Developmental changes in ERP measures of external and internal performance monitoring across middle childhood

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Background

Performance monitoring processes are critical for learning and behavioral adaptation (Tamnes et al., 2013), and are supported by external feedback (indexed by the feedback-related negativity; FRN), and internal error monitoring (indexed by the error-related negativity; ERN) (Ferdinand & Kray, 2014).

Across childhood:

- The neural regions that contribute to performance monitoring undergo significant neural maturation (Gogtay et al., 2004; Shaw et al., 2008).
- Research has shown that FRN amplitude decreases (Crowley et al., 2013), and the ERN amplitude increases (DuPuis et al., 2015).

Cross-sectional research theorizes that the utilization of external feedback processing is reduced in favor of internal error monitoring processes. However, little research has longitudinally examined the concurrent changes of these neurophysiological indices and performance monitoring across childhood.

Study Aims and Hypotheses

In the current study, we examine how FRN and ERN amplitudes change from kindergarten to 2nd grade, and whether the associations between these components also changes across this time.

We hypothesized that over middle childhood ERN amplitude would increase and FRN amplitude would decrease, and that a more negative ERN amplitude would predict less negative FRN amplitude.

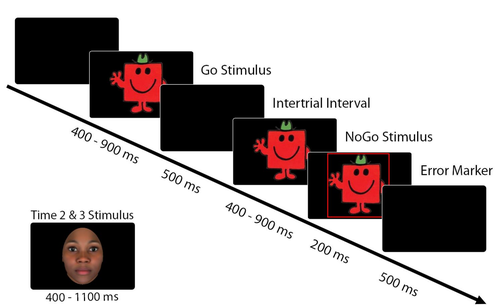
Methods

Participants of the PATHS to Success Project (Gatzke-Kopp et al., 2012)

- 339 children (M_{age} = 6.05, SD_{age} = 0.38; 64.3% male) from economically disadvantaged urban regions assessed annually from kindergarten to 2nd grade.
- 70% African American, 9% Caucasian, 20% Hispanic, 1% Asian.

EEG data collection

- Data recorded during an incentivized Go/No-Go task using a 32 Channel Biosemi ActiveTwo System.
- 3 block design with ≈ 30% No-Go trials.
- No-Go error rate between 40 – 60 %.

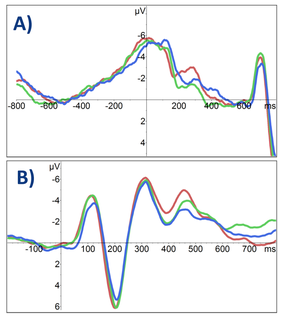


ERP Measurement

Derived at Fz for erroneous No-Go trials.

- ERN derived as the µV difference between the most positive peak -100-0ms pre-response, and the most negative peak in the 0 –100ms post-response.
- FRN was derived as the most negative peak between 250–350ms post feedback stimulus onset.

Grand average ERN (a) and FRN (b) waveforms across all time points



Results

Table 1. Means, standard deviations, and correlations of study variables

	Mean (µV)	SD	1	2	3	4	5	6
1. ERN K	-4.84	3.05	--					
2. ERN G1	-5.38	3.08	0.07	--				
3. ERN G2	-5.75	3.17	**0.17***	0.15	--			
4. FRN K	-7.94	5.26	**0.14***	0.05	0.06	--		
5. FRN G1	-7.53	5.63	0.05	0.06	-0.02	**0.36†**	--	
6. FRN G2	-7.65	6.14	-0.06	0.10	-0.04	**0.48†**	**0.43†**	--

Note: Marked cells present the within time point correlations between the ERN and FRN. K = Kindergarten; G1 = 1st Grade; G2 = 2nd grade; *p < .05; †p < .001

Models 1 & 2: Linear growth models for ERPs from kindergarten to 2nd grade

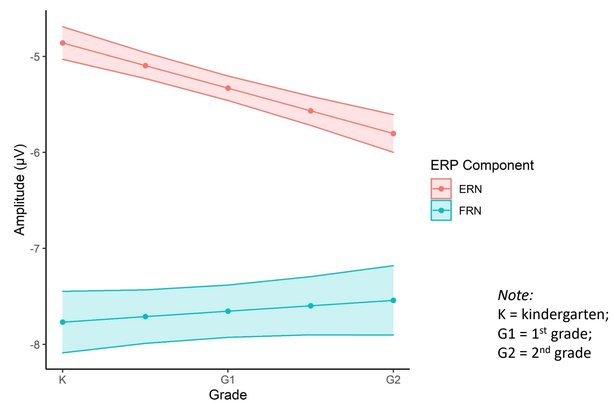


Table 2: Estimation of coefficients and standard errors for models 1 & 2

	ERN Fz		FRN Fz	
Predictors	*b* (*SE*)	*t*	*b* (*SE*)	*t*
Intercept	**-4.62 *(0.29)***	**-15.94†**	**-8.23 *(0.52)***	**-15.90†**
Sex	-0.35 *(0.36)*	-0.98	0.60 *(0.64)*	0.94
Time	**-0.63 *(0.24)***	**-2.68#**	-0.10 *(0.38)*	-0.26
Time:Sex	0.22 *(0.29)*	0.77	0.38 *(0.46)*	0.84

Note: Unstandardized coefficients. Time was treated as continuous. Sex (female) was dummy coded as 0 to serve as a reference group. #p < .01; †p < .001

- On average ERN amplitude became increasingly negative over time, and FRN amplitude showed no change.

Model 3: Association between ERN and FRN amplitude from kindergarten to 2nd grade

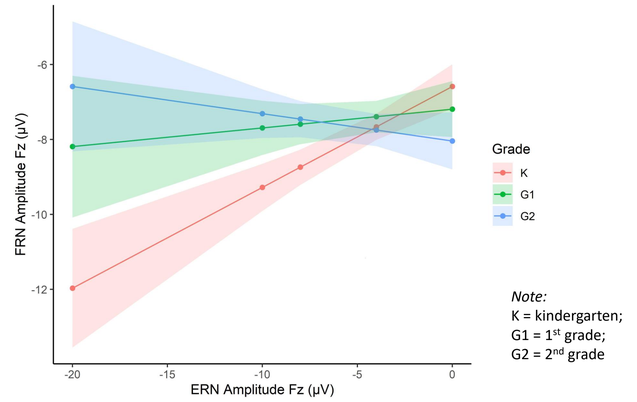


Table 3: Estimation of coefficients and standard errors for Model 3

	Outcome: FRN amplitude	
Predictors	*b* (*SE*)	*t*
Intercept	**-7.32 (0.69)**	**-10.58†**
Sex	1.08 (0.59)	1.84
Grade 1	-0.60 (0.89)	-0.67
Grade 2	-1.45 (0.90)	-1.62
ERN amplitude	**0.27 (0.10)**	**2.65#**
Grade 1:ERN amplitude	-0.22 (0.16)	-1.39
Grade 2:ERN amplitude	**-0.34 (0.15)**	**-2.25***

Note. Unstandardized coefficients. Reference groups dummy coded as 0 include sex (female) and grade (kindergarten). *p < .05; #p < .01; †p < .001

- In kindergarten a more negative ERN predicted a more negative FRN.
- In 2nd Grade a more negative ERN predicted a less negative FRN.

Conclusions

Children may initially incorporate both external and internal information in monitoring behavior, but ***shift to*** a stronger reliance on ***internal monitoring with age***.

- Feedback salience may be retained as a means of confirmation, whereby the classification of feedback provides a simplistic metric to evaluate internal models.
- Individual differences related to this transition may have meaningful implications for children's cognitive development.

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