Error-related Negativity (ERN/Ne) in Children and Adolescents

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Summary

The error-related negativity (ERN or Ne) is a negative ERP component seen in error trials that is most prominent when the ERPs are time-locked to the response. The ERN has been reported as diminished in the elderly but we have seen no reports of the ERN in childhood.[1] We examined the ERN in 82 children (7-17 y) and 22 young adults (19-25 y). The ERN was recorded during a standard 480-trial visual flanker task. The ERPs were time-locked to response and the ERN amplitude and latency were scored in error trials. Age correlated strongly with correct RT (r = -.76, p<.0005), incorrect RT (r = -.67, p<.0005) and with the difference (r = -.29, p<.02, calculated by linear regression). Age correlated significantly with ERN amplitude (r = -.38, p<.0005) and latency (r =.45, p <.0005) at Cz, less so at Pz, and not at Fz. Thus, the ERN is attenuated in children and the latency increases with age. The latter finding is consistent with reduction in response latency and impulsivity with age. Individual differences indicate that despite the children's attenuated ERN amplitudes, some children at each age level have adult-like ERNs.

Introduction

The ERN is produced during error monitoring tasks, and can be influenced by response strategy or style. Previous work has shown that it is greater in OCD patients, is diminished in individuals demonstrating more impulsive responding, and is reduced in certain contexts amongst individuals very low in socialized beliefs.[2,3,4] Dipole localization identifies the anterior cingulate cortex as the physiological generator.[5,6] We were interested in seeing whether the ERN would be different in younger children despite their ability to perform the task. If this were the case, then we would have to conclude that children process errors differently as they mature.

Method

Participants:

• 82 children aged 7 to 17 years; 22 adults 19-25 years (see Table 1).

Procedure:

- 480-trial 5-letter arrays visual flanker task[7]
- 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
- Fz, FCz, Cz, Pz scored (some Ss missed FCz so we are omitting analyses at this site here)
- EOG artifact rejection (+/- 100 µV)
- referenced offline to averaged ear
- recorded at 500 samples/s
- .23 to 30 hz band pass

Table 1 - Participants

Table 1. Current Number of Participants

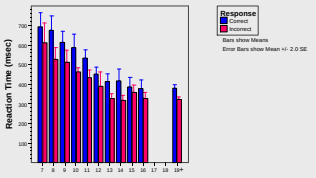
		Gender		
		F	M	Total
Age	7	3	4	7
	8	8	2	10
	9	10	5	15
	10	4	4	8
	11	7	2	9
	12	6	6	12
	13	5	2	7
	14	3	1	4
	15	3	1	4
	16 - 17	4	2	6
	Adults	13	9	22
Total		66	38	104

Results

Behavioral Data

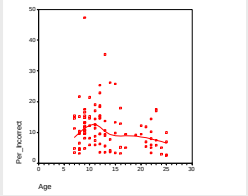
Reaction times (see Figure 1): RT correlated with age in correct trials (r = -.76, p <.0005) and incorrect trials (r = -.67, p <.0005). Repeated measures ANOVA showed incorrect responses were significantly faster than correct responses ($F_{1,89}$ = 152.8, p <.0005) and a significant difference in age group ($F_{10,89}$ = 20.4, p<.0005) and an interaction between RT of response type and age groups ($F_{10,89}$ = 2.91, p = .003).

Figure 1 - Reaction time in ms by age



Error rates (see Figure 2): Percent errors were not significant across ages ($F_{10,89}$ = 1.28, n.s.).

Figure 2 - Error rate by age



Electrophysiological Data

ERN amplitude correlates with age (r = -.38 p < .0005) and ERN is significantly different across age groups ($F_{10,89}$ = 4.09, p < .0005) See Figures 4-6.

Figure 3 - ERN amplitude by age-group (all adults in the 20-year-old group) at Cz

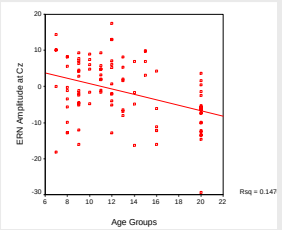


Figure 5 - Average waveform at Cz for each age group

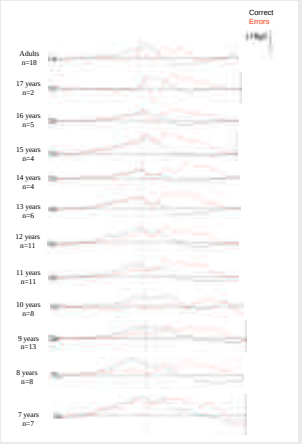
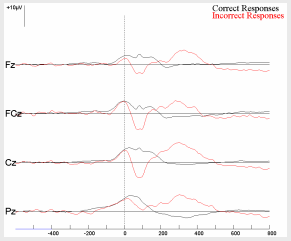


Figure 4 - Average for adults (age 19-25)



The ERN waveforms are much more variable in children than adults (see figures 7-9)

Figure 7 - Selected waveforms from individual adults (age 19-25) at Cz. Almost all adults had a strong ERN and Pe, one of the smallest shown last in this figure.

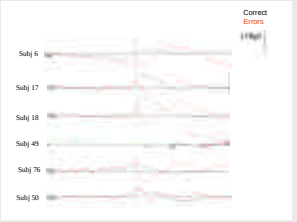


Figure 8 - Selected waveforms from individual adolescents (ages 13-17) at Cz. Adolescents sometimes exhibit an ERN, and always a Pe.

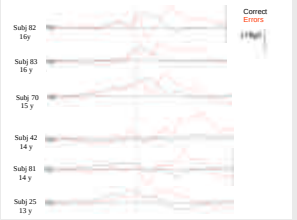
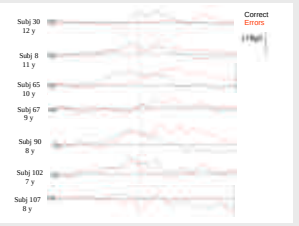


Figure 9 - Selected waveforms from individual children (ages 7-12) at Cz. Younger children hardly ever exhibit a strong ERN, always a Pe, with a rare strong ERN, shown last in this figure.



Conclusions

1) Older children sometimes show an ERN and most always a Pe.

2) Younger children hardly ever show a strong ERN but most always a Pe.

3) Children are able to perform the task as adults. They show similar error rates.

4) Children know that they are making errors but children have different ERPs to error responses. Further analyses are needed to determine possible differences in the nature of error monitoring reflected in the ERPs.

References

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