COGNITIVE CONTROL IS IN THE EYE OF THE BEHOLDER: THETA AND ALPHA MODULATION IN A CUED SACCADE TASK

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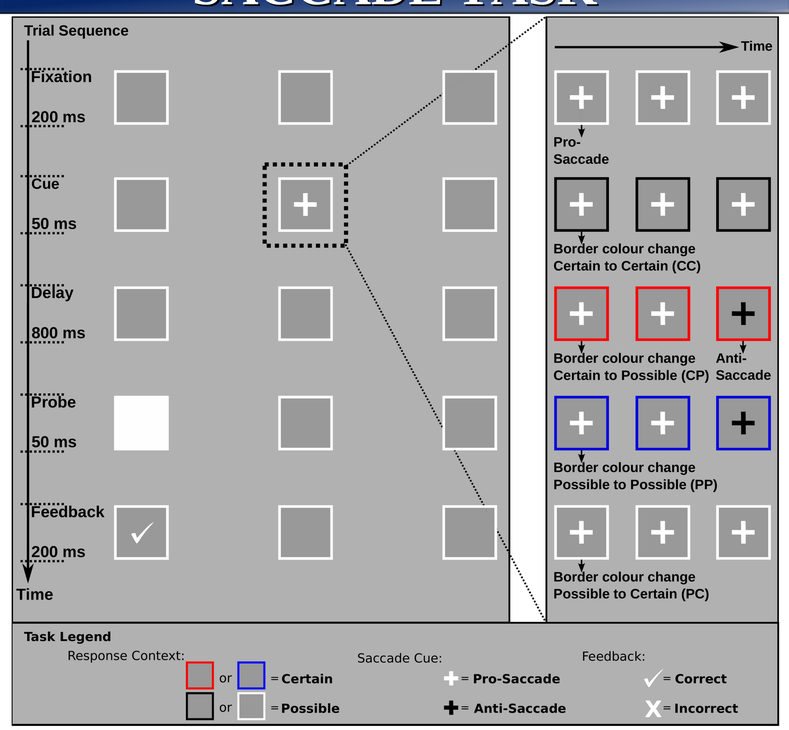
BACKGROUND

- The medial frontal cortex is an important neural substrate of performance and response monitoring, and its activation is consistently linked to theta oscillations (~ 3 to 8 Hz) [1].
- Reduction in posterior alpha activity (~ 8 to 15 Hz) is also observed during periods of increased vigilance and task difficulty[2].
- Traditional performance monitoring paradigms focus on brain responses evoked by stimuli (NoGo N2, FRN) or response outcomes (ERN).
- There is a lack of research focusing on the cognitive state induced during response preparation and how it is reflected in theta and alpha oscillations.

CURRENT STUDY: Using a novel saccade cueing paradigm, we investigated the role of theta and alpha in relation to response preparation, as opposed to response outcomes, as a prerequisite for successful control over behavior.

SACCADE TASK



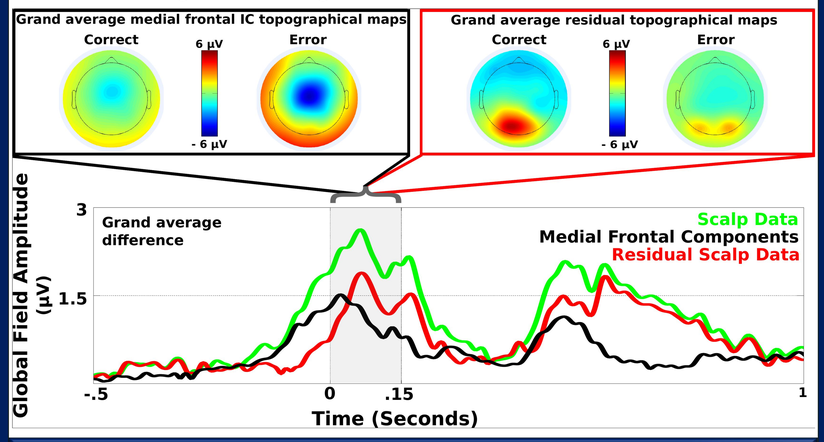
Participants responded as quickly as possible to a cue ("+") presented inside a coloured square that signaled response context:
Certain involved only "pro-saccade" (toward the probe) trials, and *Possible* involved both "pro-saccade" and "anti-saccade" (away from the probe) trials.

- Border colour switched every 3 to 7 trials simultaneously with the onset of a pro-saccade cue.

METHODS

- 128 channel EGI HCGSN sampled at 500 Hz
- Automated pre-processing to remove bad channels, periods of non-stationarity, and independent components (ICs) identified as biological artifact (EOG, ECG, EMG).
- Data processing and bootstrap re-sampling performed using MATLAB, EEGLAB, and Octave.

- Medial frontal ICs were classified based on their increased activation following response errors.
- Posterior alpha ICs were classified based on (i) posterior/occipital projection, (ii) oscillatory peaks in ongoing alpha, and (iii) reduced alpha power following border changes.



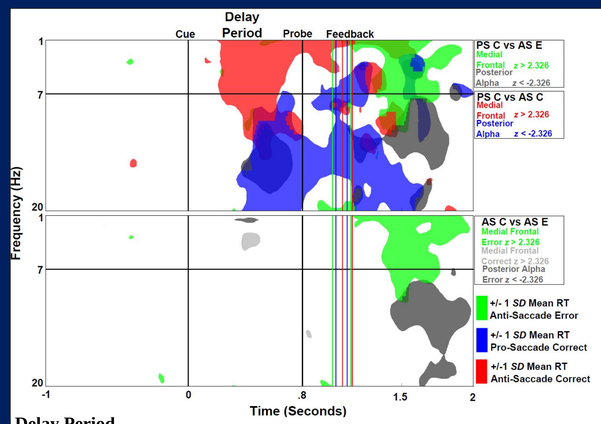
RESULTS

Pro-saccade accuracy approached ceiling levels (M = .96, SD = .06) whereas anti-saccade accuracy was lower and more variable (M = .85, SD = .15).

Reaction times varied across task conditions (robust omnibus test, $p < .001$):

- Pro-saccade correct responses were significantly faster than anti-saccade correct responses ($p < .01$, 95% CI [-17.60, -56.09]), but were not reliably different from anti-saccade errors ($p > .05$, 95% CI [43.55, -38.84]).
- Anti-saccade errors were significantly faster than anti-saccade correct responses ($p < .01$, 95% CI [79.37, 7.79]).

	Response Time (ms)	
Trial Type	M	SD
Pro-saccade error	146.89	71.9
Pro-saccade correct	309.26	39.96
Anti-saccade error	304.72	63.72
Anti-saccade correct	346.13	34.13



- Increase in medial frontal theta and suppression of posterior alpha following anti-saccade error feedback
- Increase in medial frontal theta and suppression of posterior alpha during response preparation on anti-saccade correct trials compared to pro-saccade correct trials
- Increase in medial frontal theta during response preparation on anti-saccade correct compared to anti-saccade error trials

Delay Period

Increase in Medial Frontal Theta for:

- anti-saccade correct VS pro-saccade correct and anti-saccade error
- anti-saccade correct VS anti-saccade error

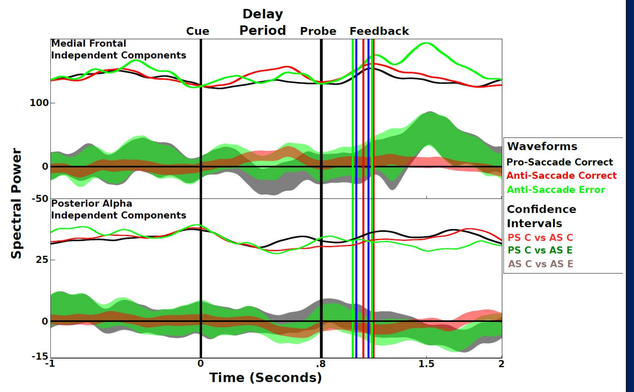
Suppression in Posterior Alpha for:

- anti-saccade correct and anti-saccade error VS pro-saccade correct

Response Feedback

Increase in Medial Frontal Theta, suppression in Posterior Alpha for:

- anti-saccade error VS anti-saccade correct and pro-saccade correct



CONCLUSIONS

- Successful control over pre-potent saccades is characterized by an increase in medial frontal theta and suppression of posterior alpha during response preparation.
- Failure to inhibit a prepotent saccade is characterized by a lack of medial frontal theta during response preparation, which instead occurs following error feedback.
- Our approach moves beyond traditional performance monitoring paradigms and demonstrates that medial frontal theta is a prerequisite for successful behavioral control within such contexts.

REFERENCES

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[2] van Driel, J., Ridderinkhof, K. R., & Cohen, M. X. (2012). Not all errors are alike: Theta and alpha EEG dynamics relate to differences in error-processing dynamics. *Journal of Neuroscience*, *32*(47), 16795-16806.

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