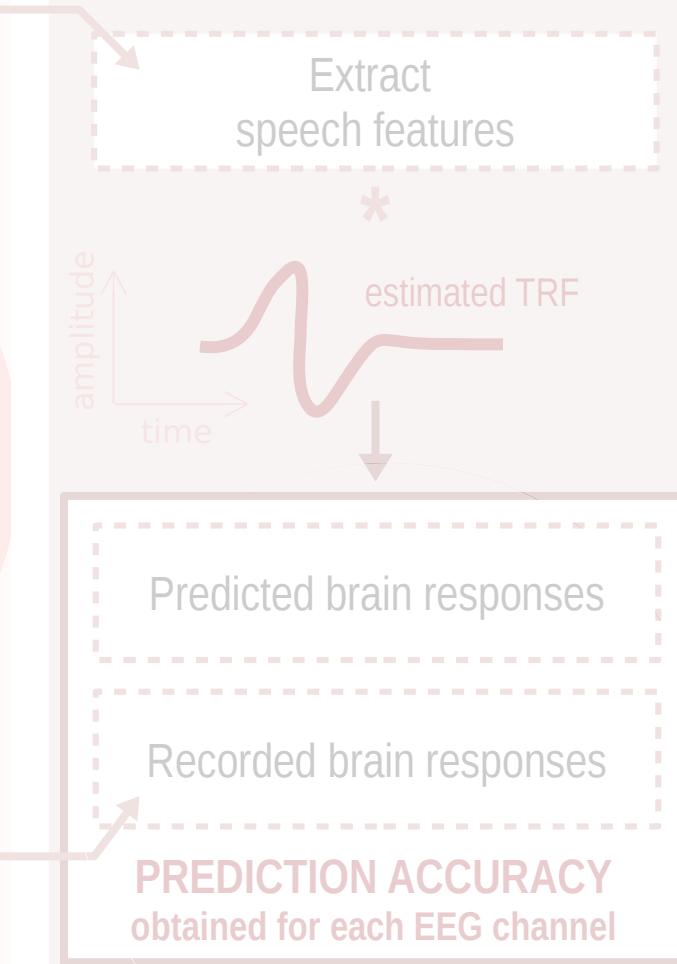




1. THE BRAIN MODEL



2. MEASURE OF NEURAL TRACKING



1. Which speech features model neural linguistic processing?

2. Do these features really reflect speech understanding?

3. Do these features really reflect speech understanding?

Methods



29 young, normal-hearing participants



45-minute story, presented in silence



Gillis, M., Vanthornhout, J., Simon, J. Z., Francart, T., & Brodbeck, C. (2021). Neural markers of speech comprehension: measuring EEG tracking of linguistic speech representations, controlling the speech acoustics. *Journal of Neuroscience*, 41(50), 10316-10329.

Which speech features?

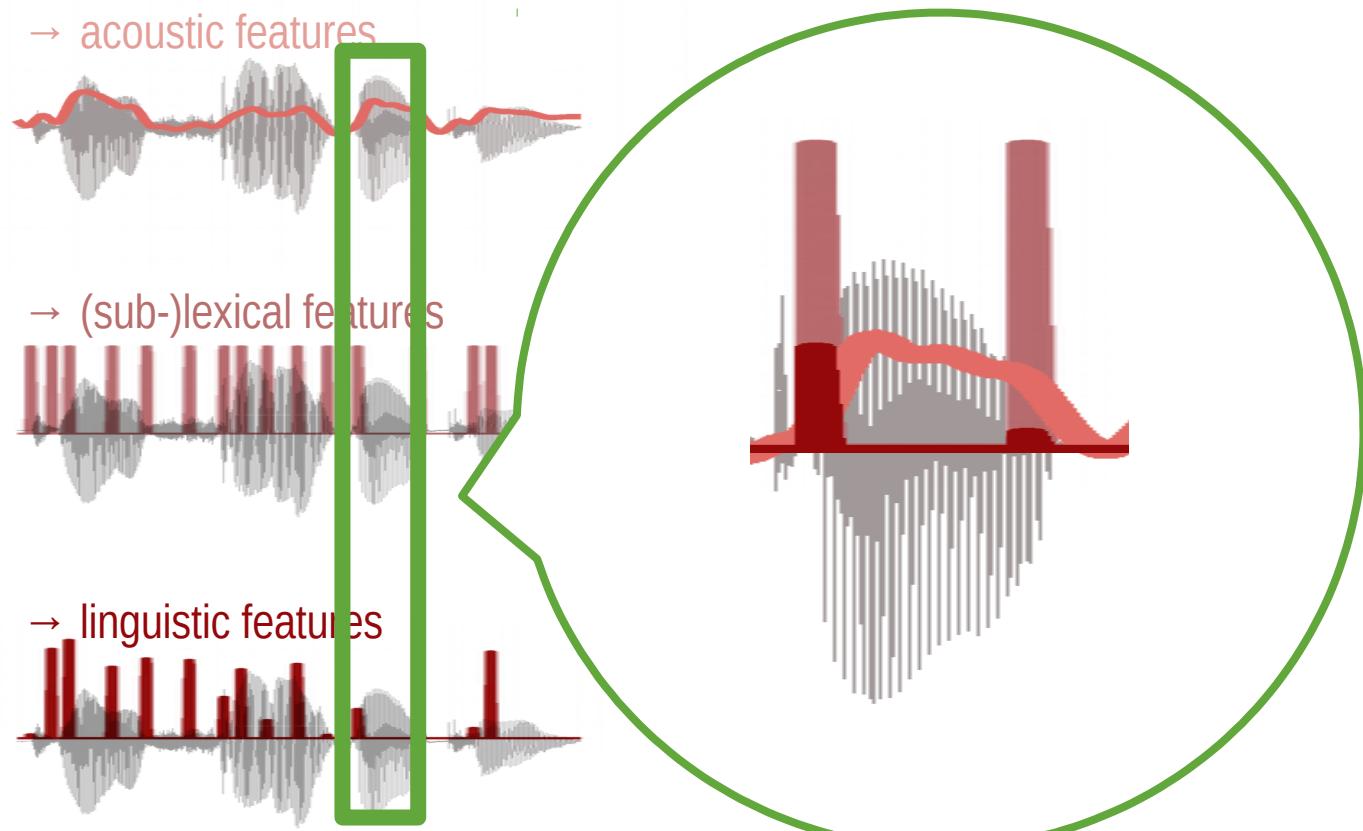
Acoustical & (sub-)lexical features	Linguistic features at <i>phoneme</i> level	Linguistic features at <i>word</i> level	Linguistic features at <i>contextual</i> level
Spectrogram Acoustic onsets Phoneme onsets Word onsets Function word onsets Content word onsets	Phoneme surprisal ^[1] Cohort entropy ^[1]	Word surprisal ^[2] Word entropy Word precision ^[2] Word frequency ^[2]	Semantic Dissimilarity ^[3]

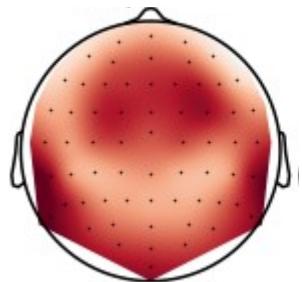
[1] Brodbeck et al. (2018). Rapid transformation from auditory to linguistic representations of continuous speech

[2] Weissbart et al. (2020). Cortical tracking of surprisal during continuous speech comprehension

[3] Broderick et al. (2018). Electrophysiological correlates of semantic dissimilarity reflect the comprehension of natural, narrative speech

1. Which speech features model neural linguistic processing?



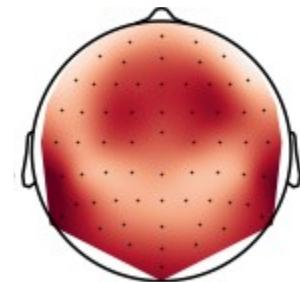


"complete model"

Acoustic features
(Sub-)Lexical features
Linguistic features



Prediction accuracy
[Pearson's r]



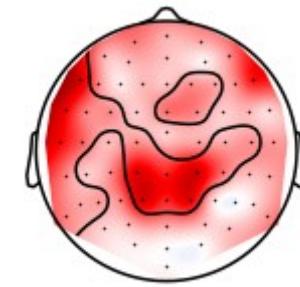
"baseline model"

Acoustic features
(Sub-)Lexical features
Linguistic features



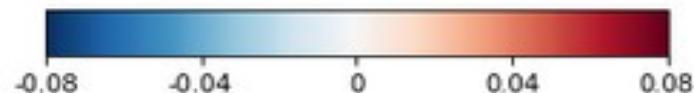
Difference in prediction accuracy [Pearson's r]

Neural tracking of linguistic features



difference in prediction accuracy

Acoustic features X
(Sub-)Lexical features X
Linguistic features V



Which speech features?

Acoustical & (sub-)lexical features	Linguistic features at <i>phoneme</i> level	Linguistic features at <i>word</i> level	Linguistic features at <i>contextual</i> level
Spectrogram Acoustic onsets Phoneme onsets Word onsets Function word onsets Content word onsets	Phoneme surprisal ^[1] Cohort entropy ^[1]	Word surprisal ^[2] Word entropy Word precision ^[2] Word frequency ^[2]	Semantic Dissimilarity ^[3]

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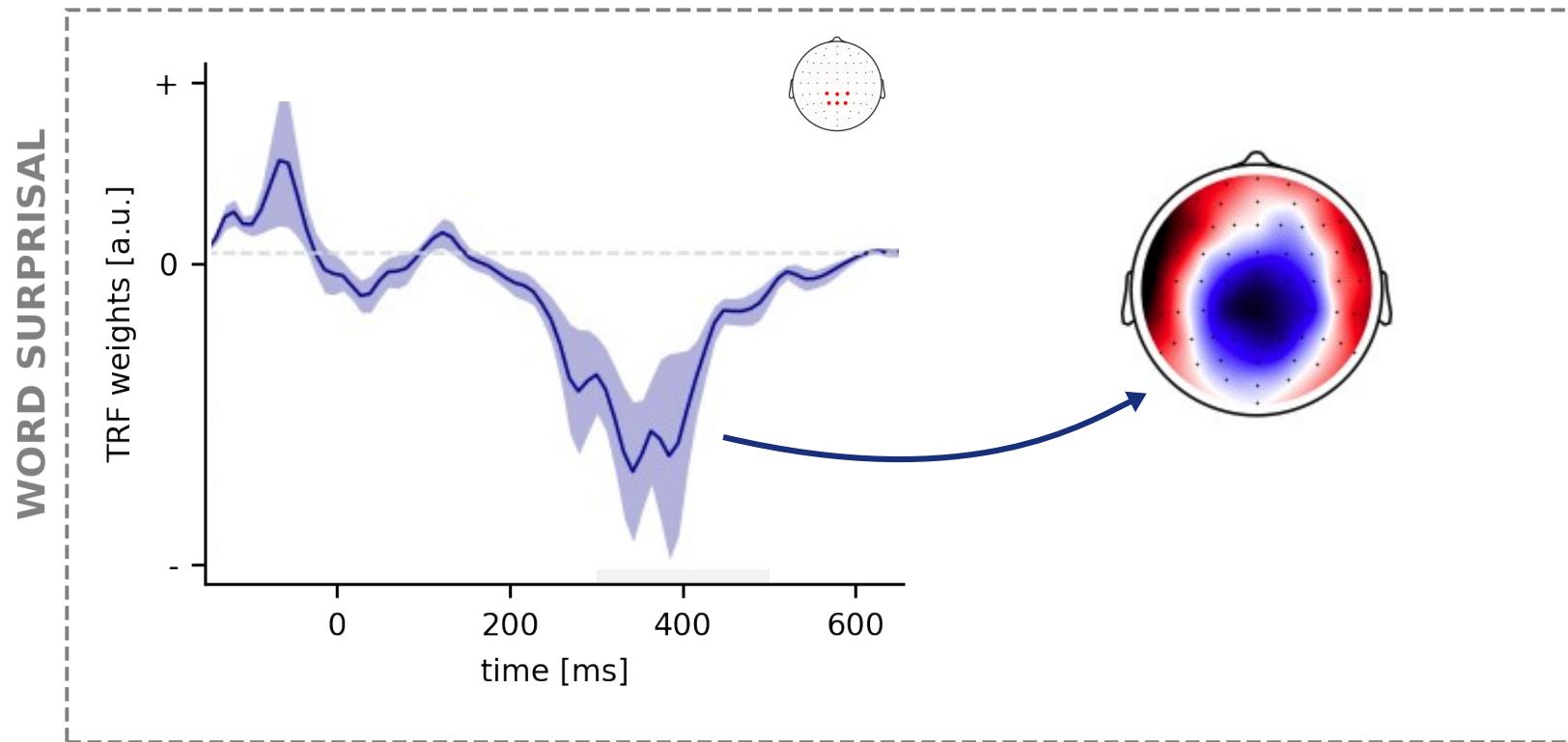
[3] Broderick et al. (2018). Electrophysiological correlates of semantic dissimilarity reflect the comprehension of natural, narrative speech

“But you know, happiness can be found even in the darkest of times, if one only remembers to turn on the ...



— J.K. Rowling, Harry Potter and the Prisoner of Azkaban

How does the brain respond?



Methods



18 young, normal-hearing participants



5-minute speech fragments presented in silence
→ total: 12 speech fragments (~ 1h)

speech fragments changed in speech rate (6 different speech rate)
→ 2 fragments per speech rate



Verschueren, E., Gillis, M., Decruy, L., Vanthornhout, J., & Francart, T. (2022). Speech understanding oppositely affects acoustic and linguistic neural tracking in a speech rate manipulation paradigm. *Journal of Neuroscience*, 42(39), 7442-7453.

Manipulating the level of speech understanding

slow



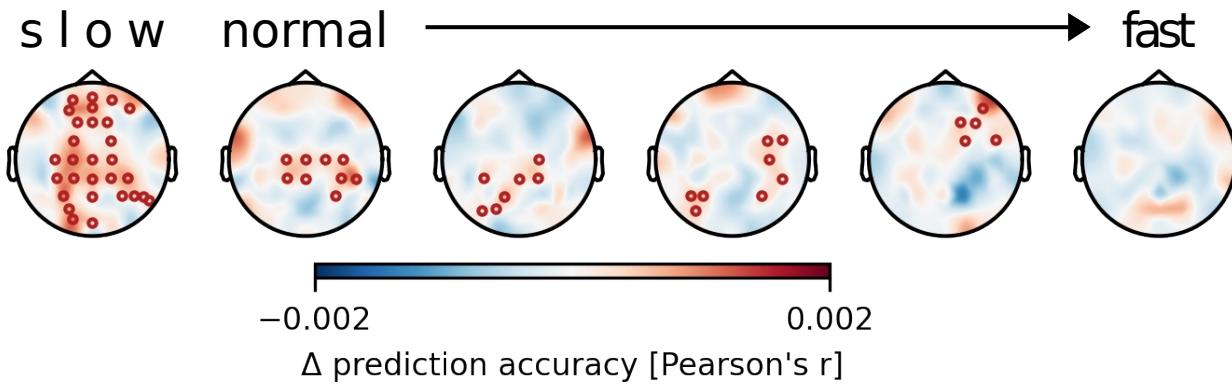
normal



fast

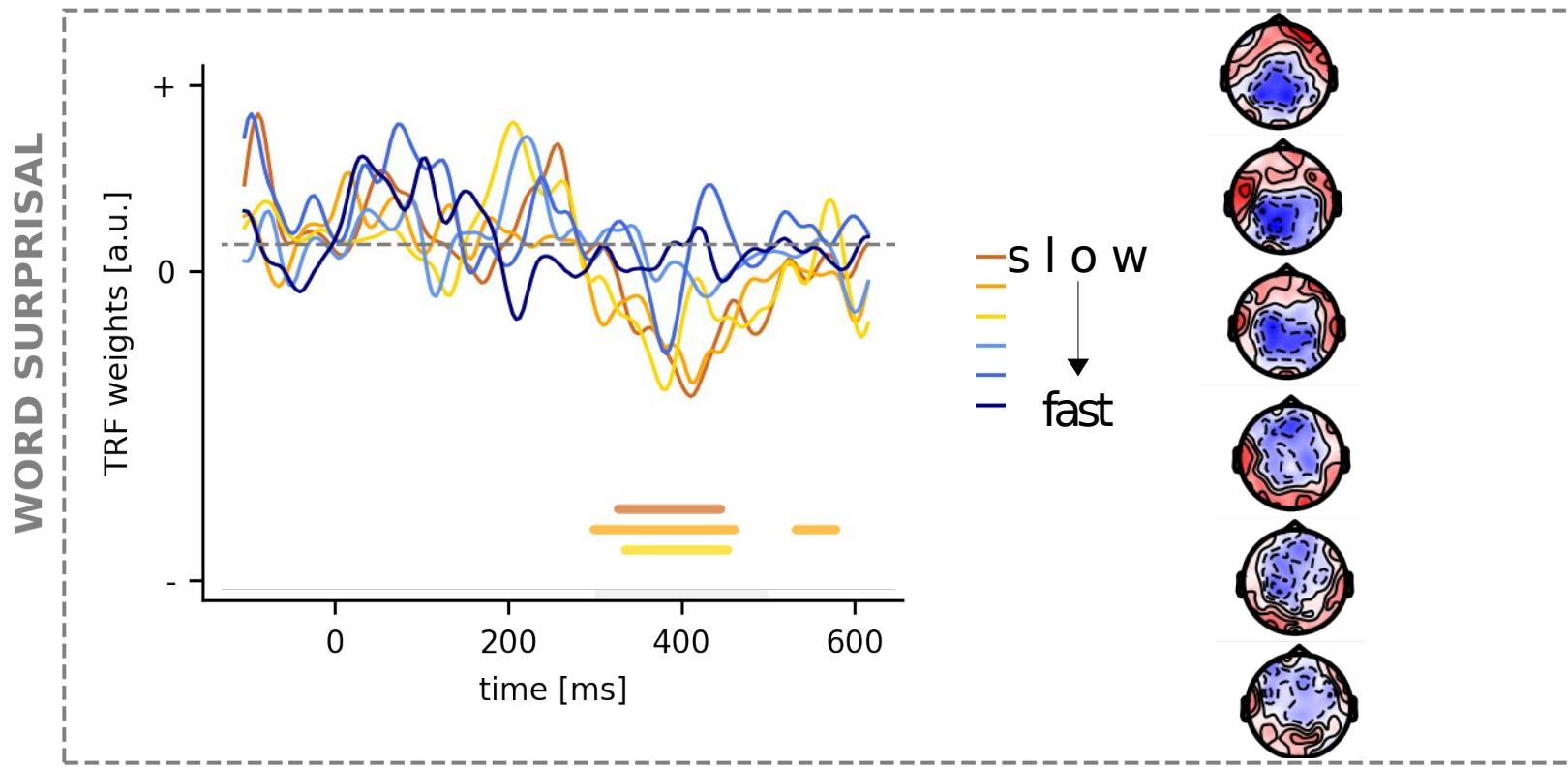


Do linguistic features improve the brain model?



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Methods



19 young, normal-hearing participants



7-minute speech fragments in Dutch, Frisian and a scrambled word list



Gillis, M., Vanthornhout, J., & Francart, T. (2023). Heard or understood? Neural tracking of language features in a comprehensible story, an incomprehensible story and a word list. *eneuro*, 10(7).

Speech fragments I used this time:

Dutch story



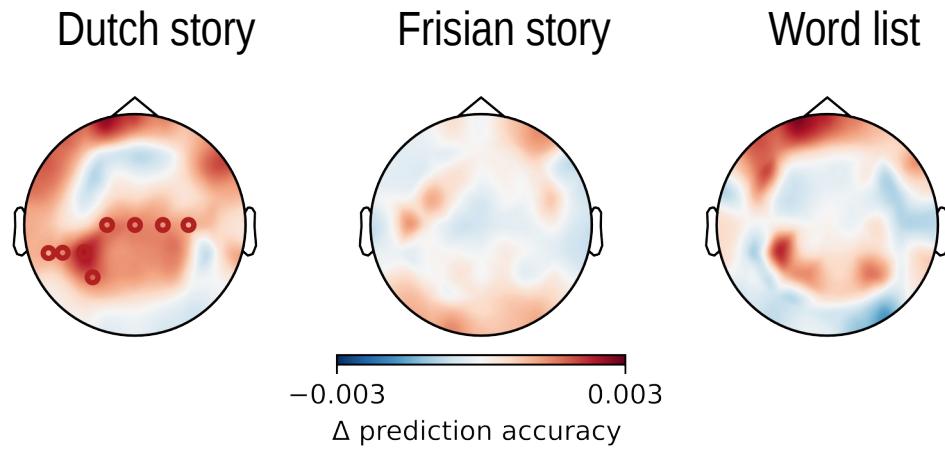
Frisian story



Word list

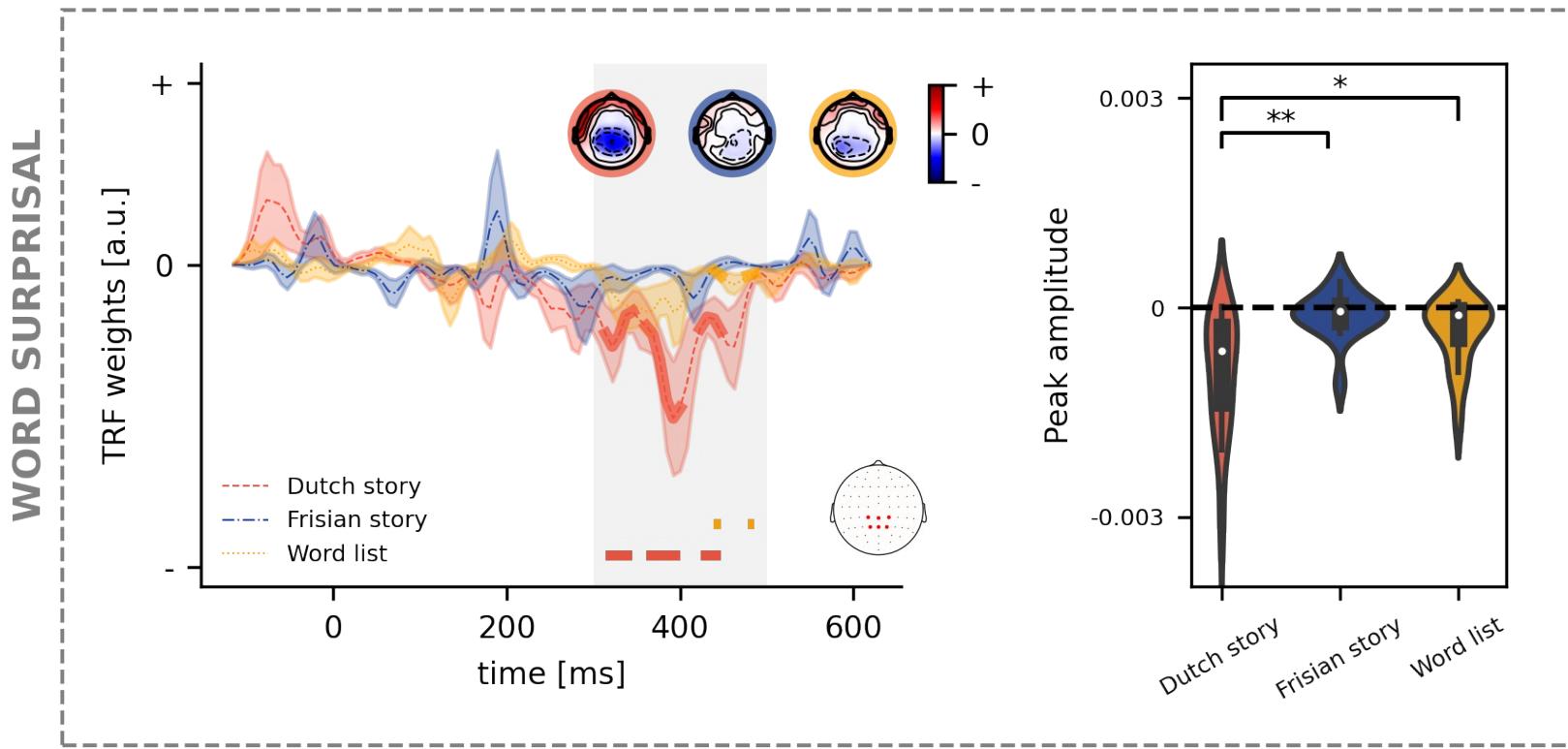


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Pro's and Con's

- Marker for speech understanding rather than acoustic tracking of the sound → ‘understanding’ vs ‘hearing’
- A lot of data is required (minimum 10 minutes)
- Small effect
- Currently only on population level (however hopefully soon a more subject specific approach)