

# Saccades are locked to the phase of alpha activity during natural reading

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## Introduction

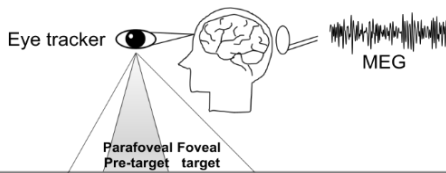
### How to coordinate saccades during natural reading?



- We make 3~5 saccades per second to extract meaning from text during reading [1].
- Saccades can modulate neuronal excitability in the visual cortex [2,3], and micro-saccades were shown to reset the phase of ongoing oscillation [4].
- Saccades locked to the phase of alpha activity predict memory encoding [5].

? We here ask if saccades are locked to the alpha phase during reading? Is this phase-locking modulated by word properties, e.g., word frequency?

## The free reading paradigm



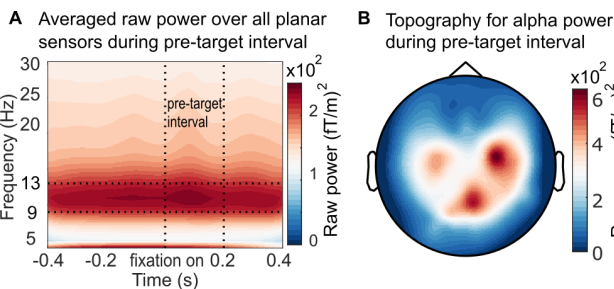
Low freq target: I felt quite **bleak** after discussing that .....

High freq target: I felt quite **weird** after discussing that .....

- Participant** | 39 native British English speakers (25 females), aged  $22 \pm 2.6$  (mean  $\pm$  SD), right-handed, with normal or corrected-to-normal vision, without any language disorder diagnosis. One participant was excluded due to few trials, which left 38 participants (n=38).
- Task** | A silent reading task. 25% of the sentences were followed by a yes-or-no comprehension question to ensure careful reading.
- Material** | 228 sentences, all plausible with unpredictable targets of either low or high word frequency. Each target pair has same word length.
- Measurements** | An eye-tracker and MEG were used to record eye movements and brain activity simultaneously.

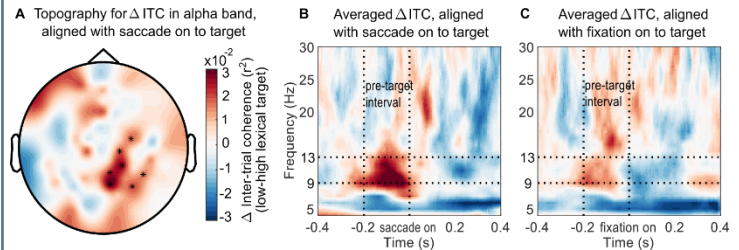
(It is the same dataset as in "Neural evidence for lexical parafoveal processing" [6])

## Alpha activity prevails during natural reading

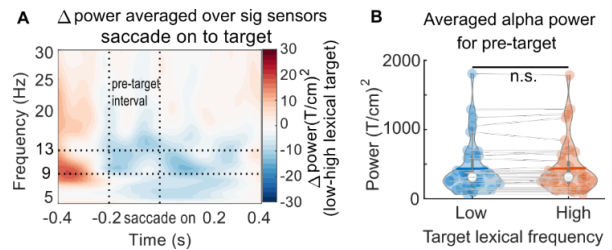


- We extracted 1s epochs, aligned with fixation on to the pre-target word. The averaged fixation duration for pre-target is 0.2 s. Raw power was estimated from 4 to 30Hz using Hilbert transformation, with a step of 1 Hz.
- Panel A showed the averaged raw power over all valid planar sensors, where the dominant power was in the alpha band (9 - 13 Hz). Panel B showed that the raw alpha power during the pre-target interval (0 - 0.2 s; planar gradients) is mainly concentrated in the visual and parietal cortex.

## Stronger phase-locking in the alpha band prior to saccading to the word with lower frequency

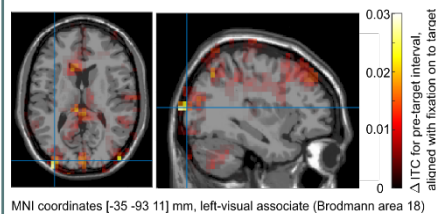


- We calculated inter-trial coherence (ITC) in the alpha band (9 - 13 Hz) for pre-target interval (-0.2 - 0 s), aligned with the saccade onset to target word.
- Panel A showed the significant cluster of sensors that had higher ITC in the alpha band when pre-processing the target with low word frequency compared to high word frequency (n=38,  $P_{cluster} < 0.05$ , shuffle 5000 times).
- Panel B showed the averaged ITC difference over this sensor cluster.
- Panel C indicates that this phase-locking in alpha band is specific to the saccade onset. We did the same analysis for pre-target interval but aligned with fixation onset to target word. No significant difference was found.



- The alpha ITC difference is not driven by power magnitude. We estimated the power difference for the pre-target interval (-0.2 - 0 s), aligned with saccade onset to target word, as shown in panel A. But no significant difference was found in the alpha power as shown in panel B (n=38,  $p=0.24$ , two-sided pairwise t-test). Therefore, saccades reset the phase of the ongoing alpha activity without affecting its power.

## The alpha ITC effect originates from the visual cortex



We localized the ITC difference in pre-target interval to the early visual cortex (BA 18) using a beamformer technique (LCMV). (sensor level result was shown as a topo in panel A above).

## Conclusions

- Saccade onsets are locked to alpha phase (but not fixations). This indicates that the ocular system collaborates with the visual system during reading.
- Stronger phase-locking helps to better prepare the visual cortex for more difficult incoming words.
- Alpha phase acts as a precise temporal sampling framework during reading.

## References

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