# ERP Measures of Efficiency during Error Processing in Children

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## Introduction

- The error-related negativity (ERN) is a component of the ERP that is associated with acknowledged incorrect responses that occur in error monitoring tasks[1,2] and is associated with the anterior cingulate cortex (ACC).[3,4]
- Recent evidence indicates that the ERN amplitude in error trials increases with age, qualified by a nonlinear change (Figure 1).[5]
- The averaging method for revealing ERPs assume that the brain response to an event is unique, invariant and time-locked to the onset of the event in the same manner for each trial.
- However, given that the ERN is a result of several cognitive processing steps, the assumption of components being uniquely time-locked to the response is questionable.
- When considerable trial-to-trial variability of the ERN component exists, the amplitude measure of the averaged component will be reduced.[6]
- Thus, one plausible explanation for the lower ERN amplitudes observed at younger ages may be that there is increased variability in the timing of the cognitive and motor processes involved in monitoring and execution of incorrect responses.

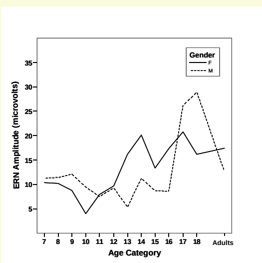


**Figure 1.** Age x Gender interaction in ERN amplitude measured peak-to-peak (P3r-to-ERN) in µV. Linear and quadratic age effects in the ERN accounted for 20.4% and 9.5% of the variance in the ERN, respectfully, F(1,122) = 31.2, p < .001 and F(1,121) = 16.4, p < .001. Baseline-to-ERN produced the same results.

## Purpose

- To determine if the use of an adaptive Woody filter technique[7] can adjust for the trial-to-trial variability of ERN in children and adults.
- To determine if trial-to-trial variability of ERN latency decreases with increasing age.
- To determine the nature of the developmental trend of the ERN after adjusting for latency variability.

## Method

### Participants – 5 Age Groups

- 8 year olds; n = 13
- 12 year olds; n = 18
- 15 year olds; n = 16
- 18 year olds; n = 12
- Adults (20-25 years); n = 19

### Procedure

- 480-trial 5-letter arrays visual flanker task
- Stimuli: 160 congruent (HHHHH, SSSSS) and 320 incongruent (HHSHH, SSHSS)
- Stimulus duration: 250 ms
- ISI: 1 s (age 10 to adult) 1.5 s (age 7-9)

### Electrophysiological Measurements

- 29 scalp sites, 2 bipolar eye monitors
- Recorded at 500 samples/s
- ERN scored at Cz (some Ss missed FCz)
- Re-referenced offline to averaged ears
- .23 to 30 Hz band pass (12 dB/octive)
- Segmented -600 to 800 ms
- EOG artifact rejection (+/- 100 µV)
- Baseline corrected from -600 to -400 ms

### Adaptive Woody-Filter Technique

For each individual:

- A template was obtained by averaging all segments
- For each segment, determine the minimum time shift needed to produce the maximum correlation coefficient by
- Calculating correlation coefficients across 150 data points (0-300 ms) to corresponding points in template
- Segmenting time shifted by incremental steps of a single data point up to +/- 150 points
- After each shift calculating a new correlation and record coefficient and time shift (i.e., lag)
- Adjusted ERP waveform obtained by shifting segments to align lag with zero time, then averaging

### Dependent Measures

- Mean of correlations
- Standard deviation of lag values
- ERN peak-to-peak amplitude

## Results

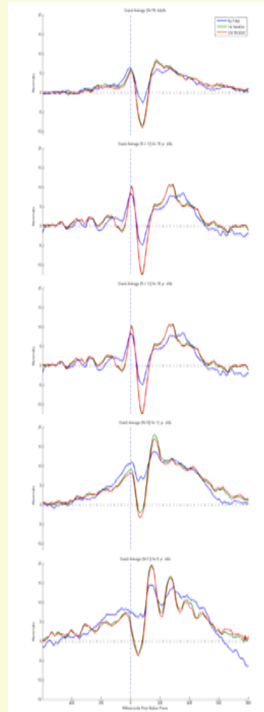

**Figure 2.** Grand averages of ERPs before and after adjusting for trial-to-trial latency variability. Blue lines represent before adjusting, green lines after first iteration of Woody filter and the red lines after second iteration.

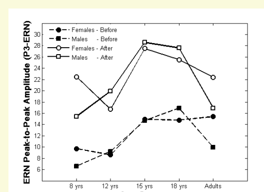


**Figure 5.** Mean peak-to-peak measures of the ERN component for each group prior to and after the first iteration of the Woody filter.

### Assessing the Utility of the Woody-Filter

- Mean correlations were found to significantly differ after adjusting for latency jitter; $F_{(1,67)} = 330.57$, $p < .00001$, $\eta^2_p = .83$ (see Figure 3).

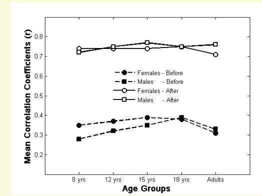


**Figure 3.** Mean of the mean correlations for each group prior to and after the first iteration of the Woody filter.

### Measuring Trial-to-trial Variability

- A significant linear trend with latency jitter decreasing as age increases; $F_{(4,67)} = 6.85$, $p = .0001$, $\eta^2_p = .29$ (see Figure 4).

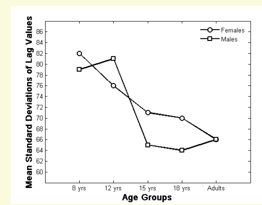


**Figure 4.** Means of the standard deviation measures for each group after the first iteration of the Woody filter.

### Changes in ERN Peak-to-Peak Amplitude

- Significantly larger ERN measures were found for all age groups after latency correction; $F_{(1,67)} = 76.75$, $p < .00001$, $\eta^2_p = .53$.
- The main effect for Age Group was also found to be significant, $F_{(4,67)} = 3.34$, $p = .015$, $\eta^2_p = .17$
- The Latency-Correction by Group interaction was also significant; $F_{(4,67)} = 3.34$, $p = .015$, $\eta^2_p = .17$ (see Figure 5).

## Conclusions

- Though a simple computational procedure, the adaptive Woody-filter technique does allow for a straightforward measurement of the trial-to-trial latency variability present in the ERN component of each participant regardless of his/her age.
- The developmental trend found for the trial-to-trial latency variability of the ERN appears to be linear in nature where the variability decreases as age increases. This variability may be due to variations in the timing of the activation and the coordination of any or all of various neural circuits responsible for attentional control, stimulus recognition, response planning, motor activation and response evaluation. Differences in motor performance control and even muscle development of the index fingers used to press the button may also contribute to the varying amounts of desynchronization of the ERN component with the button press .
- After latency correction was applied, significantly larger peak-to-peak amplitudes of the ERN measures were found across all age groups. However, the adjustment does not appreciatively account for the non-linear trend originally observed in developmental trajectory of the ERN amplitude. On the contrary, adjusting for jitter sharpened the quadratic trend as seen graphically and verified by statistical analyses which show that the linear tread was no longer significant after adjusting for latency jitter.

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