ERPS AND NEUROPSYCHOLOGICAL TASKS SHOW PREFRONTAL MATURATION IN ADOLESCENTS

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Summary

We examined the relationship between changes of the Contingent Negative Variance (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.

Method

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

Table 1. Current Number of Participants

<table>
<thead>
<tr>
<th>Gender</th>
<th>F</th>
<th>M</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age 7</td>
<td>7</td>
<td>7</td>
<td>14</td>
</tr>
<tr>
<td>8</td>
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<tr>
<td>9</td>
<td>12</td>
<td>6</td>
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<td>10</td>
<td>5</td>
<td>4</td>
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</tr>
<tr>
<td>11</td>
<td>7</td>
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<td>5</td>
</tr>
<tr>
<td>15</td>
<td>5</td>
<td>1</td>
<td>6</td>
</tr>
<tr>
<td>16-17</td>
<td>5</td>
<td>2</td>
<td>7</td>
</tr>
<tr>
<td>Adults</td>
<td>17</td>
<td>10</td>
<td>27</td>
</tr>
<tr>
<td>Total</td>
<td>79</td>
<td>43</td>
<td>122</td>
</tr>
</tbody>
</table>

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

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

Go trials CNV average amplitude was significantly different from Nogo trials for the full epoch (F₁,111 = 10.63, p = .001) and was significantly different across age groups (F₁₀,111 = 4.43, p < .0005; see Figure 2). A significant interaction between go/nogo and age (F₁₀,111 = 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).

Conclusion

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

1. Baske, L. F. H., Brander, D. G., Tarkka, I. M. and Papanicolaou, A. C. (1997). Magnetic fields from human prefrontal cortex differ negative with age and maturation so we expect significant correlations between CNV and age. The CNV amplitude correlated significantly with age (F₁₀,111 = 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 averaged CNV amplitude.

<table>
<thead>
<tr>
<th>Total IQ (Standardized)</th>
<th>Word Recall</th>
<th>Working Memory</th>
<th>2-back</th>
<th>Stroop Color Words</th>
<th>“Prefrontal” Function</th>
<th>“Posterior” Function</th>
</tr>
</thead>
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<tr>
<td>.09</td>
<td>-.11</td>
<td>-.16</td>
<td>-.12</td>
<td>-.15</td>
<td>-.12</td>
<td>-.15</td>
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Table 3 - Correlations (r values) of scores on behavioral tests with averaged CNV amplitude.

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Figure 1 - Illustration of the stimuli presentation

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

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

Figure 4 - Illustration of the stimuli presentation

Figure 5 - Illustration of the stimuli presentation

Electrocorticography and Neuropsychological Tests Show Prefrontal Maturation in Adolescents

1. Baske, L. F. H., Brander, D. G., Tarkka, I. M. and Papanicolaou, A. C. (1997). Magnetic fields from human prefrontal cortex differ negative with age and maturation so we expect significant correlations between CNV and age. The CNV amplitude correlated significantly with age (F₁₀,111 = 1.13, p = 3.35). Most of the behavioral tests significantly correlated with age (see Table 2).

Relationship of EEG and Behavioral Data

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