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Short communication

THE DEVELOPMENT OF SUSTAINED ATTENTION IN CHILDREN MIGHT BE RELATED TO THE MATURATION OF FRONTAL CORTICAL FUNCTIONS

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Abstract. The relationship between the development of sustained attention and the ability to inhibit responding to external stimuli was investigated in seventy five children, 8, 10 and 12 years old. An important period in the development of both functions is between 8 and 10 years of age. A positive correlation was found between the number of signals detected (sustained attention) and the number of succesfully suppressed reflexive saccades to the peripherally located target (the ability to inhibit responding to external stimuli).

Sustained attention improves with age, the important period being between 8 and 9 years (3). Neurophysiological studies point to the regulatory influence the frontal cortex exerts in tasks demanding the maintenance of attention (2, 7, 8). It seems therefore reasonable to investigate the development of sustained attention (or vigilance) and its hypothetical relationship to the maturation of frontal cortical functions.

The present study is meant to provide a correlative analysis of the relationship between the vigilance performance in one test and the ability to inhibit responding to external stimuli in another one. The ability to

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inhibit responding to task-irrelevant stimuli closely depends on the intactness of the mature frontal cortex (6). Besides, developmental studies have specified the time of maturation of this function to be between 4 and 7 years (6).

The subjects of the present study were seventy five children of 8 ($n = 25$), 10 ($n = 24$) and 12 ($n = 26$) years of age. Boys and girls were evenly represented in each age group.

The vigilance performance was assessed in the group variant of the auditory vigilance test. Tones with a frequency of 1 kHz and duration of 500 ms were taken as non-signal stimuli. They were applied from a loudspeaker at regular intersignal intervals of 2,500 ms. Shorter tones (350 ms) of the same frequency were used as signal stimuli. In total, 28 signal stimuli replaced pseudorandomly non-signal stimuli in four ten minutes blocks of seven signals each. The children were asked to draw a line on a printed form for every non-signal stimulus, and a dash for every signal stimulus. The number of detected signals (or hits) and false alarms was evaluated in each 10 minute block. The test lasted 40 min.

The ability to inhibit responding to task-irrelevant stimuli was assessed in the following task (saccade test).

Horizontal eye movements were recorded with DC electro-oculography and displayed on a rectilinear chart recorder.

Individually tested subjects were seated in front of an arc (radius 100 cm, eye-arc distance 180 cm) consisting of dimly shining points. Reflexive saccades were elicited by illumination of the peripherally located target (light emitting diode). In this test the task of a subject was

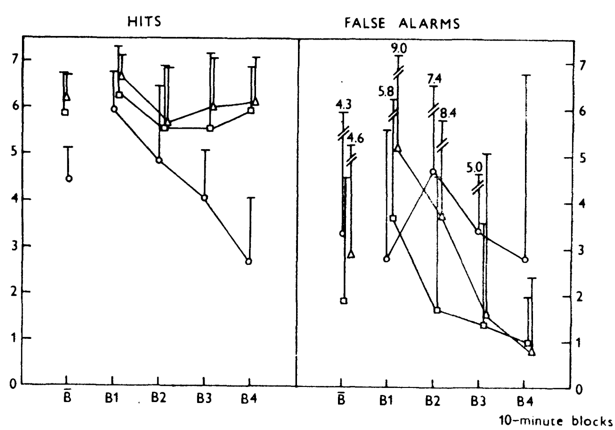

Fig. 1. Number of detected signals (hits) and false alarms in the auditory vigilance task. Circle, squares and triangles mark 8, 10 and 12 years old children. B, average values; B1, B2, B3, B4, values in successive 10-min blocks.

to move his or her eyes slowly to the right along the horizontal arc and fast to the left from the end to the beginning of the arc. This eye movement cycle lasted from 3 to 6 s and was repeated about 30 times in the saccade test. Presentations of peripheral targets during the eye movement cycles were announced to the subject in advance. The subject was instructed not to make saccades to this target. Peripheral targets were switched-on for 500 ms at the moment when the eyes passed over the middle of the arc (from left to right). Thus the target position was left and the target amplitude varied between 12° and 14°. The target was applied every third cycle on average. There were 10 peripheral targets in total. The number of saccades to the target was evaluated from the electrooculogram. The duration of the saccade test was about 3 min.

Vigilance and saccade tests were administered in different days, two weeks apart.

The average number of hits and false alarms and their time trend are illustrated in Fig. 1. Applying Kruskal–Wallis test, significant results were obtained with respect to age for hits ($Q = 24.81$, $P < 0.001$), but not for false alarms ($Q = 1.12$, NS). Using the Holm's procedure on Wilcoxon signed ranks test the significant differences between the following 10-minutes' blocks in hits were obtained: B1v. B2, B1v. B3, B2v. B4, B3v. B4 ($P < 0.05$) and B1v. B4 ($P < 0.01$) in the 8 year olds, B1v. B2 ($P < 0.05$) in the 12 years group. No significant differences were found between blocks in the 10 years group. Thus, a marked vigilance decrement was found in the 8 year olds only.

The average number of saccades to the target was 2.6 ± 4.7, 0.13 ± ± 0.3, and 0.15 ± 0.36 for 8, 10 and 12 years old children respectively. The effect of age proved to be highly significant using Kruskal-Wallis test ($Q = 19.23$, $P < 0.001$). Frequencies in each age group are illustrated in Fig. 2. Using Pearson chi-square test, the significant effect of age was obtained ($\chi^2 = 16.14$, $P < 0.001$), and a posteriori Fisher test revealed significant differences between 8v. 10 and 8v. 12 age groups only.

Spearman rank correlation coefficients were computed for subjects who completed both vigilance and saccade test. A significant positive correlation was revealed between the total number of hits (vigilance performance) and the number of supressed saccades to the peripheral target (ability to inhibit responding to task-irrelevant stimuli) in 8 years old children ($r = 0.61$, $P < 0.05$, $n = 15$). Nonsignificant correlations were found between these parameters in 10 and 12 years old children (saccades occurred only exceptionally).

The sensitivity of the saccade test to frontal cortex damage was confirmed in a pilot study (Fig. 2). The sample of patients was divided into a frontal and temporal group on the basis of the localization of their cortical lesion. The localization of lesions was based on CT scans. All the patients had tumours (actrocytoma mostly) and underwent partial resection of the lobe affected at least 1 year before the examination. The mean age for the frontal and temporal group was 41 and 35 respectively, with 4 males and 4 females in the first group and 3 males and 3 females in the second one.

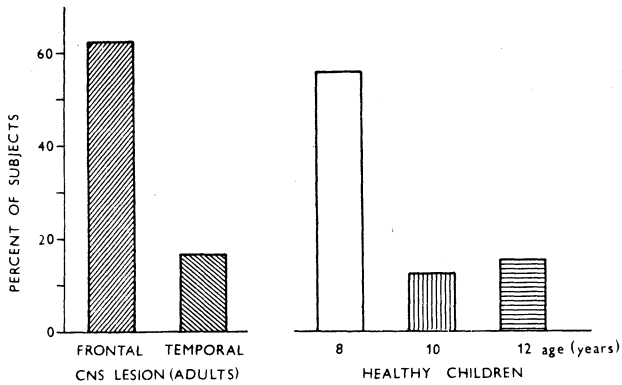

Fig. 2. Relative frequency of subjects with one or more saccades to the peripherally located target in children and the patient group (adult subjects).

The results speak in favour of the significance of the frontal cortical functions maturation for the increased capacity to sustain attention in older children. Such relationship is in agreement with the recent view on the brain and cognitive development (1, 4). The important period in the development of both functions was found to be between 8 and 10 years. Anatomical data (5) confirm these results; neuronal and synaptic density in the human frontal cortex declines late in development and the human brain is practically fully grown after the age of 7 years. However, further studies are required to determine which of the regulatory functions of the frontal cortex (guidance of behavior, initiation and/or verbal programming of voluntary behavior) are the most important for the ability to sustain attention in a monotonous environment.

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