ERPS AND NEUROPSYCHOLOGICAL TASKS SHOW PREFRONTAL MATURATION IN ADOLESCENTS

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Summary

We examined the relationship between changes of the Contingent Negative Variation (CNV) and functional changes in performance on 15 behavioral tasks (9 associated with "prefrontal" functions, 6 with "posterior" functions, plus estimated IQ). A total of 122 participants (27 adults 19-25 y and 95 children 7-17 y) performed a CNV paradigm with 40 Go and 40 Nogo trials. Average amplitude of the CNV 800-2000 ms epoch on go trials correlated with age (r = -.52, p<.0005). Similarly, almost all the behavioral tasks correlated with age (r = .42 - .82, p<.001). In order to see which aspects of cognitive performance are specific to CNV independent of age, we correlated CNV with performance partialling out age. This produced significant correlations between CNV and working memory (1-back and dual task), word recall, vocabulary, and some measures of perceptual-motor speed, but no evidence of correlation with measures of simple attention (Digit Span) or perception (line orientation). Stronger effects are found when the correlations are restricted to subjects in the younger age ranges. This suggests that there are factors other than age influencing CNV amplitude in preadolescents and adolescents. The CNV has been associated with generators in the prefrontal cortex, and present results support the construct of the CNV reflecting good performance of functions associated with this region, replicating earlier work that did not include such a broad age span.

Introduction

The CNV is a slow negativity in the EEG that appears during the anticipation period between a warning stimulus (S1) and a target-response "imperative" stimulus (S2). Its neural generators are thought to be in the prefrontal cortex.[1,2] The paradigms used to evoke the CNV are very simple behaviorally, and can be easily performed well by young children. However, there is now considerable evidence that the prefrontal cortex is relatively late to mature in children. Therefore, we were interested in seeing whether the CNV would relate to behavioral tasks that are associated with "prefrontal" functioning and not associated with tasks reflecting more "posterior" functioning.

Method

Participants:

- 95 children aged 7 to 17 years; 27 adults 19-25 years (see Table 1).

Table 1. Current Number of Participants

		Gender		
		F	M	Total
Age	7	3	7	10
	8	8	3	11
	9	12	6	18
	10	5	4	9
	11	7	2	9
	12	8	5	13
	13	5	2	7
	14	4	1	5
	15	5	1	6
	16 - 17	5	2	7
	Adults	17	10	27
Total		79	43	122

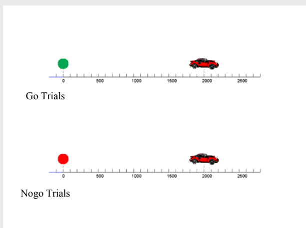
Behavioral Testing:

- 9 tasks associated with "prefrontal" functions
- 6 tasks associated with "posterior" functions

EEG Procedure:

- S1-S2 interval = 2 s
- 40 Go and 40 Nogo trials
- Stimulus duration = 250 ms
- Time between trials = 2 to 7 s
- S1 = circle; S2 = racing car (see Figure 1)
- Go = green warning circle
- Nogo = red warning circle

Figure 1 - Illustration of the stimuli presentation



Electrophysiological Measurements:

- 29 scalp sites, 2 bipolar eye monitors
- averaged amplitude scored for four 400 ms and one 1200 ms epochs (400-800, 800-1200, 1200-1600, 1600-2000, 800-2000 ms) at Fz, Cz, Pz
- EOG artifact rejection (+/- 100 μV)
- eye regression for subjects with fewer than 9 trials after artifact rejection
- rereferenced offline to averaged ears
- recorded at 500 samples/s
- .03 to 30 hz band pass

Results

Behavioral Data

Estimated IQ Scores were not significantly different across age groups ($F_{10,114}$ = 1.13, p = 3.35). Most of the behavioral tests significantly correlated with age (see Table 2).

Table 2 - Correlations of scores on behavioral tests with age.

	r values
Estimated IQ	
Total IQ	.16
IQ Vocabulary	**.80*****
IQ Matrix Reasoning	**.60*****
"Prefrontal" Function	
Word Recall	**.42*****
Working Memory 1-back	**.59*****
Working Memory Dual Task	**.63*****
Working Memory 2-back	**.70*****
Stroop Color Words	**.79*****
Mazes	**.52*****
Embedded Figures	**.59*****
Digit Span Backward	**.66*****
Search for A's	**.71*****
"Posterior" Function	
3 Number comparison	**.29****
1 Number comparison	.005
Cross off A's	**.82*****
Digit Span Forward	**.66*****
Line Orientation	**.60*****
Reaction Time Working Memory	**.57*****

* p < .05 ** p < .01 *** p < .005

Electrophysiological Data

CNV in Go trials should become more negative with age and maturation, so we would expect negative correlations between CNV and age. Go trials CNV amplitude correlated significantly with age for all epochs at Cz (r = -.43, -.58, -.42, -.47, -.52, all p<.0005 for the 5 epochs) and somewhat less so at Fz and Pz. The Nogo trials did not correlate with age for any of the epochs or sites except for the first two epochs which may be influenced by P300.

Go trials CNV average amplitude was significantly different from Nogo trials for the full epoch ($F_{1,111}$ = 10.63, p = .001) and was significantly different across age groups ($F_{10,111}$ = 4.43, p < .0005; see Figure 2). A significant interaction between go/nogo and age ($F_{10,111}$ = 2.60, p = .007) was found. This interaction is due to a number of the children exhibiting a reversal of go and nogo trials (i.e., go waveform is more positive than nogo waveform; see Figure 3).

Figure 2 - Average waveforms for age groups with some groups collapsed.

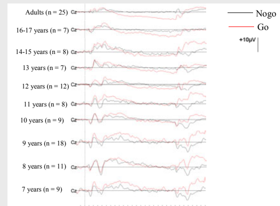
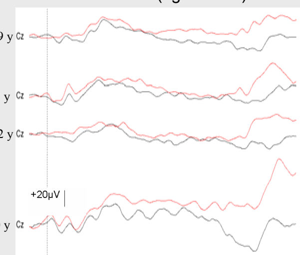


Figure 3 - Selected waveforms from individual children (ages 9 -13) at Cz.



Relationship of EEG and Behavioral Data

CNV in Go trials becomes more negative with age so we expect negative correlations between CNV and performance. Go trials CNV amplitude correlated with a number of the behavioral tasks associated with "prefrontal" functioning and less so with tasks associated with "posterior" functioning (see Table 3).

Table 3 - Correlations (r values) of scores on behavioral tests with averaged CNV amplitude.

	Epoch Durations				
	400-800	800-1200	1200-1600	1600-2000	800-2000
Estimated IQ					
Total IQ	**-30*****	**-.22***	-.07	-.08	-.13
IQ Vocabulary	**-.21***	**-.35*****	**-.28****	**-.27***	**-.32*****
IQ Matrix Reasoning	-.03	-.11	.05	.05	-.01
"Prefrontal" Function					
Word Recall	-.11	**-.29****	**-.28****	**-.25***	**-.29****
Working Memory 1-back	-.05	**-.43*****	**-.31*****	**-.21***	**-.34*****
Working Memory Dual Task	-.16	**-.35*****	**-.36*****	**-.31*****	**-.36*****
Working Memory 2-back	-.07	**-.24***	-.16	-.06	-.16
Stroop Color Words	-.11	-.16	-.12	-.10	-.13
Mazes	-.12	-.15	-.11	-.14	-.14
Embedded Figures	.12	-.08	.01	.05	-.01
Digit Span Backward	-.03	.01	-.10	-.15	-.09
Search for A's	-.13	**-.25***	**-.21***	-.19	**-.23***
"Posterior" Function					
3 Number comparison	-.20	-.17	**-.25***	**-.35*****	**-.27***
1 Number comparison	.09	.07	.14	**.24***	.16
Cross off A's	-.02	**-.25***	**-.22***	-.19	**-.24***
Digit Span Forward	-.00	-.09	-.02	-.04	-.05
Line Orientation	.01	-.05	-.01	.03	-.01
Reaction Time Working Memory	-.03	.18	.14	.12	.15

* p < .05 ** p < .01 *** p < .005

Conclusions

1. Go trials, which demand sustained attention, did not always generate the negative amplitude in young children as seen in adults and older children.
2. Younger children can sustain attention (since they complete the task well) but use mechanisms that are different from those of adults.
3. The degree to which children produced a relatively normal CNV on the Go trials correlated with a variety of cognitive measures suggesting that a major component to intellectual development in adolescents is the growth of the frontal lobe attentional system.
4. The neurocognitive underpinnings of sustained attention shows a remarkably slow maturation, with considerable immaturity even at 11 years of age.
5. These results support the prevalent developmental model of late maturation of the prefrontal cortex.

References

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