On the practice of replicating an electrophysiology study with the Center for Open Science

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Introduction

The Reproducibility Project (RP) has been organized by the Center for Open Science (COS), a non-profit organization seeking to establish infrastructure for scientists to make their research process more transparent.

The goal of the RP is to test the reproducibility rate of published research findings as well as to develop methods to improve the practice and dissemination of direct replication experiments.
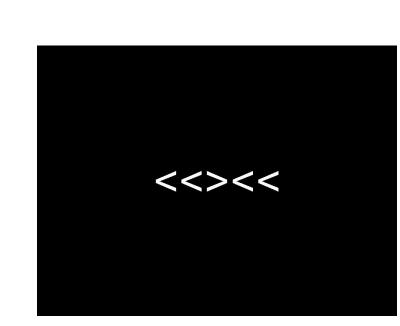
Here, we discuss first-hand experience in conducting a replication experiment as part of the RP, from experimental design and data analysis to the submission of a complete report to the COS.

The experiment involved electroencephalographic (EEG) and electromyographic (EMG) recordings associated with motivational aspects of error monitoring.

The key finding was the correlation between the error-related negativity (ERN; a sharp ERP deflection that peaks shortly after commission error) and the error-potentiated startle (EPS), i.e. magnitude of startle following a correct response subtracted from the startle magnitude following an error.

Methods

Participants were 42 undergraduate students (23 female, 19 male). A power analysis was performed in advance to estimate that 42 participants were needed to adequately test for the key effect (power = 80%).

Participants performed a modified flanker task in which they viewed five horizontally aligned arrows on a computer screen and were to specify the direction of the center arrow.

If participant's current and just previous response was correct: .04 probability of a 50ms 100dB white noise startle probe 300 ms post-stimulus. If participant's current or just previous response was incorrect: .5 probability of a startle probe.

Auditory stimulus was obtained from original author, but visual stimuli and program for presenting stimuli (Presentation) were generated independently for the replication and sent to original author for review.
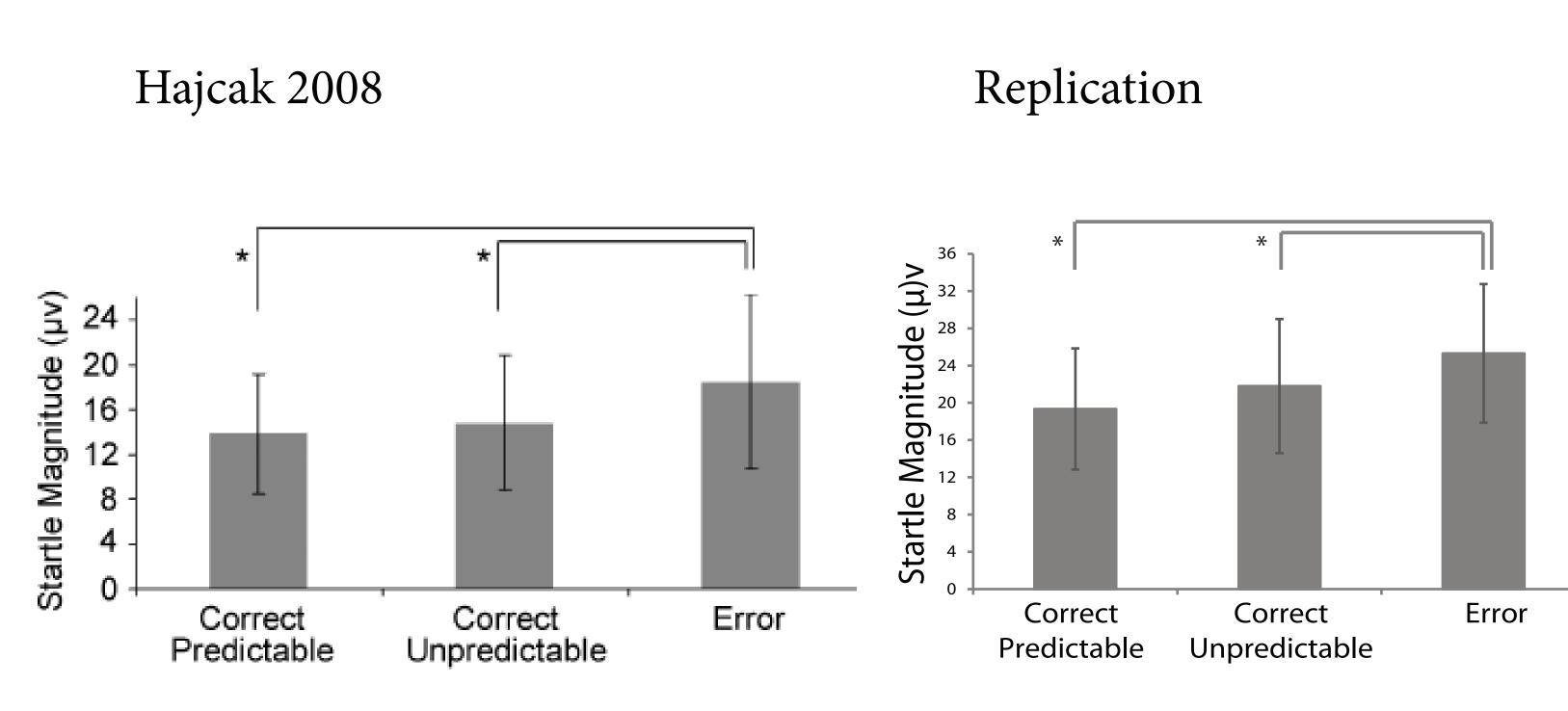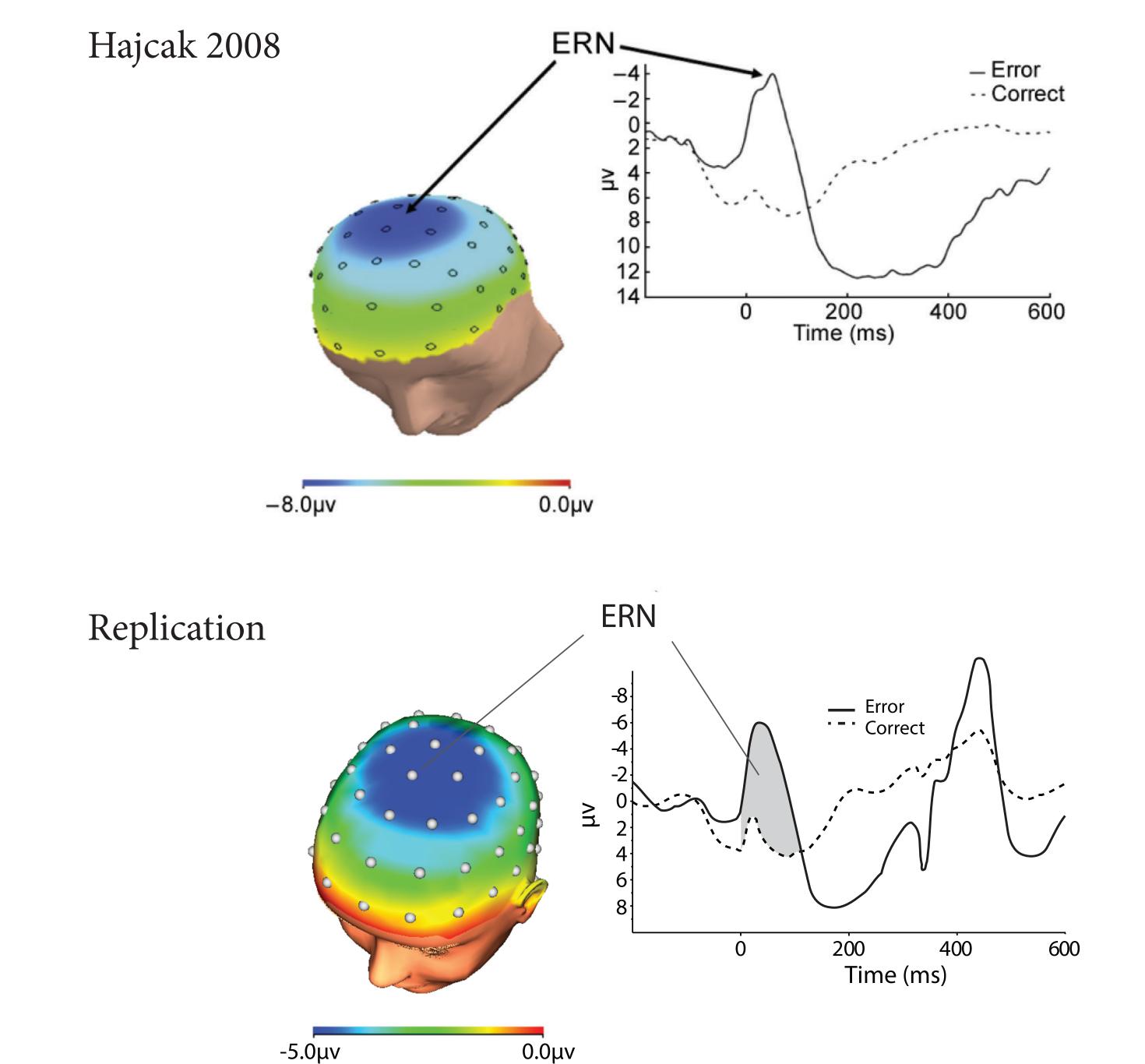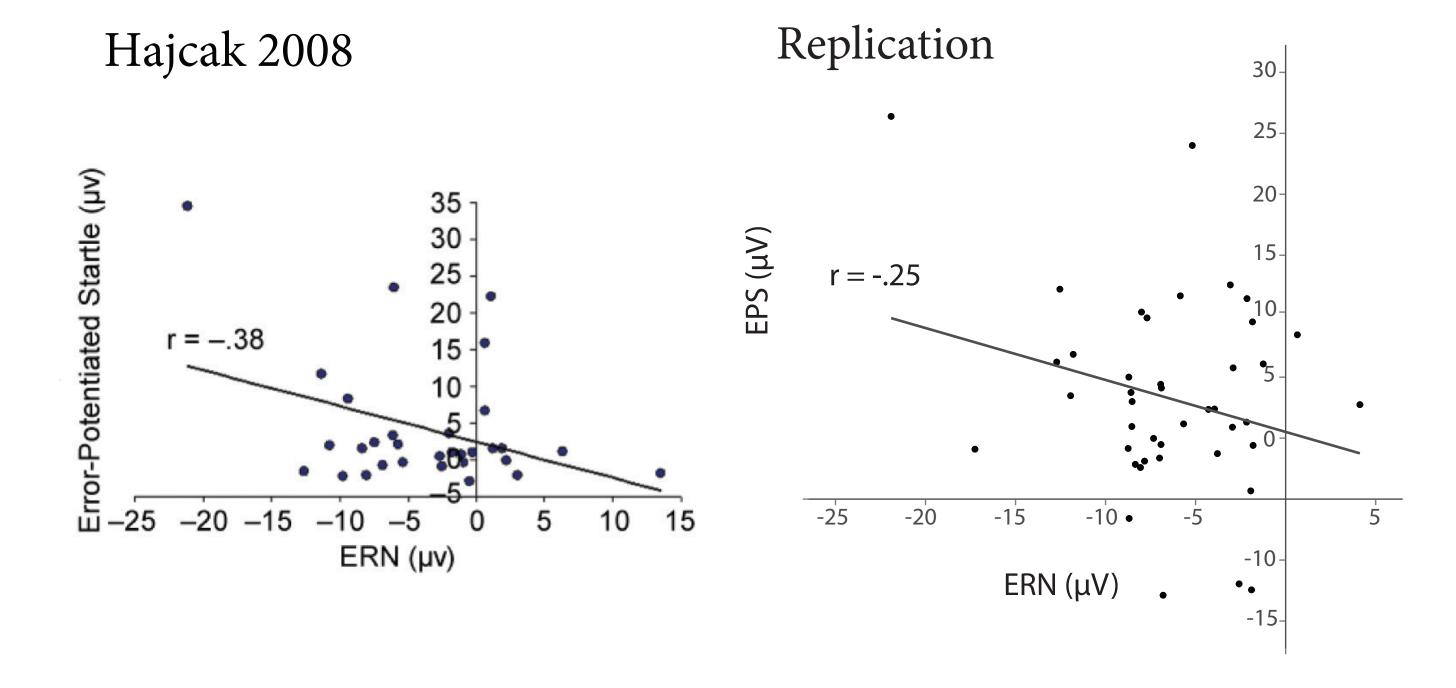
Results: Hajcak & Foti 2008 (Original) and Replication Experiments
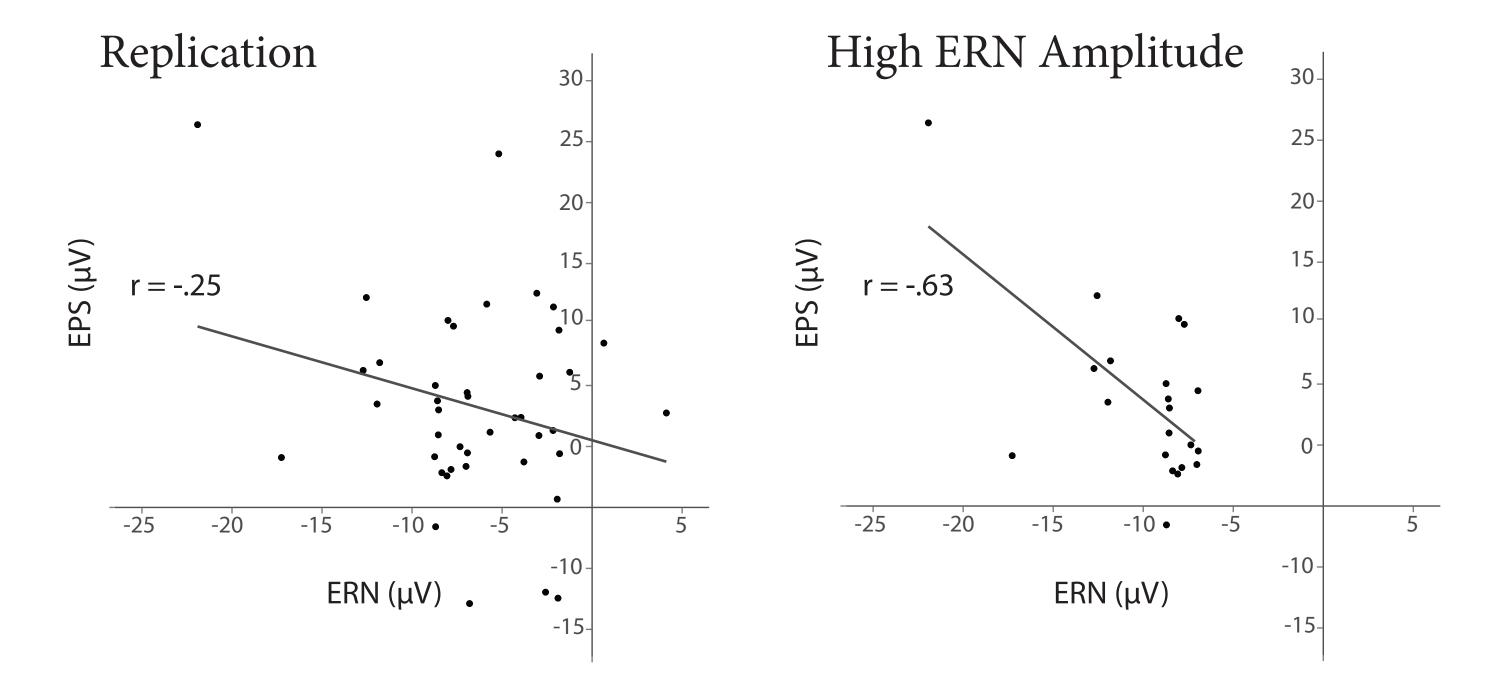

1 Comparison of mean startle magnitude by trial type from original and replication study. Error bars represent the 95% confident interval. Asterisks indicate significant differences between trial type, p < .01.
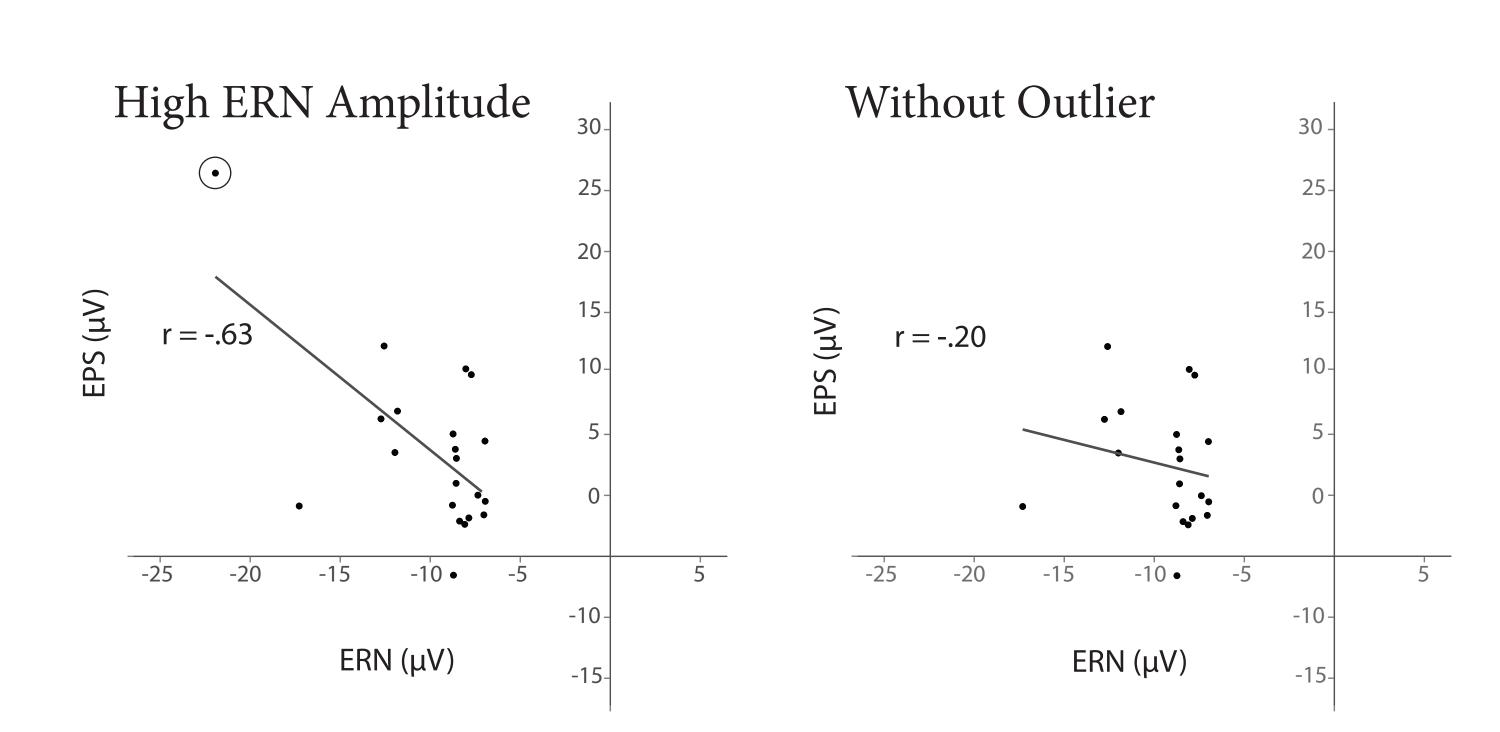

2 Comparison of mean event-related potentials time-locked to correct and erroneous responses at analogous electrode sites between the original (top) and replication studies (bottom). ERPs (right) plot voltage over time, where response occurs at 0 ms. The ERN's amplitude is calculated as the voltage difference between errors and correct responses in a 100-ms time window. The ERN is plotted over the scalp (left) and is maximal at the frontal-central midline.
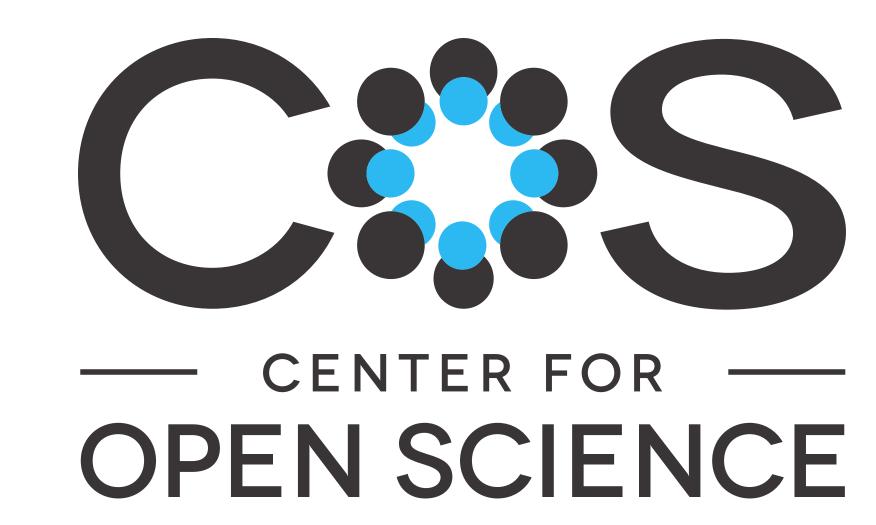

3 Left: Original scatterplot depicting the magnitude of the EPS as a function of ERN amplitude. Right: replication findings, not significant (p = .11)

4 Left: Replication scatterplot (identical to scatterplot in 3). Right: correlation plot including only participants whose ERN amplitudes were above median 6.91 μV, as performed in original author's replication.[3]

5 Left: Scatterplot of participants whose ERN amplitudes are above median 6.91 μV (identical to right in 4), outlier (EPS: 2.91 standard deviations from the mean; ERN: 3.27 sd) circled. Right: Same as left, but without outlier (p = .40).

Discussion

Results for the error-related negativity and for error-potentiated startle aligned closely with those of the original study, but the correlation between the EPS and ERN did not hold (3).

The original author has also faced difficulty replicating this finding.[3] A significant correlation between ERN amplitude and startle magnitude was only found among those participants whose ERN amplitude was above the median (4).

In the current replication, when an outlier (circled in 5) is removed, the correlation fails to be significant even when participants are split by the median.

The Future of Replications

The process of replication presented several interesting technical challenges: precisely designing the experiment required collaboration with the original author, who also provided crucial insight into the background of the research and his own replication.

A replication provides valuable training experience because it provides a structure for the student to adhere to and analyze, and because replications will be a cornerstone of their research professionally.

Finally, it also encourages the replicating researcher to consider in what ways his or her own research can be made more amenable to replication, both in the nature of incorporating documentation and archiving into the workflow, and in finding infrastructure to store and share that work.

To view the materials, stimuli, data, and other components of this project, visit http://bit.ly/osfmeli.

Selected References

[1] Hajcak, G., & Foti, D. (2008). Errors are aversive: defensive motivation and the error-related negativity. *Psychological Science, 19*(2), 103–108. PMID: 18271855. URL http://www.ncbi.nlm.nih.gov/pubmed/18271855

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[3] Riesel, A., Weinberg, A., Moran, T., & Hajcak, G. (2013). (in press). Time course of error potentiated startle and its relationship to error-related brain activity. *International Journal of Psychophysiology*.