Induced Alpha and Beta Electroencephalographic Rhythms Covary With Single-Trial Speech Intelligibility in Competition

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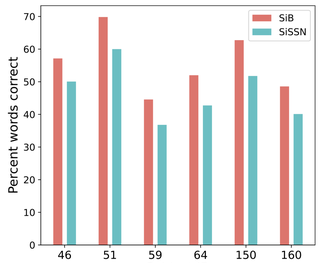
Background and motivation

- Neurophysiological studies across species suggest that intrinsic brain oscillations influence sensory processing, especially of rhythmic stimuli like speech **[1,2]**
- Prior work suggests that brain rhythms may mediate perceptual grouping and selective attention to speech amidst competing sound **[3–8]**, as well as more linguistic aspects of speech processing like predictive coding **[9–11]**, which is thought to stabilize speech representation in noise **[12,13]**
- However, we know of no prior studies that have directly tested, at the single-trial level, whether brain rhythms relate to speech-in-noise outcomes
- **Goal:** Investigate whether trial-by-trial variations in induced brain oscillations in different canonical bands relate to simultaneously measured trial-wise speech intelligibility in competition

Experiment design

- 6 human subjects (1 male, 5 female), 19–31 years old, normal hearing (20 dB HL or better up to 8 kHz)
- IEEE sentences **[14]** presented in four-talker babble (-2 dB SNR) or speech-shaped stationary noise (-5 dB SNR)
- Speech and masker sources were presented diotically
- Intelligibility measurements and 32-channel EEG were simultaneously acquired
- Intelligibility was scored for each trial on five keywords and converted to a percent-correct score

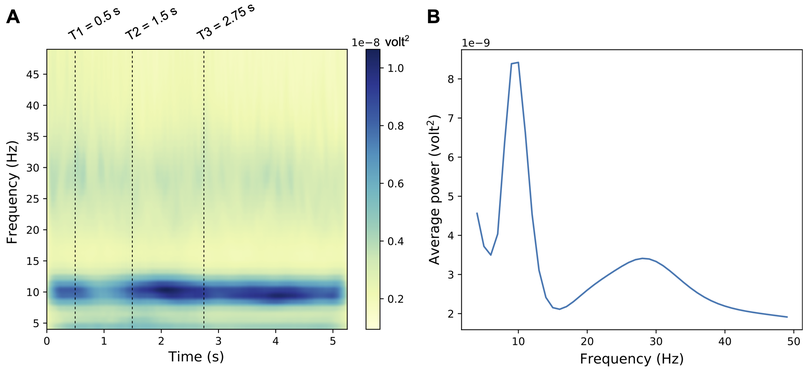


SiB = Speech in Babble;
SiSSN = Speech in Speech-Shaped Stationary Noise

EEG pre-processing

- Channel data were re-referenced to the average of two earlobe reference electrodes
- Signal space projection method was used to remove eye blink and saccade artifacts **[15]**
- Data were filtered between 1 and 400 Hz and epoched into different trials

Induced brain oscillations seen in the alpha (7–15 Hz) and beta (13–30 Hz) bands



Average EEG response spectrogram (A) and spectrum (B); At T1, subjects were visually cued to "stay still and listen now"; At T2, the audio stimulus started; At T3, the target speech started and lasted until at least 5.25 s

References

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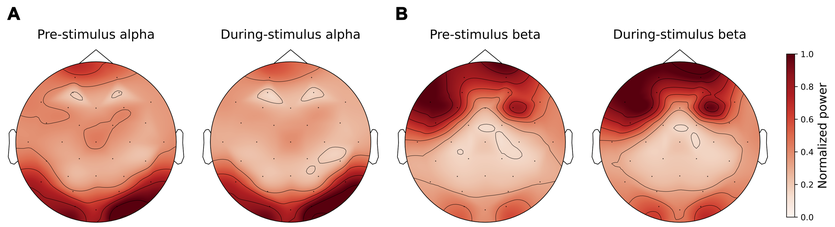
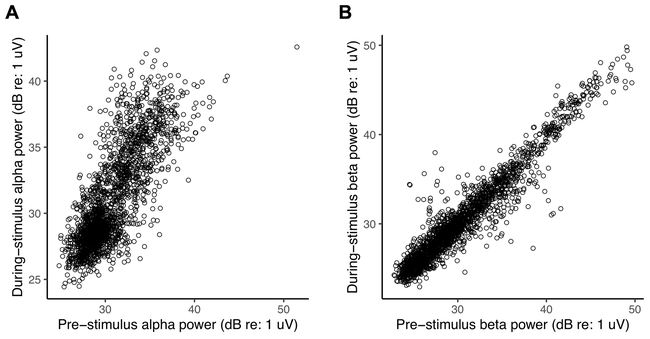
Strongest alpha power occurred in parieto-occipital channels and strongest beta power in frontal channels



Average scalp topography maps for the induced oscillatory power in the alpha (A) and beta (B) bands

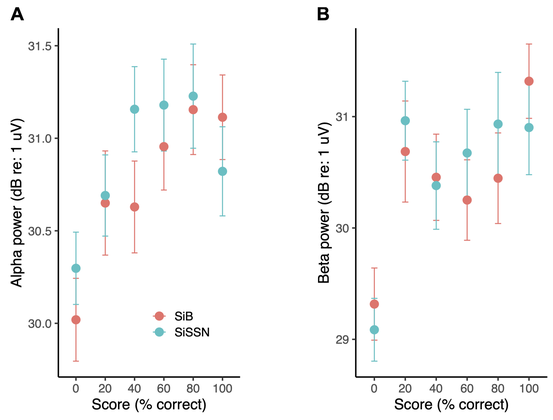
→ We used parieto-occipital channels (A9, A10, A11, A12, A13, A14, A15, A16, A17, A18, A19, A20, A21, and A22) for alpha and frontal channels (A1, A2, A3, A4, A5, A6, A25, A26, A27, A28, A29, A30, and A31) for beta in all further analyses

Across trials, pre- and during-stimulus induced oscillatory power was significantly correlated for both alpha ($R^2 = 0.6292$, p < 2e-16) and beta ($R^2 = 0.9151$, p < 2e-16)



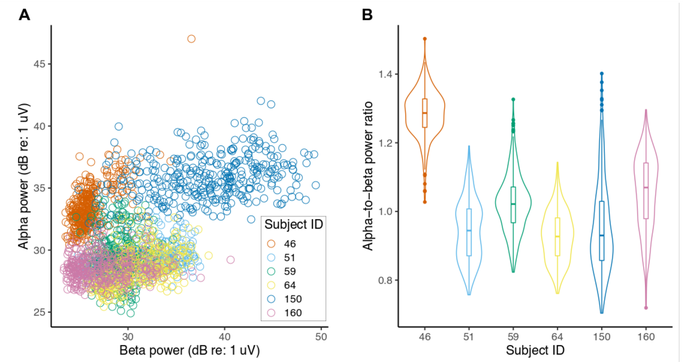
→ We averaged the pre- and during-stimulus periods for all further analyses

Alpha (F = 4.7789, p = 0.0002397) and beta (F = 6.4915, p = 5.346e-06) power both covaried significantly with percent correct score within condition



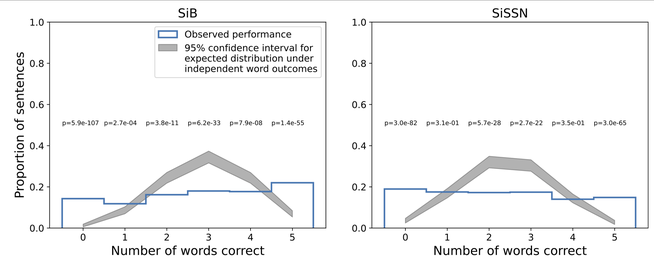
- Posthoc analyses revealed that the largest contribution to the main effect of score on alpha and beta power came from the linear term (T = 4.216, p = 2.59e-05 for alpha; T = 4.173, p = 3.13e-05 for beta)
- Pairwise t-tests revealed that alpha and beta power increased when percent-correct score increased from 0 to 20 (T = 1.994, p = 0.0463 for alpha; T = 4.249, p = 2.24e-05 for beta); however, for the successive steps (20 to 40, 40 to 60, etc.), the increase in power was not significant for either alpha or beta

Alpha-beta correlation and individual differences



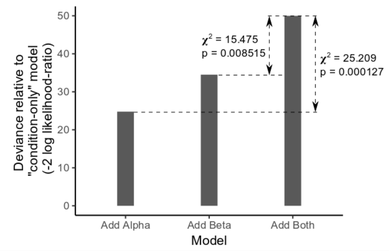
- Alpha and beta power were correlated across trials (F = 175.7166, p < 2e-16), even within subject (A)
- There were large individual differences in the overall magnitude of alpha and beta power (A), and in the alpha-to-beta power ratio (B) across trials

High correlation in performance across different words in a trial suggests that either selective attention or predictive coding, or both, influenced behavioral outcomes



Histogram of no. of words correct per sentence; p-values under null hypothesis of independent word outcomes also shown

Despite being correlated, alpha and beta power each provide significant independent contributions to predicting single-trial behavioral outcomes



Likelihood ratio deviances (relative to a base model with condition as the only predictor) for three different multinomial models of percent-correct score

Conclusions

- Induced parieto-occipital alpha and frontal beta rhythms independently contribute to simultaneously measured single-trial speech-in-noise outcomes → consistent with their posited roles in selective attention **[7,8]** and fronto-motor predictive coding **[9–11]**, respectively
- Individual differences in the overall magnitude of alpha and beta power, and in the alpha-to-beta power ratio across trials ⇒ listeners may have employed different task strategies
- Results can inform models of speech processing and guide noninvasive measures to index different neural processes that together support complex listening

Acknowledgments

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