

# Effects of post-error arousal on cognitive control: Adaptive or maladaptive?

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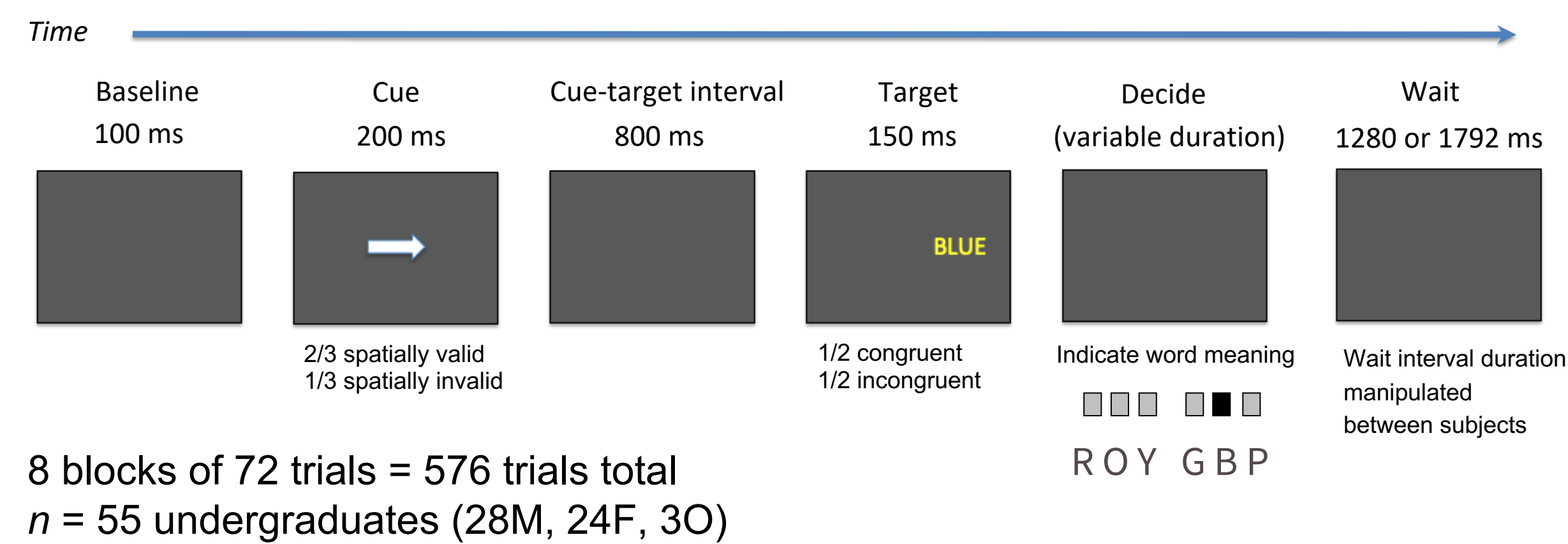
## Research Question

How does arousal generated by a performance error affect ongoing performance?

- **Adaptive Control:** sharpened attentional focus
- **Maladaptive Effect:** performance decrement
- **Hybrid Model:** benefits of arousal are seen only with enough time between trials to implement control?

## Methods

Simultaneous EEG and eye-tracking during a spatially-cued reverse Stroop task.



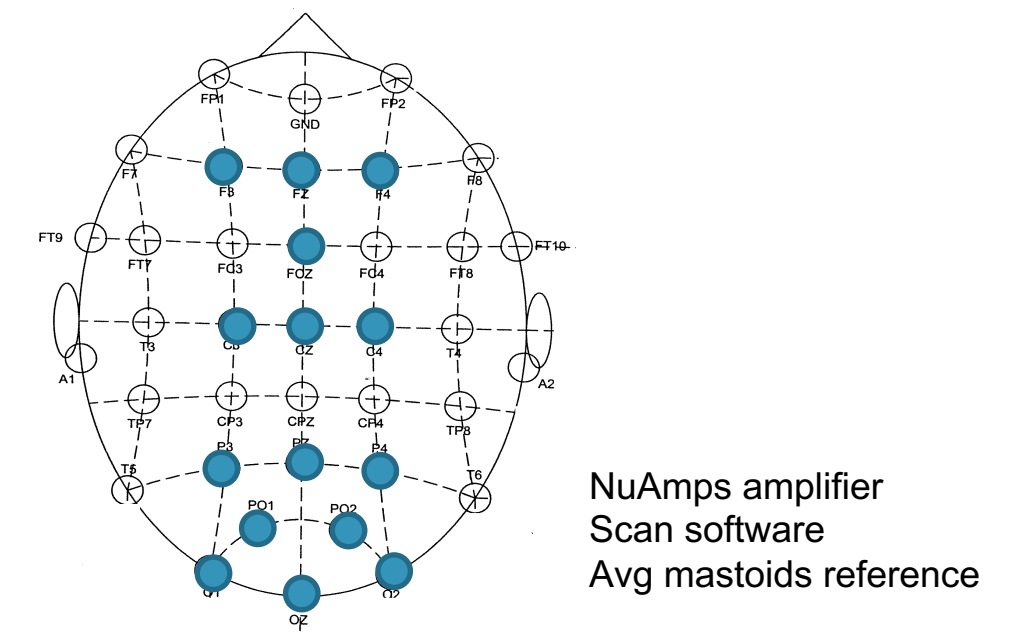
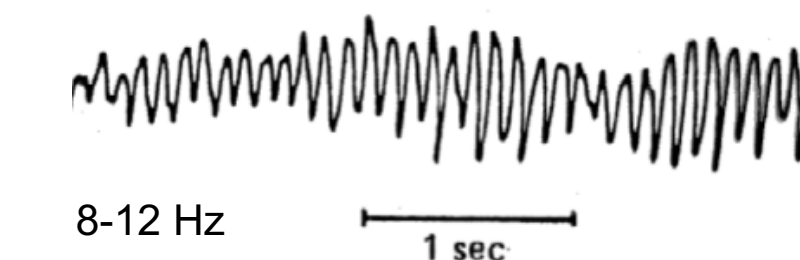
### Measures of attention:

- Cue validity effect
- Stroop congruency effect



### Measures of arousal:

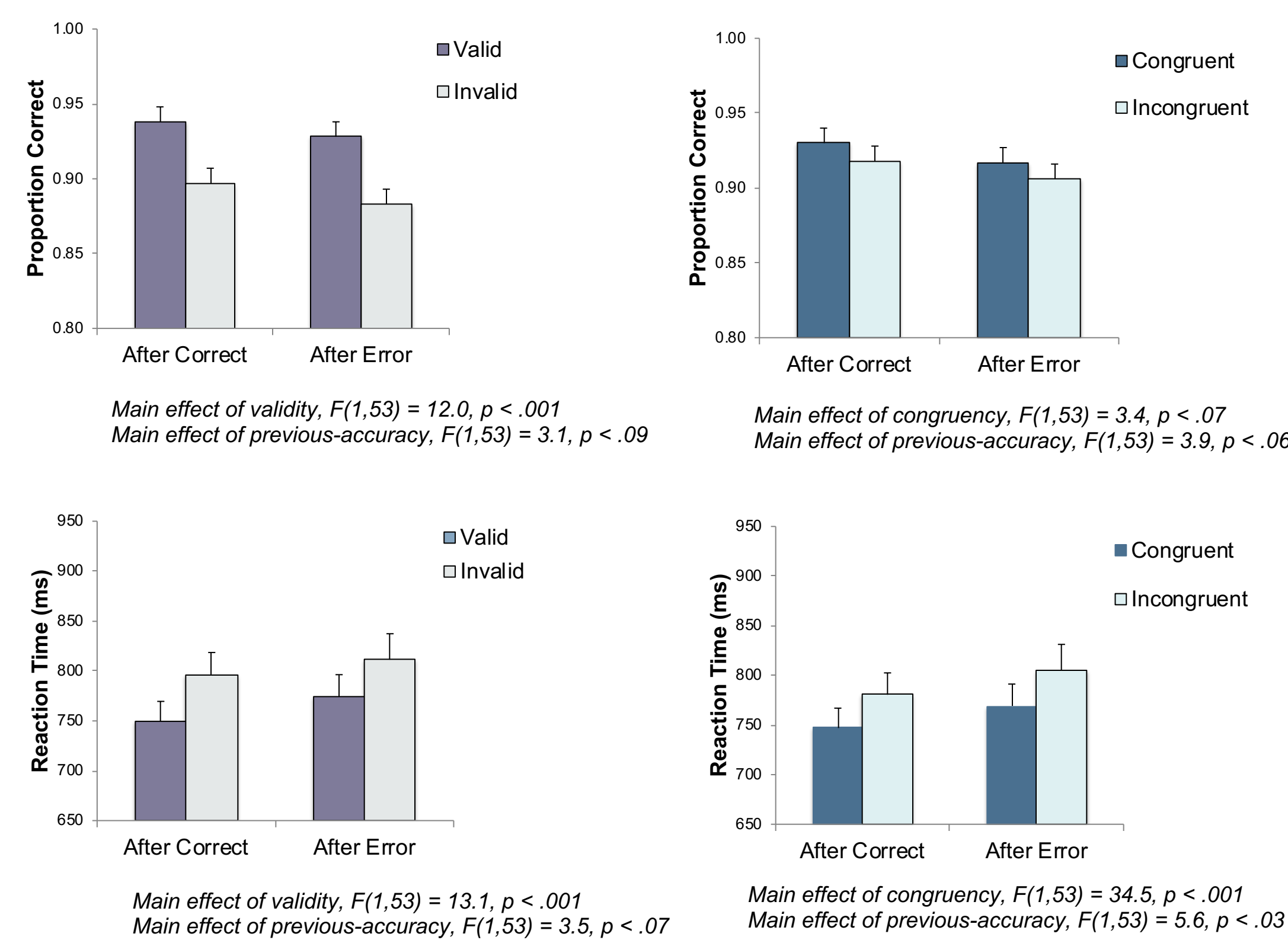
- Pupil diameter
- EEG alpha power



## Results

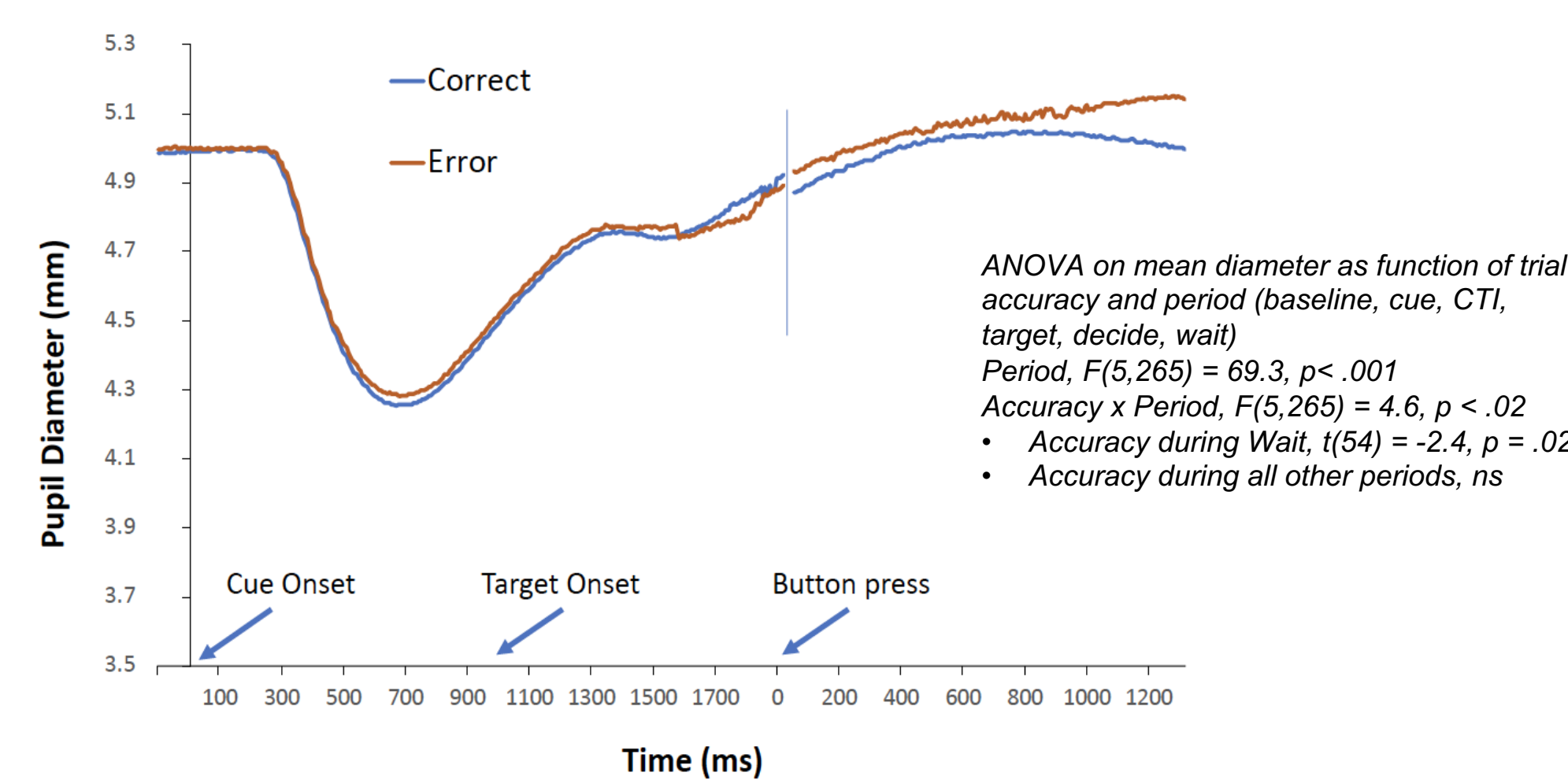
### Performance

- Robust effects of Cue Validity and Stroop Congruency
- These attentional effects not further modulated by accuracy on prior trial
- Following errors, responses tend to be slower and less accurate
- No modulation of effects based on duration of inter-trial interval
- Results are more consistent with maladaptive arousal than adaptive control (replicating Compton et al., 2018)



### Pupil Diameter

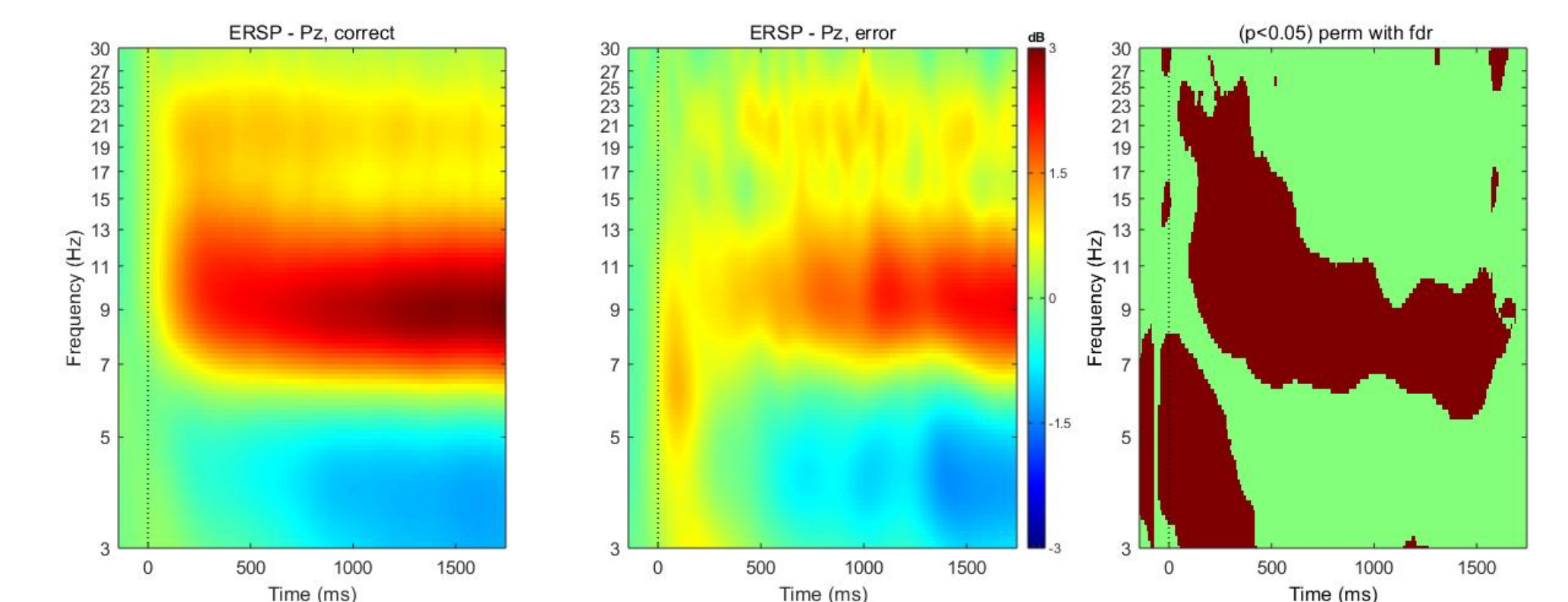
- Pupil diameter following button-press is greater for error vs. correct trial (replicating Critchley et al., 2005; Wessel et al., 2011)



- Within-subjects correlations between pupil diameter (following button-press) and next-trial performance:
  - Following correct responses, greater pupil diameter predicts slower next-trial RT,  $t(50) = 3.7, p = .001$
  - Following error responses, greater pupil diameter predicts slower next-trial RT,  $t(43) = 4.5, p < .001$
  - Relationship is consistently stronger following errors,  $t(43) = -2.5, p < .02$
  - Pupil diameter did not predict next-trial accuracy,  $ps > .15$
- No modulation of effects based on duration of inter-trial interval
- Results support maladaptive arousal better than adaptive control

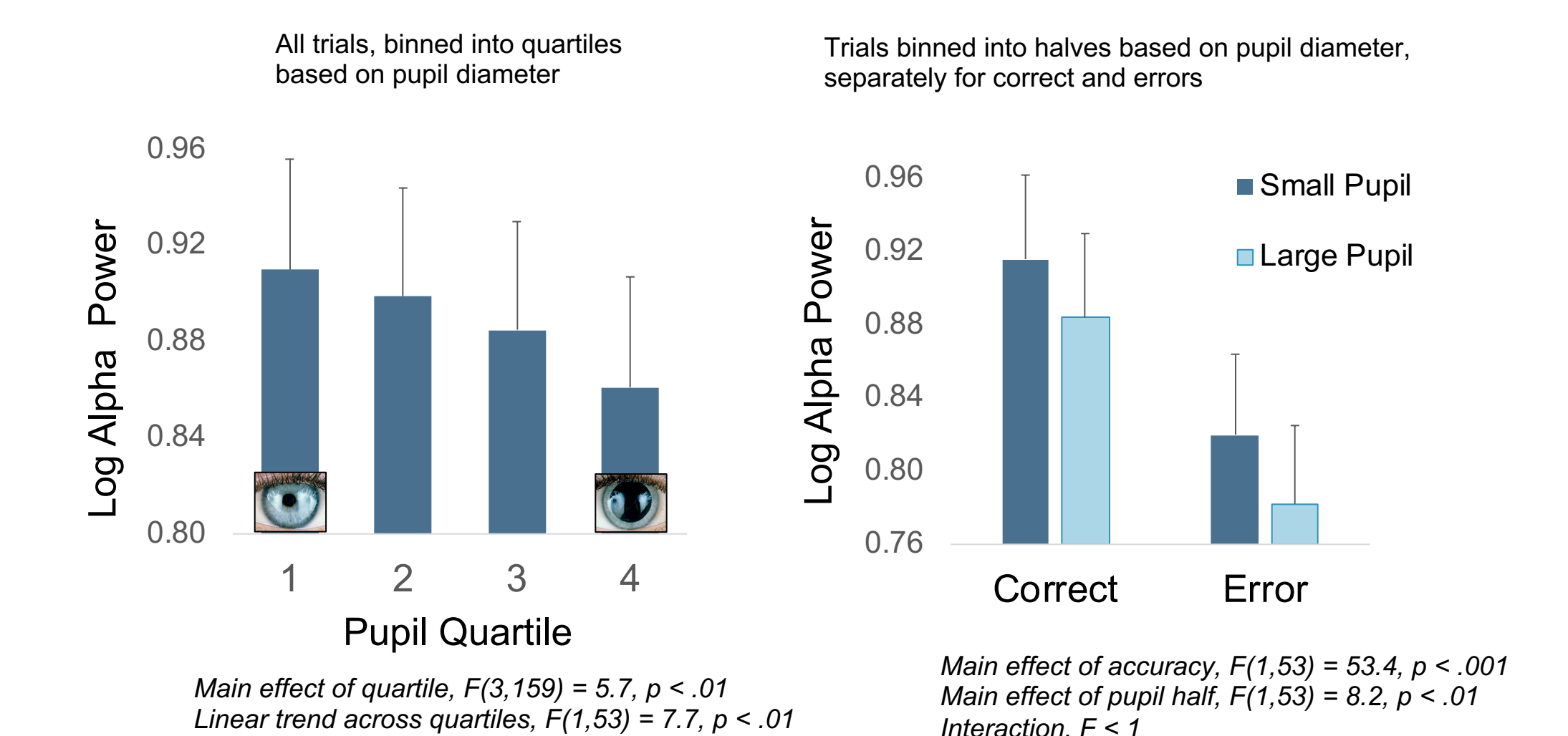
### EEG Alpha Power

- Alpha power during post-response "wait" period is reduced following error versus correct response (replicating Carp & Compton, 2009; Compton et al., 2018)



Time-frequency plot shown for Pz electrode to illustrate error-correct difference observed at all sites. Analysis of log alpha power based on FFT, main effect of trial accuracy,  $F(1,53) = 14.0, p < .001$

- Pupil diameter during "wait" period is inversely related to alpha power, supporting arousal interpretation of post-response alpha suppression



## Conclusions and Next Steps

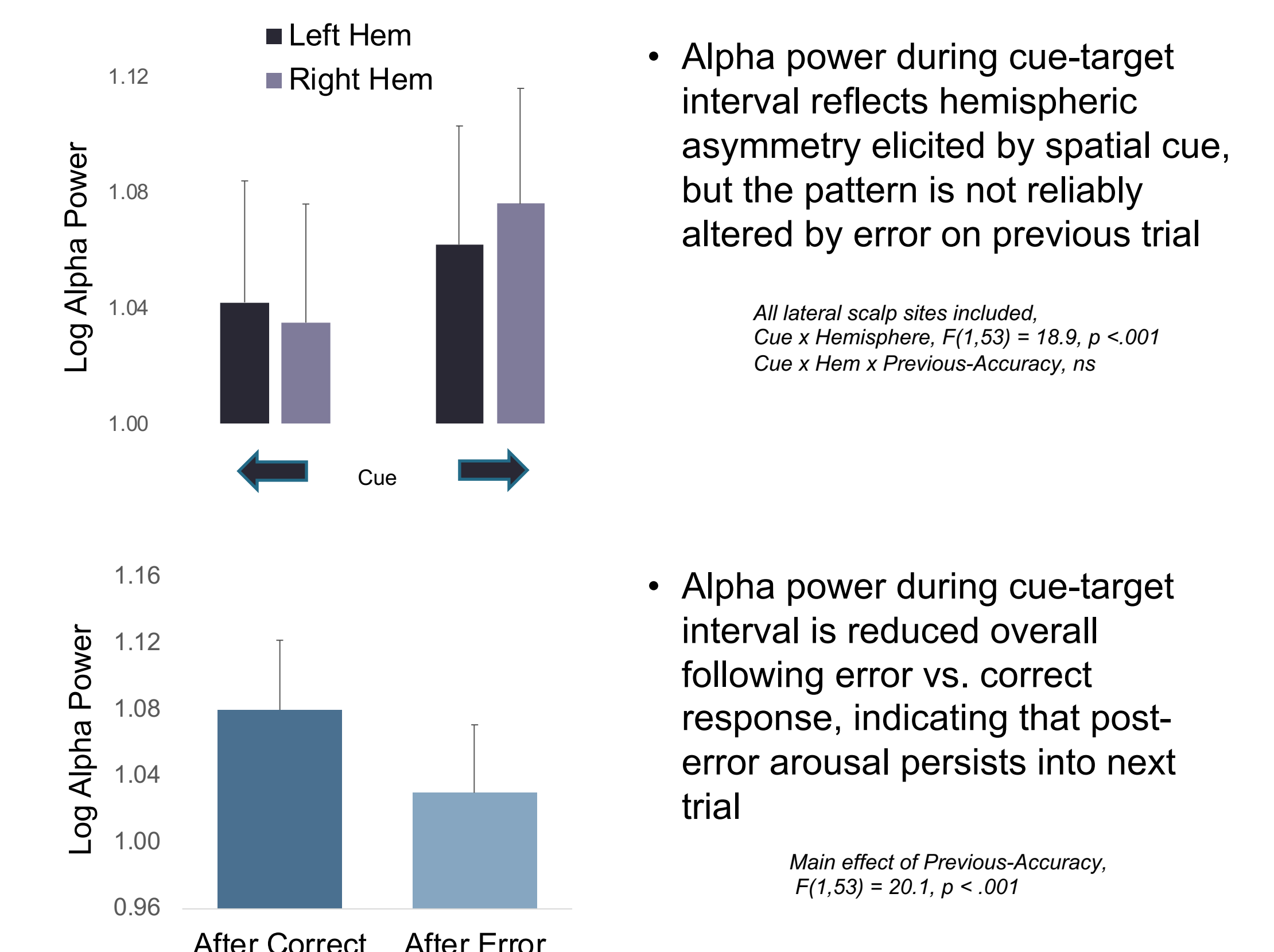
- Overall, results support a maladaptive arousal account more than an adaptive control or hybrid model
  - Performance errors are followed by correlated indicators of arousal (increased pupil dilation and decreased alpha power)
  - Performance errors are followed by response slowing without any evidence of increased attentional focus
  - Post-response pupil diameter predicts next-trial response slowing, especially for errors
  - In general, increasing duration of interval between trials does not alter this pattern
- Next steps will address whether pupil dilation, as an index of arousal, predicts next-trial hemispheric asymmetry in response to spatial cueing or target-locked ERP measures of attention

## References

- Carp, J., & Compton, R.J. (2009). Alpha power is influenced by performance errors. *Psychophysiology*, 46, 336-343.
- Compton, R.J., Heaton, E., & Gaines, A. (2018). Is attention enhanced following performance errors? Testing the adaptive control hypothesis. *Psychophysiology*, 55(4), e13022.
- Critchley, H.D., et al. (2005). Anterior cingulate activity during error and autonomic response. *Neuroimage*, 27, 885-895.
- Wessel, J.R., Danielmeier, C., & Ullsperger, M. (2011). Error awareness revisited: accumulation of multimodal evidence from central and autonomic nervous systems. *Journal of Cognitive Neuroscience*, 23, 3021-3036.

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- Alpha power during cue-target interval reflects hemispheric asymmetry elicited by spatial cue, but the pattern is not reliably altered by error on previous trial

All lateral scalp sites included. Cue x Hemisphere,  $F(1,53) = 18.9, p < .001$ . Cue x Hem x Previous-Accuracy, ns

- Alpha power during cue-target interval is reduced overall following error vs. correct response, indicating that post-error arousal persists into next trial

Main effect of Previous-Accuracy,  $F(1,53) = 20.1, p < .001$