

# Activity in the corrugator supercillii muscle as a novel index of punishment-guided cognitive control

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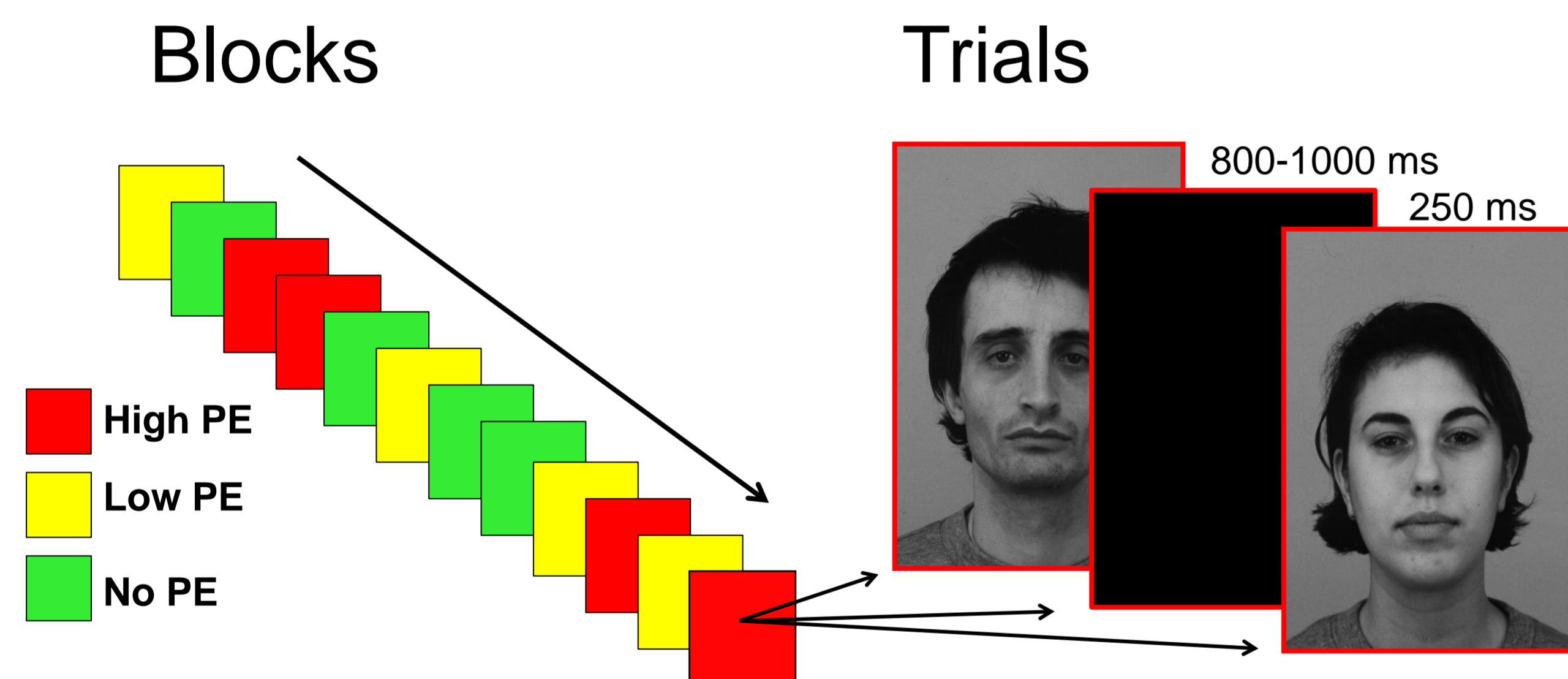
## Summary

Electromyographic (EMG) activity in the corrugator supercillii (CS) muscle of the upper face was highly sensitive to punishment expectancy (PE) and response errors in a two-choice response time task.

## Background

- Cognitive control is needed when mistakes are punished by potentially harmful consequences.
- Little is known about how motivation to avoid punishment affects cognitive control.
- Recently, the Adaptive Control Hypothesis (1) suggested that the anterior medial cingulate cortex (aMCC) control behavior in cognitively demanding and potentially dangerous situations.
- The aMCC output to the CS muscle of the upper face, which is involved in facial expressions of negative affect.
- **Hypothesis:** EMG activity in the CS would index the computational process attributed to the aMCC in a task which crossed cognitive conflict and PE.

## Method and Design

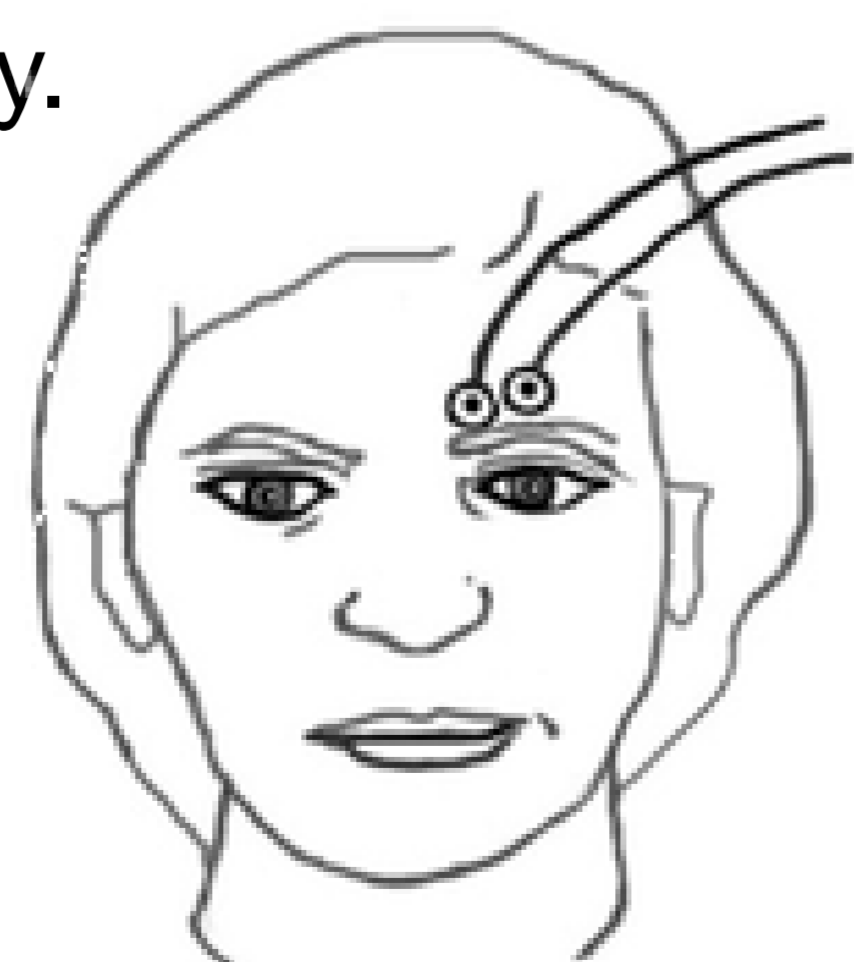


• Twenty-two participants performed a two-choice response time task with a **2 (Cognitive Conflict: Low/High) x 3 (Punishment Expectancy: No/Low/High)** mixed event/block design.

• PE was induced by instruction that any error commissions during PE blocks might be punished by electric shocks following the block.

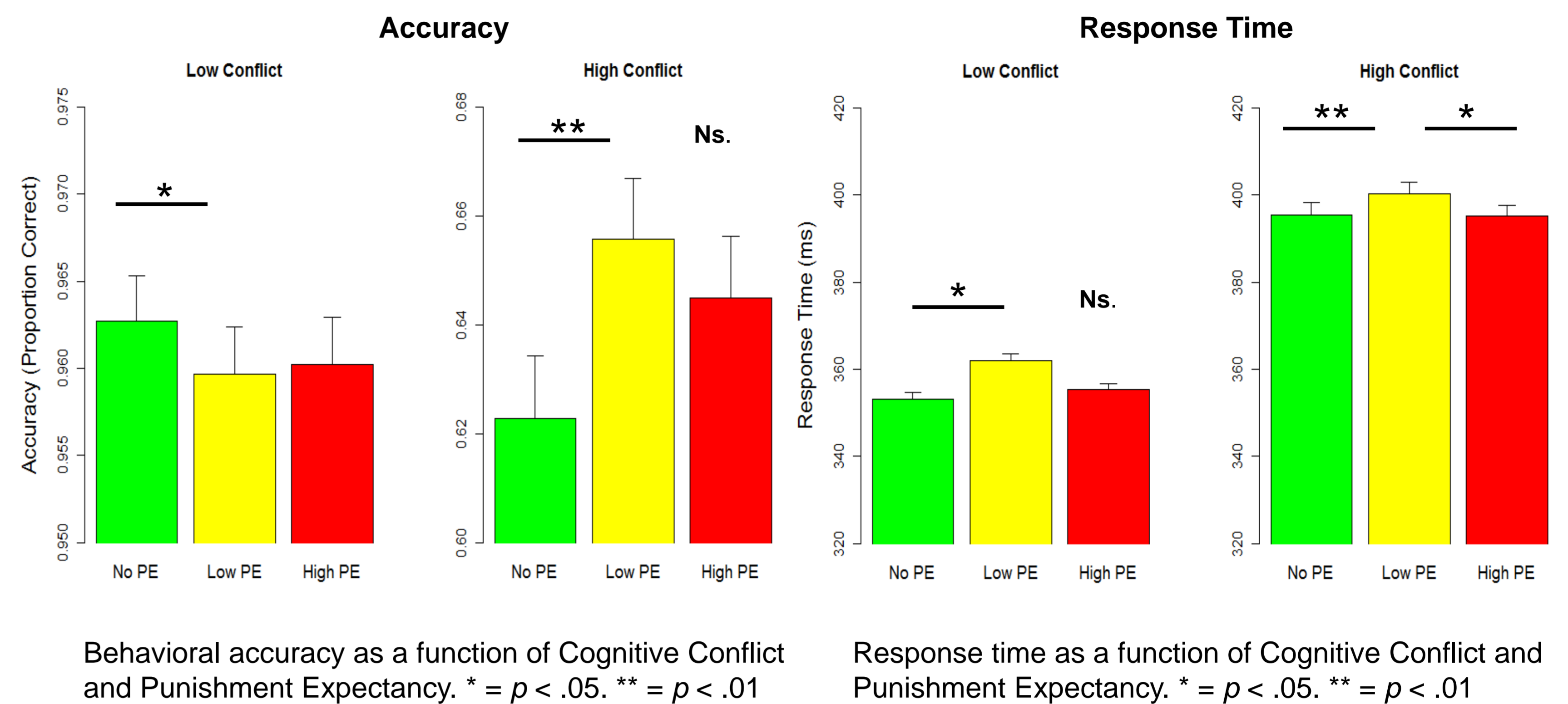
• However, the number of shocks was held constant across participants using a cover story.

• EMG activity was extracted trial-by-trial time-locked to the behavioral response.



## Results

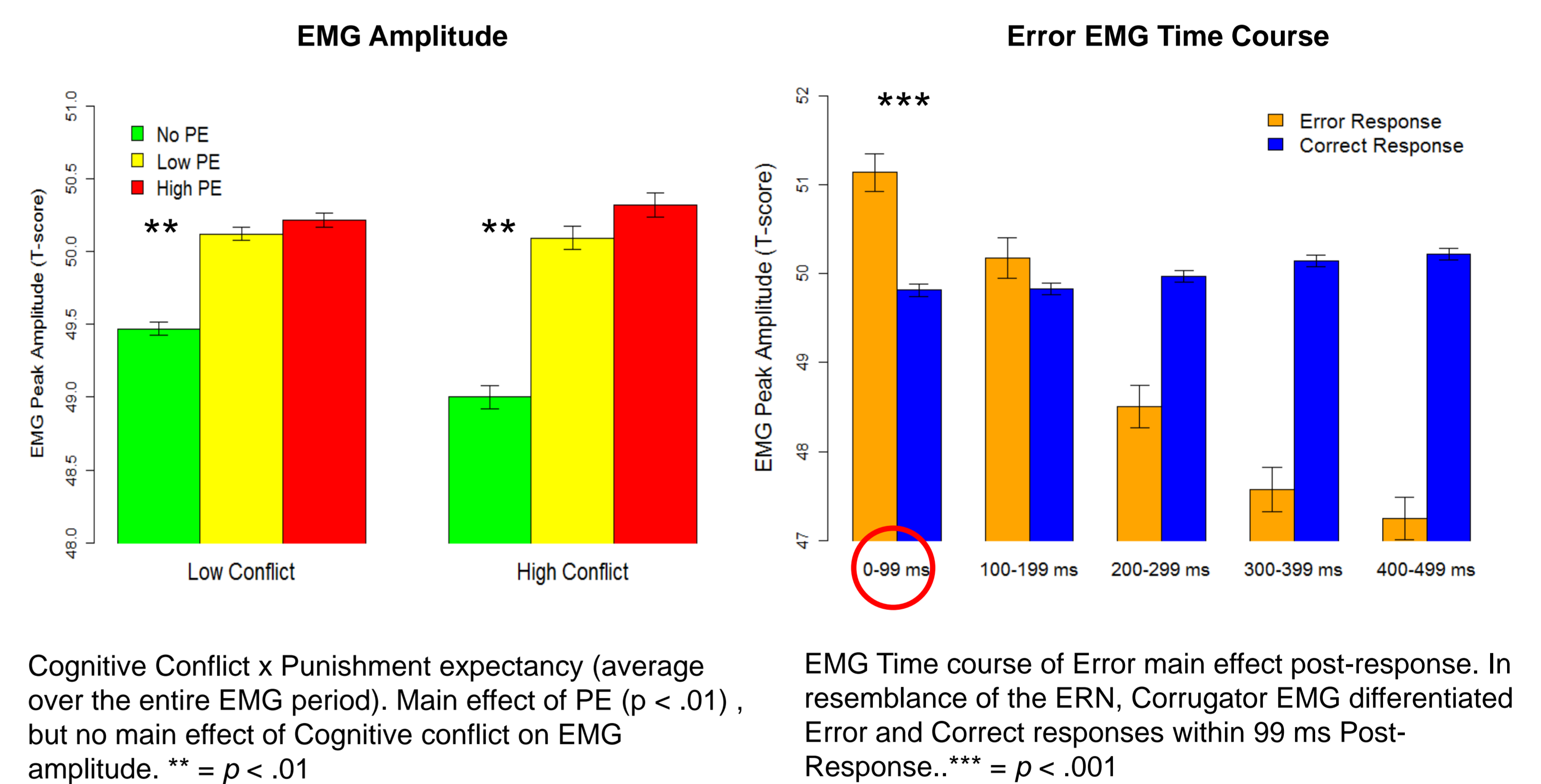
### Behavioral Performance



Behavioral accuracy as a function of Cognitive Conflict and Punishment Expectancy. \* =  $p < .05$ . \*\* =  $p < .01$

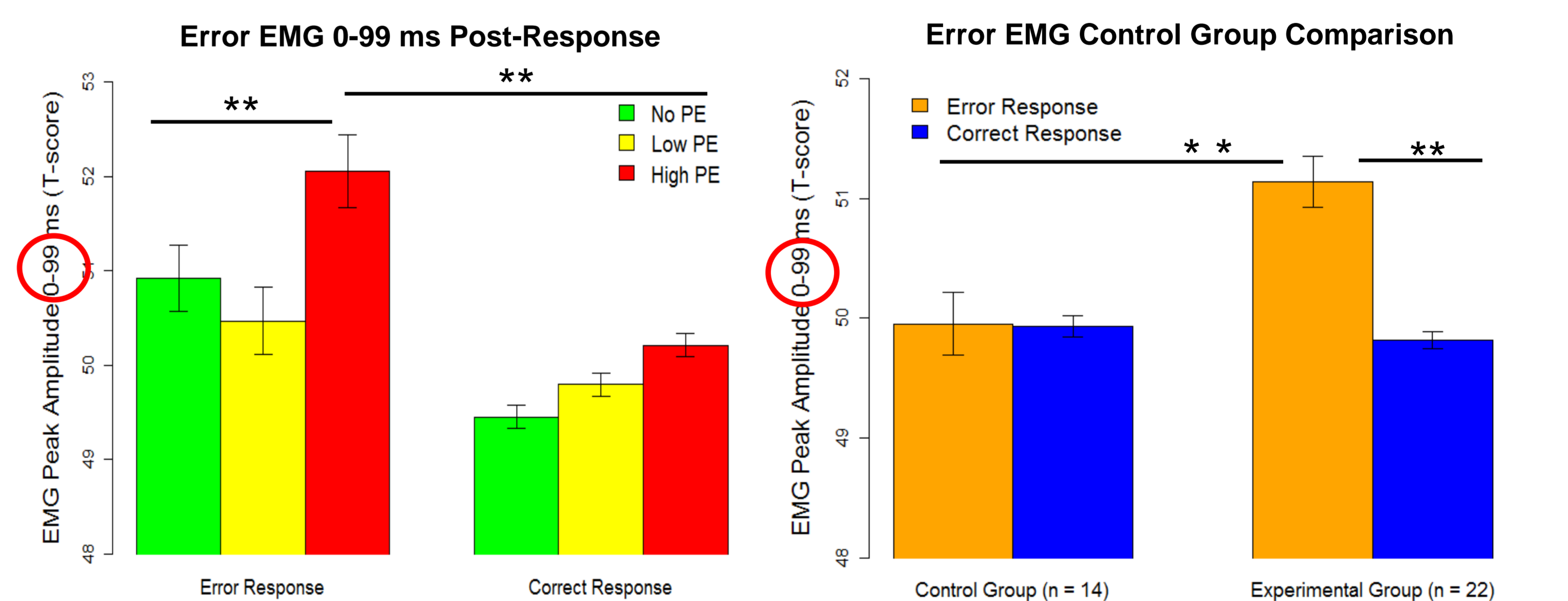
Response time as a function of Cognitive Conflict and Punishment Expectancy. \* =  $p < .05$ . \*\* =  $p < .01$

### EMG Results



Cognitive Conflict x Punishment expectancy (average over the entire EMG period). Main effect of PE ( $p < .01$ ), but no main effect of Cognitive conflict on EMG amplitude. \*\* =  $p < .01$

EMG Time course of Error main effect post-response. In resemblance of the ERN, Corrugator EMG differentiated Error and Correct responses within 99 ms Post-Response.\*\*\* =  $p < .001$



EMG Error x Punishment Expectancy interaction 0-99 ms Post-Response. \*\* =  $p < .01$

The effect of errors on EMG 0-99 ms Post-Response was driven by the expectation that error commissions would be punished by electric shocks (Experimental Group).\*\* =  $p < .01$ .

## Conclusion

- I. Corrugator EMG is amplified by response errors and increased punishment expectancy.
- II. The time course of error Corrugator EMG resembles the Error-related Negativity (ERN). This ERN likeness is enhanced by punishment expectancy.
- III. The results support the hypothesis that Corrugator EMG reflects the role of the aMCC in punishment-guided control (1).

### References

1. Shackman, A. J., Salomons, T. V., Slagter, H. A., Fox, A. S., Winter, J. J. & Davidson, R. J. (2011). The integration of negative affect, pain and cognitive control in the cingulate cortex. *Nature Reviews Neuroscience*, 12, 154-167