

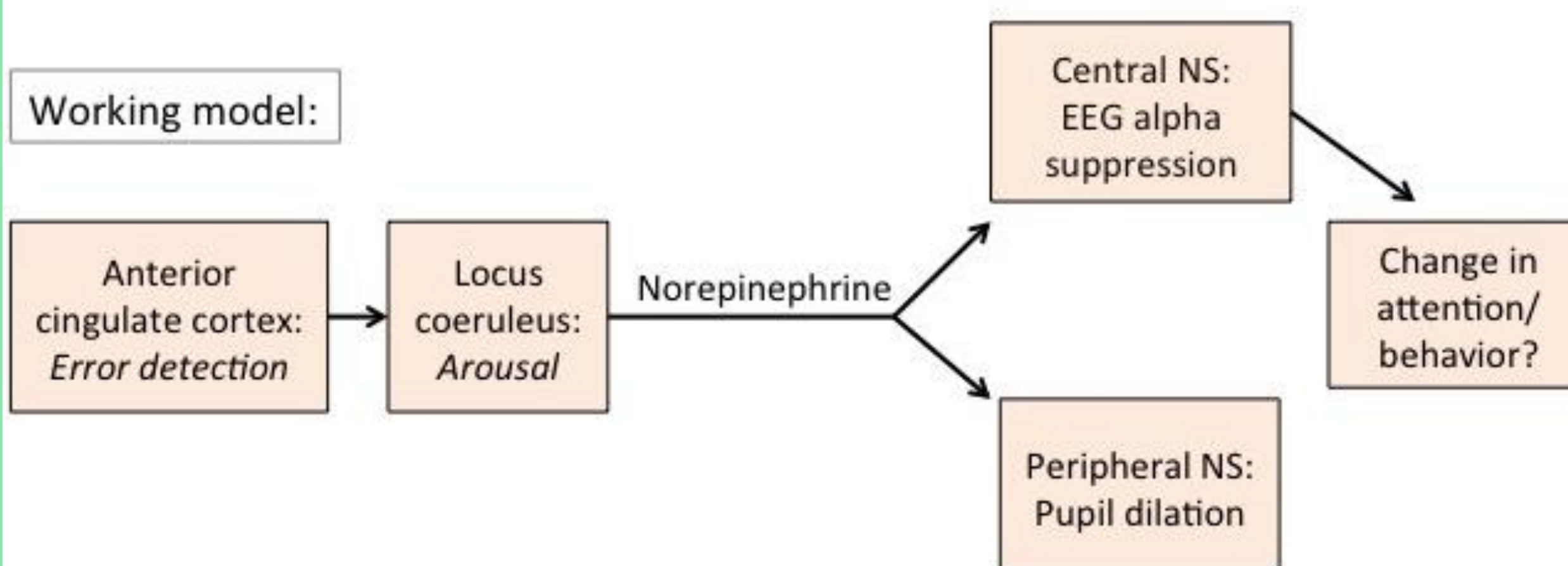


Background

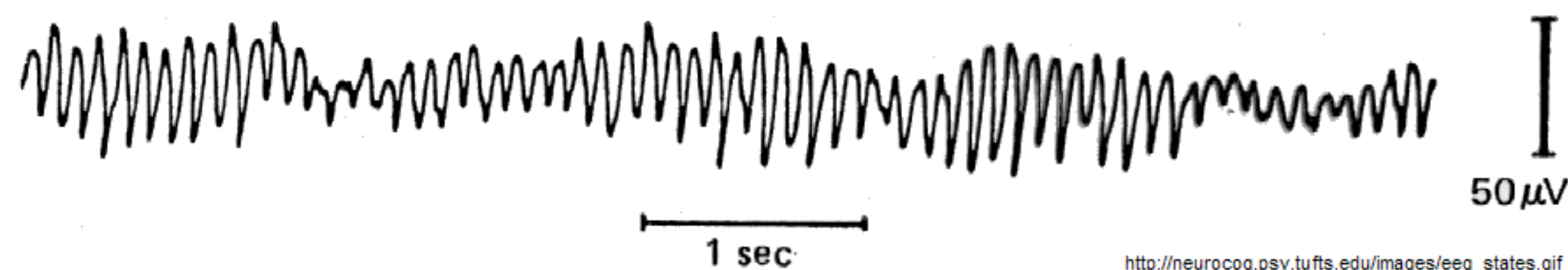
General Aims: The relationship between error detection, arousal, and behavior, through the mechanisms of alpha suppression and pupil dilation was explored.

Working Model: Error detection triggers an arousal response that is reflected in EEG patterns and pupillary responses and may impact subsequent behavior.

Hypothesis: Pupil dilation following mistakes will be correlated with error-related changes in EEG oscillations, due to common neural mechanisms.



Alpha oscillations: 8-12 Hz



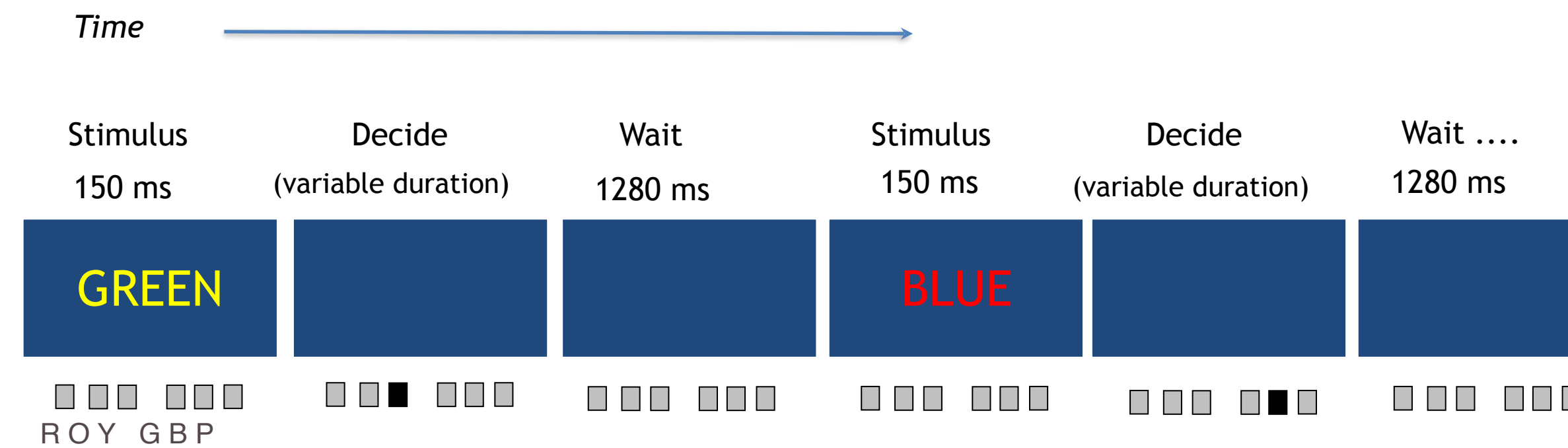
- EEG alpha-wave oscillations are suppressed in the inter-trial interval following errors (Carp & Compton, 2009).
- Error-related alpha suppression may occur because errors trigger an arousal/alerting response. Supporting this view, explicit warning cues also lead to alpha suppression (Klimesch et al., 1998).
- The neural mechanism of error-related alpha suppression is poorly understood, but it could result from NE projections to the forebrain.
- Pupil diameter provides a valid index of error-evoked NE activity.
 - Pupil diameter is under direct control of the locus coeruleus/NE system (Murphy et al., 2011, 2014).
 - Pupil diameter increases after errors during cognitive performance tasks (Critchley et al., 2005; Murphy et al., 2016).

References

- Carp, J., & Compton, R.J. (2009). Alpha power is influenced by performance errors. *Psychophysiology*, 46, 336-343.
- Critchley, H.D., et al. (2005). Anterior cingulate activity during error and autonomic response. *Neuroimage*, 27, 885-895.
- Klimesch, W., et al. (1998). Induced alpha band power changes in the human EEG and attention. *Neuroscience Letters*, 244, 73-76.
- Murphy, P.R., et al. (2011). Pupillometry and P3 index the locus coeruleus–noradrenergic arousal function in humans. *Psychophysiology*, 48, 1532-1543.
- Murphy, P.R., et al. (2014). Pupil diameter covaries with BOLD activity in human locus coeruleus. *Human Brain Mapping*, 35, 4140-4154.
- Murphy, P.R., et al. (2016). The pupillary orienting response predicts adaptive behavioral adjustment after errors. *PloS One*, 11(3), e0151763.

Methods

Used EEG with eye-tracking software simultaneously to record correct vs. incorrect responses during a Stroop Task.

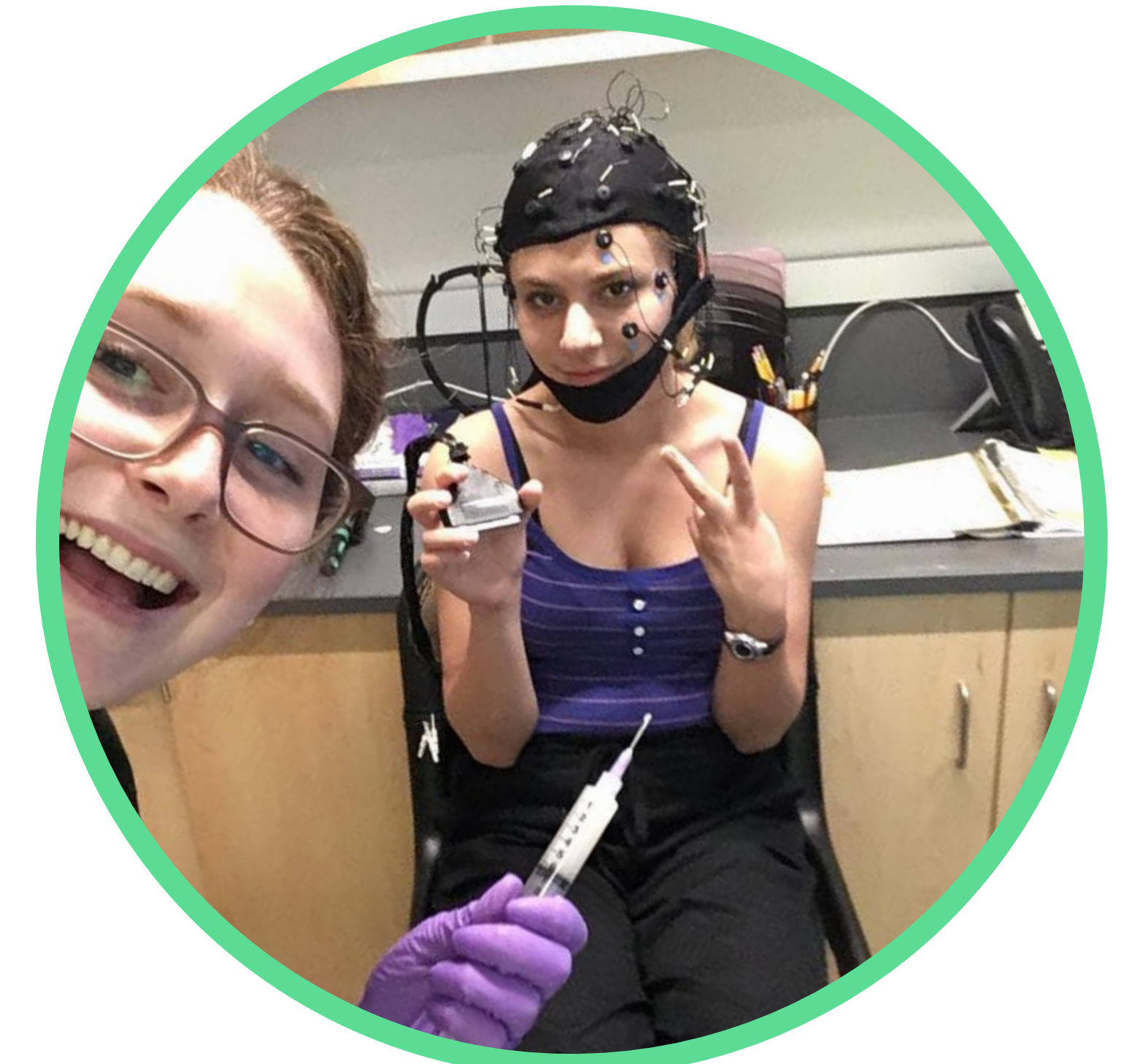


What color is the word?

Six choices to respond (using keyboard)
red, orange, yellow, green, blue, purple
12 blocks of 72 trials = 864 trials total
~ 92% overall accuracy

Self-Report Questionnaires Used

- Mind-Wandering Questionnaire (MWQ)
- Positive and Negative Affect (PANAS)
- Five-Facet Mindfulness (FFMQ-15)
- Mood and Anxiety Symptom (MASQ)



Results: Pupil Diameter and EEG

ERN: Event Related Negativity

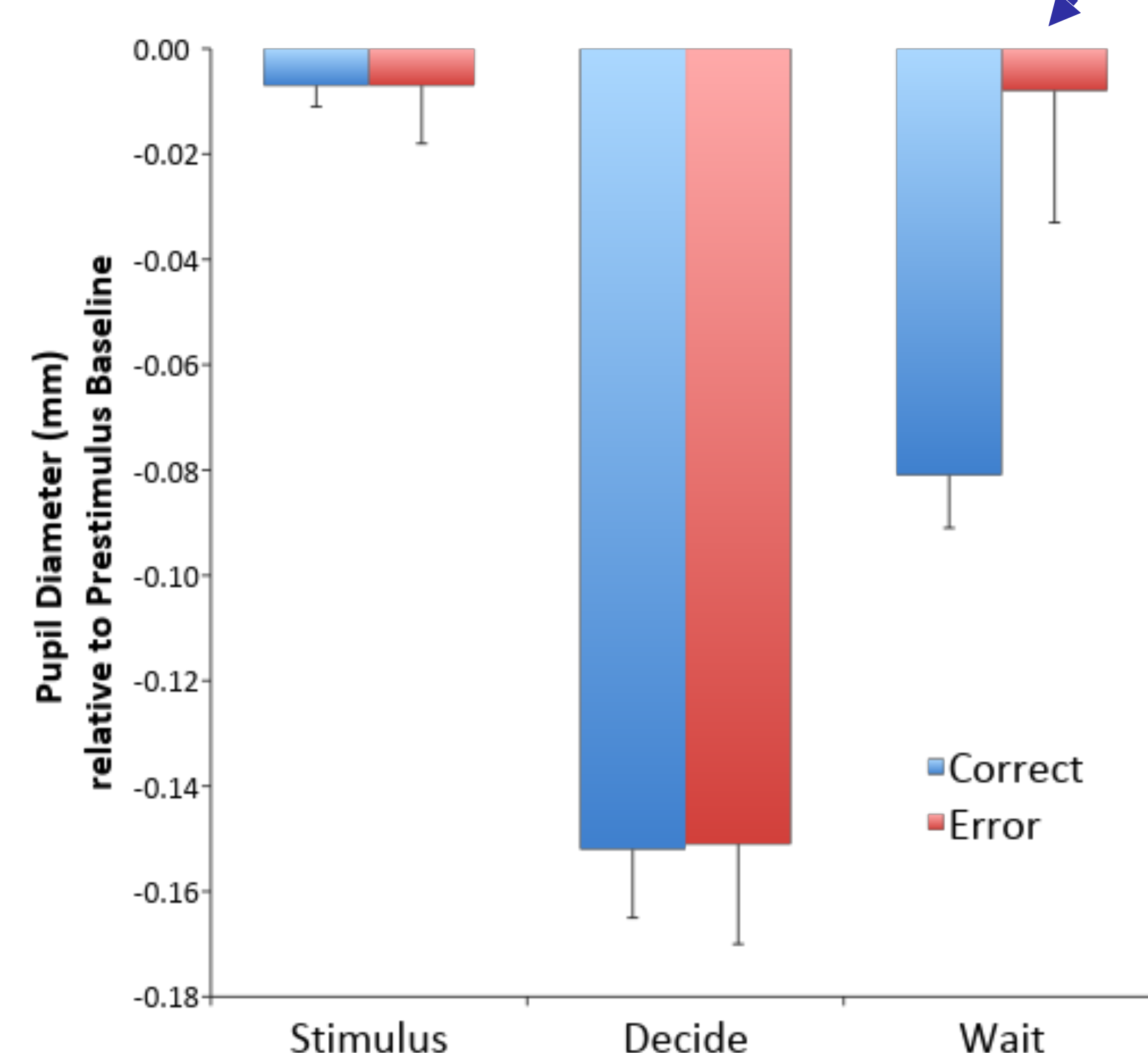
- The main effect of trial type, $F(1, 59) = 140.4$, $p < .0001$, was due to higher (negative) peaks for error trials ($M = -5.46$ V, $SEM = 0.31$) than for correct trials ($M = -1.46$ V, $SEM = 0.12$).
- These results show how the brain notices its own errors. (immediate)

ERAS: Error Related Alpha Suppression

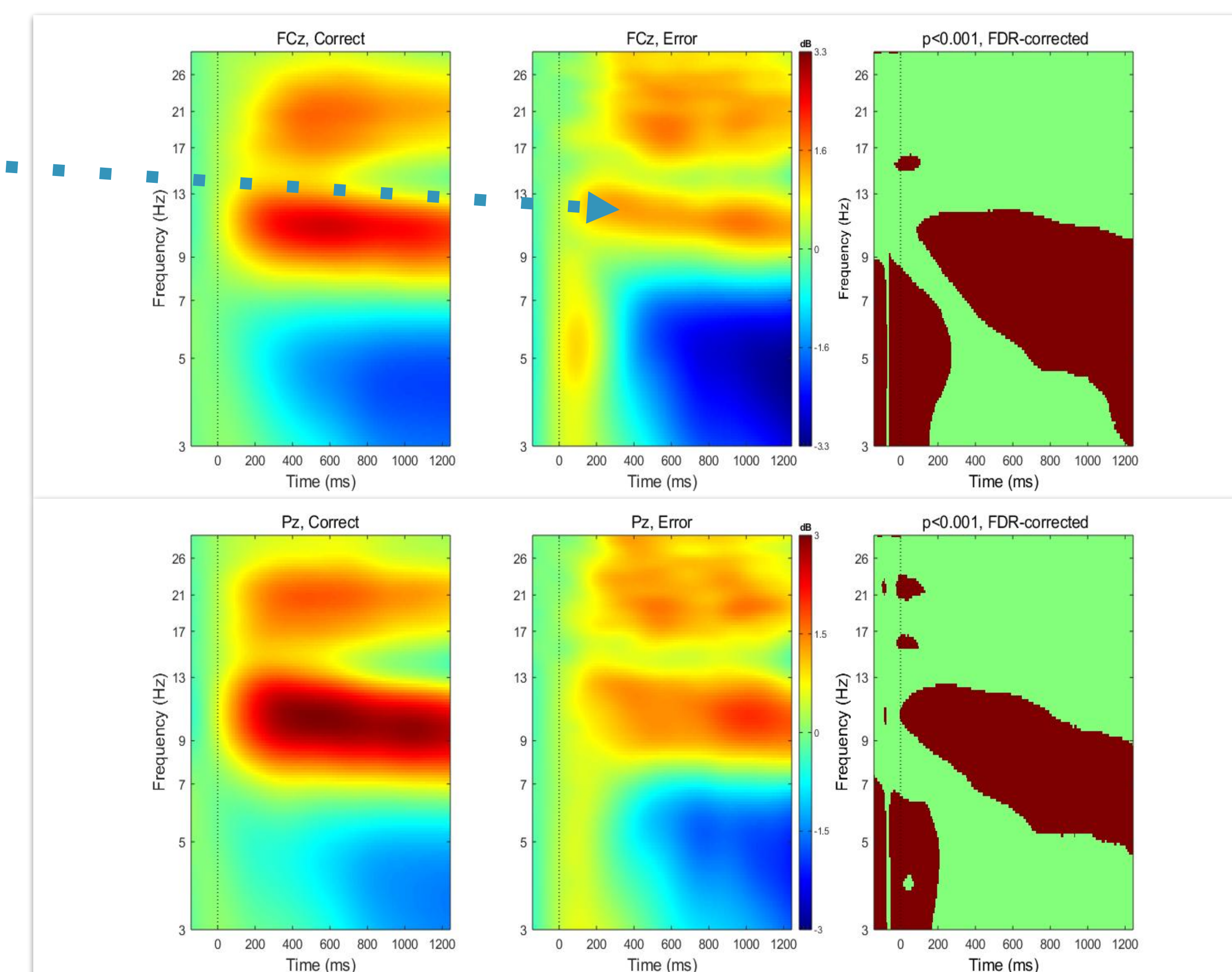
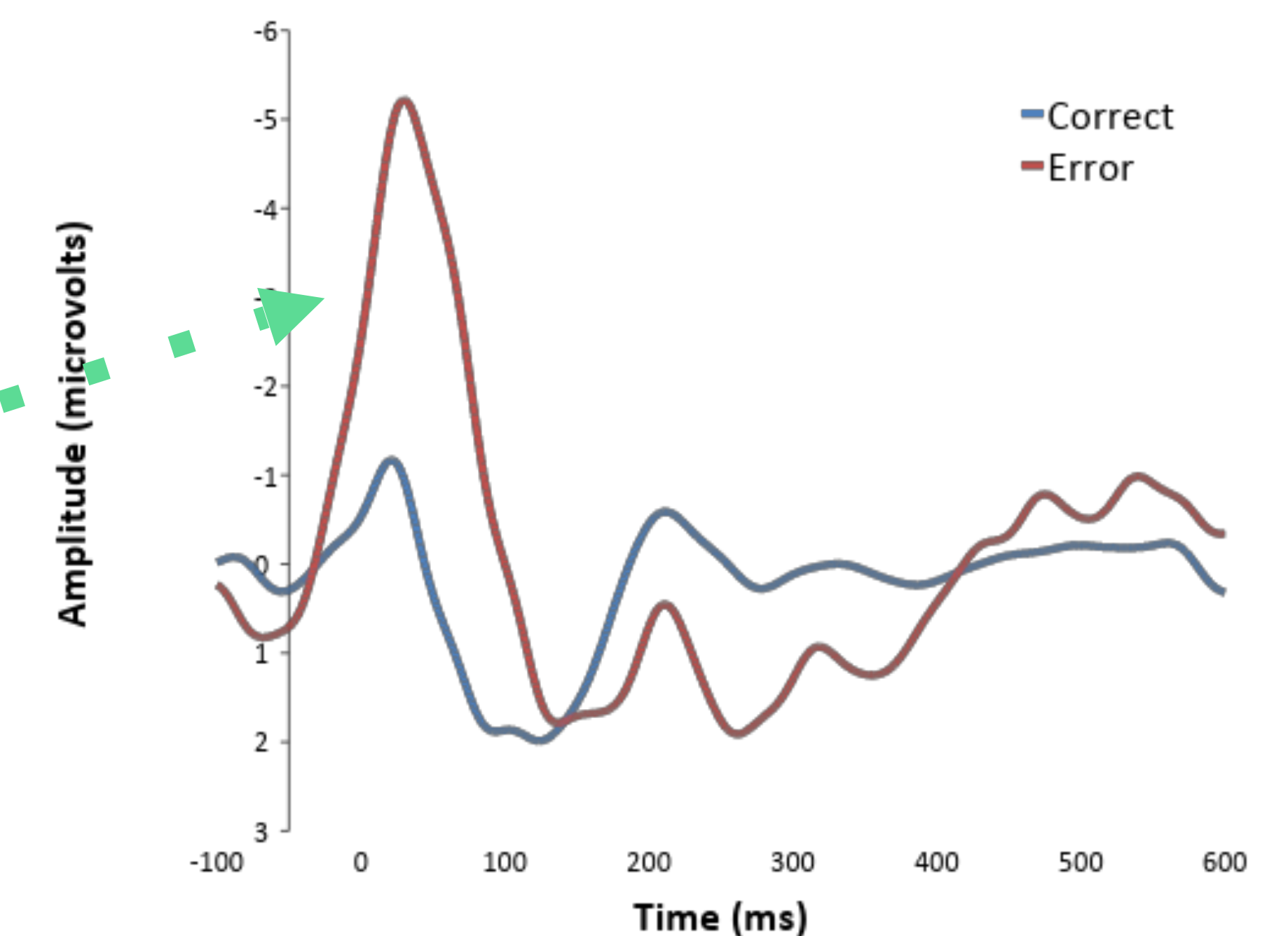
- Main effect of trial type, $F(1, 59) = 38.33$, $p < .001$. Higher alpha power following correct responses.
- These results support the expected pattern of alpha suppression following errors.(sustained)

Pupil diameter varied across periods.

- Main effect of period: $F(1, 59) = 75.07$, $p < .001$, depending upon the interaction of trial type x period: $F(2, 118) = 10.70$, $p < .001$, during the *wait* period, pupil diameter was greater following error trials compared to correct trials



All three of these measures show physiological responses immediately following error.



Conclusions and Next Steps

- Results were consistent with the literature and support a relationship between both indexes of arousal following error-detection.
- Future research will examine performance changes following error, to explore a potential predictive relationship.