Development of the Contingent Negative Variation (CNV) in Children and Adolescents

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Summary

The Contingent Negative Variation (CNV) paradigm consists of a warning stimulus followed by a target (imperative) stimulus at a known interval requiring a response. In adults, the CNV ERP component is generated leading to the second stimulus. Motivation, expectancy, attention and alertness have been shown to affect CNV amplitude. Previous studies strongly implicate the dorsolateral prefrontal cortex as the physiological generator, and executive functions have been shown to correlate with the initial portion of the CNV in various groups. The few studies on children's CNV report that it is less developed in children, but typically include only older children (11 and 12 y) and have not looked at the development across childhood. We examined the CNV in 57 children (7-17 y) and 20 young adults (19-25 y) in a standard CNV paradigm with 2 s SOA between stimuli (40 Go and 40 Nogo trials) and variable intertrial intervals (2 - 7 s). Average amplitude was measured in several epochs (400-800, 800-1200, 1200-1600, 1600-2000, 800-2000 ms) following the warning stimulus. Age grouping correlated significantly with CNV amplitude for all epochs at Cz for Go trials (r = -.49, -.54, -.34, -.41, -.46; all p < .002 for the 5 epochs) and somewhat less so at Fz and Pz. The Nogo trials do not correlate with age for any of the epochs or sites. Thus, the negativity of the Go trials increases with age but children's EEG is similar to adults on the Nogo trials.

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 much evidence that the prefrontal cortex is relatively late to mature in children. Therefore, we were interested in seeing whether the CNV 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 the neural strategy used by children in this paradigm changes as they grow.

Method

Participants:

• 57 children aged 7 to 17 years; 20 adults 19-25 years (see Table 1).

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

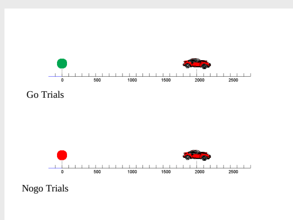
Electrophysiological Measurements:

• 29 scalp sites, 2 bipolar eye monitors
• averaged amplitude scored for four 400 ms and one 1200 ms epochs at Fz, Cz, Pz
• EOG artifact rejection (+/- 100 µV)
• rereferenced offline to averaged ears
• recorded at 500 samples/s
• .03 to 30 hz band pass

Table 1. Current Number of Participants

		Gender		
		F	**M**	**Total**
Age	**7**	**1**	**2**	**3**
	8	**6**	**1**	**7**
	9	**7**	**3**	**10**
	10	**2**	**4**	**6**
	11	**5**	**1**	**6**
	12	**4**	**3**	**7**
	13	**5**	**2**	**7**
	14	**2**	**1**	**3**
	15	**2**	**1**	**3**
	16 - 17	**3**	**2**	**5**
	Adults	**11**	**9**	**20**
Total		**48**	**29**	**77**

Figure 1 - Illustration of the stimuli presentation

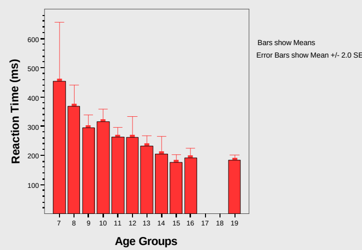


Results

Behavioral Data

Reaction times (see Figure 2): RT correlated with age in go trials (r = -.63, p <.0005). ANOVA indicated a significant difference in age groups ($F_{10,66}$ = 9.23, p < .0005).

Figure 2 - Reaction time in ms by age groups (all adults in the 19-year-old group; 16 + 17 year olds grouped).



Response accuracy:

• ANOVA indicated that there are no significant differences between age groups in the mean percent correct responses on the Go trials ($F_{10,66}$ = 1.08, p = .39). The means by age groups ranged from 76% - 96% with the 7 year olds having the highest score and adults having 86% correct.

• Only 15% of the participants responded on Nogo trials (1 adult and 2 adolescents responded on 2 Nogo trials; and 1 adult, 3 adolescents and 5 younger children responded on only 1 Nogo trial), all other participants made no errors on Nogo trials.

Electrophysiological Data

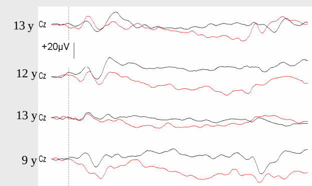
Go trials CNV amplitude correlated significantly with age for all epochs at Cz (r = -.49, -.54, -.34, -.41, -.46, all p < .002 for the 5 epochs) and somewhat less so at Fz and Pz. The Nogo trials did not correlate with age for any of the epochs or sites.

Using regression to predict age-group from CNV on Go trials while partialling out Nogo trials produced the same results (r = .52, 27% of variance). This value was considerably smaller at Fz (10%) and Pz (13%).

The average amplitude was significantly different between Go and Nogo trials for the full epoch ($F_{1,66}$ = 5.48, p = .022) and was significantly different across age groups ($F_{10,66}$ = 3.29, p = .002; see Figure 3).

Figure 4 - Selected waveforms from individual children (ages 9 -13) at Cz.

Children sometimes exhibit a mature CNV…



… and sometimes they don't show a CNV at all, in fact, a reversal.

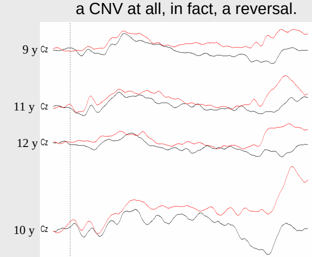
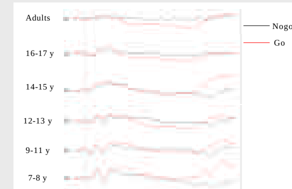


Figure 3 - Average waveforms for age groups with some groups collapsed.



Conclusions

The S1-S2 task is easily performed by children from 7-years-old up to adulthood.

However, the Go trials, which demanded sustained attention, did not always generate the negative amplitude in young children as seen in adults and older children.

Thus, the neurocognitive underpinnings of sustained attention shows a remarkably slow maturation, with considerable immaturity even at 11 years of age.

This supports the prevalent developmental model of late maturation of the prefrontal cortex. However, it does so without being confounded with the performance of a complex task tapping executive functions that are poorly performed by young children.

References

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