Event-Related Potentials Study in Children with Borderline Intellectual Functioning

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ABSTRACT

Background: Low general cognitive ability is a common cause for learning and academic difficulties. The present study was undertaken to objectively investigate the cognitive functioning of children having borderline intelligence using electrophysiological measures. Materials and Methods: The study was conducted on children having borderline intelligence (IQ: 70-85). The cognitive functioning of children was assessed using event-related potentials. Results: Significant prolongation of the latency of P200, N200, and P300 with no significant difference in the amplitudes was seen in the children having borderline intelligence as compared to controls. Conclusions: Brain systems that are important for stimulus discrimination and using cognitive representation to guide cognition and behavior are impaired in children with borderline intelligence.

Key words: Borderline intelligence, event-related potentials, P300

INTRODUCTION

Intelligence is one of the important prognostic variables in the academic outcome of the children. A considerable percentage of children with scholastic backwardness who are referred for evaluation have no mental retardation, but they score below average in standard IQ tests and may be grouped as borderline intelligent or slow learners.[1] Academically slow learners are usually identified based on their scores on intelligence tests with IQs between 70 and 85.

Rate of slow learning direct these children to lag behind in their normal development skills acquisition and they tend to grasp basic concepts of living (i.e., social interaction, communication, memory skills, and thinking pattern) about 1-2 years late in comparison to peers.[2,3] They rarely meet eligibility criteria for special education as a student with intellectual disabilities or learning disabilities, but have remarkably high failure rates in the general education setting.[4] Slow learners have been reported to experience severe emotional distress, lose their self-esteem and by adolescence are at risk to develop mood and conduct disorders. Low general cognitive ability is a common cause for learning and academic difficulties.[5,6] Efficiency of information processing is considered to be a major architectural feature that predicts the development of control process and in turn general mental ability.[7]

Various noninvasive methods are being used to study and understand the neuronal functions and connectivity in the brain and to help in evaluating quantitatively the neurophysiological functions in different disease states.[8,9] Event-related potentials (ERPs) are those potentials of the electroencephalography, which are evoked by the perception of or the preparation for events,
and they include an early sensory evoked potential and a late cognitive response (P300 component).\[10\] ERPs, which can be recorded through the scalp, are generated by neural activity associated with specific sensory, cognitive and motor processes. ERPs provide a continuous index of processing between the stimulus and the response, allowing mental chronometry. As a result, ERP data can be used to isolate different processing stages. The different waves of the auditory ERP have been found to reflect cognitive processes associated with different aspects of selective attention. Electrophysiological responses are applicable clinically in diagnosing the children with learning problems and to separate individuals who have auditory system based deficits from individuals who have deficits originating later in the perceptual process.

We have previously studied the possibility of deficits in auditory and visual pathways in children with borderline intelligence and could not find any auditory conduction abnormality, but a weaker visual evoked potential response in them.\[11,12\] The literature available on the cognitive status of these children is very scant. Hence, the present study was planned to explore the cognitive functioning of children having borderline intelligence.

**MATERIALS AND METHODS**

The present study was conducted in the Electrophysiology Laboratory, Department of Physiology, University College of Medical Sciences, Delhi. The subjects were selected from the school for special children of Delhi. These subjects were referred for classroom behavioral or academic problems, and they were tested by a psychological evaluation team. All those students having IQ between 70 and 85 and not in the category of specific psychological disorders such as Learning disability (LD), attention deficit hyperactivity disorder (ADHD), and mental retardation were selected for the study. Out of 31 children diagnosed as slow learners five could not participate in the study due to lack of consent from parents or prolonged absenteeism from school, and eight had associated ADHD, dyslexia or other psychological problems and were excluded from the study. Hence, 19 slow learners, 10 males and 9 females with a mean age of 10.55 ± 1.92 years participated in the present study. Fifteen age and sex matched controls (9 males and 6 females) with a mean age of 10.87 ± 2.94 years who had good school performance, were recruited from elementary school in the vicinity of our institution. All the subjects and controls had a hearing threshold below 20 dB. Children with emotional disorders like anxiety or depression, children with hearing or visual defects and physical illness were excluded from the study. The clearance from the Ethical Committee of the institution and informed written consent was obtained from the parents after the recording procedure was explained to them. The recording was done in the presence of either one of the parents or teacher.

A detailed history of clinical, academic, physical, psychological, and neurological examinations was noted. The parents were interviewed to get specific information about their child’s birth history, developmental history and other relevant behavioral problems. A clinical psychologist conducted the standard IQ test by using Malin’s Intelligence Scale for Indian Children an Indian adaptation of Wechsler intelligence scale for children.

**Recording of event-related potentials**

The recordings were done in a soundproof room. A trial session was given to subjects a day before the recording to familiarize them with the stimuli and the recording procedure. The ERPs were recorded on Nihon Kohden Neuropack μ MEB 9100 (Nihon Kohden Corporation, Head Office 31/4, Nishiochiai 1-chome, Shinjuku-ku, Tokyo 161-8560, Japan) using silver-silver chloride disk electrodes from Fz, Cz and Pz (active electrodes) with FPz as a grounding electrode and A1 and A2 as the ear reference electrodes placed according to the 10-20 international system. The skin-electrode contact impedance was kept below 5 KΩ. The subjects were instructed to close their eyes to avoid blink artifacts.

Oddball paradigm was used to record ERPs wherein two stimuli (target and nontarget) were presented in a random order by headphones. The target stimulus was a 2 KHz sound with 20% occurrence and the nontarget 1 KHz with 80% occurrence. The auditory stimuli had a 10 ms rise/fall time, 100 ms duration and intensity of 60 dB above the hearing threshold. The responses were filtered with a band pass of 0.1-50 Hz and averaged for 30 responses. The analysis time was 100 ms before to 900 ms after the stimulus. The subjects pressed a button in response to the target stimulus. Data for two trials were obtained, stored and averaged by computer. The ERP peak latencies and baseline to peak amplitudes were evaluated.

**Statistical analysis**

The data obtained were analyzed using SPSS software (Version 17.0) (Inc.,233 South Wacker Drive, 11th Floor. Chicago, IL, 60606-6307). The statistical analysis for the comparison between the study group and the controls for the three electrode montages, that is, Fz, Cz, Pz, was performed using repeated measures ANOVA followed by Tukey’s test. The repeated measures ANOVA used one between factor and one within
factor. The three electrodes (montages - Fz, Cz, and Pz) combined, served as the within factor, while the between factor was group (control and study group). All tests were two-tailed. The results are expressed as mean values ± standard deviation.

RESULTS

The mean IQ of slow learners was 81.36 ± 4.15, which was significantly lower as compared to that of controls having mean IQ of 99.73 ± 8.63 (P < 0.001). Table 1 shows the absolute peak latencies of the waves of the ERPs in the controls and children with borderline intelligence. A significant prolongation of the latency of P200, N200, and P300 was seen in the children having borderline intelligence when compared to the controls. N100, was also prolonged in the study group, but was statistically insignificant. There was no significant difference in the amplitudes [Table 2] of ERP's in study group when compared to that of controls.

DISCUSSION

The present study shows a significantly prolonged latency of P200, N200, and P300 in the children having borderline intelligence as compared to the controls. Our findings are comparable to those of other studies. It was reported that poor readers lacked normal asymmetry of central conduction time and wave amplitude in early evoked potential while late evoked potential (cortical) were reduced in amplitude. A significant difference in P200 and P300 component between gifted and LD and the normal and LD was also observed. These differences were interpreted as a deficit in either attentional mechanisms or information processing of the learning disabled group. Similar results were reported by others, indicating the relationship between P3 component and cognitive ability.

Electrophysiological responses are applicable clinically in diagnosing the children with learning problems and to separate individuals who have auditory system based deficits from individuals who have deficits originating later in the perceptual process. Auditory ERPs have different waves, and each has been found to reflect cognitive processes associated with different aspects of selective attention. The N100 component is thought to represent the initial extraction of information from the sensory analysis of the stimulus or the excitation associated with the allocation of a channel for information processing from the primary cortex. Since N100 is not decreased in our study group, it indicates that perception and attention is intact in them. The P200 component may represent inhibition of sensory input from further processing possibly via automatic stimulus identification and discrimination/classification or inhibition of other channels of information competing for attention and further processing. The N200 component is thought to represent an endogenous mismatch detection process related to stimulus discrimination. This component has been associated with response identification and response selection. Prolongation of N200 and P200 in our study indicates deficiency in stimulus discrimination in the study group.

P300 latency has been associated with the timing of stimulus evaluation processes and its amplitude indicates the amount of processing required by a given stimulus. The P300 component has also been found to be generated in a number of cortical regions including the temporal-parietal lobes. Parietal P300 has often been connected to attention, allocation which is

Table 1: Mean latencies (ms) of event related potential components

| Latency  | Control (n = 15) | Study group (n = 19) | P value |
|---------|------------------|----------------------|---------|
| Fz      | 129.14±18.61     | 132.67±24.56         |         |
| N100    |                  |                      |         |
| Cz      | 113.14±21.86     | 124.78±22.39         | 0.228   |
| Pz      | 110.21±17.68     | 122.22±33.72         |         |
| Fz      | 190.64±18.58     | 210.38±31.88         |         |
| P200    |                  |                      |         |
| Cz      | 187.43±16.25     | 201.69±26.85         | 0.045*  |
| Pz      | 188.14±30.25     | 209.94±46.38         |         |
| Fz      | 231.73±21.45     | 307.38±71.59         |         |
| P300    |                  |                      |         |
| N200    |                  |                      |         |
| Cz      | 230.07±20.83     | 300.75±69.83         | 0.001*  |
| Pz      | 231.27±39.56     | 286.81±73.42         |         |
| Fz      | 337.40±26.18     | 385.72±70.80         |         |
| N100    |                  |                      |         |
| Cz      | 325.07±26.46     | 385.78±83.78         | 0.05*   |
| Pz      | 347.53±45.10     | 392.22±91.46         |         |

*P<0.05

Table 2: Mean peak amplitudes (µV) of event related potential components

| Amplitudes (µV) | Control (n = 15) | Study group (n = 19) | P value |
|-----------------|------------------|----------------------|---------|
| Fz              | 10.94±2.39       | 10.48±6.20           |         |
| N1              |                  |                      |         |
| Cz              | 9.47±4.56        | 8.97±4.43            | 0.682   |
| Pz              | 6.88±3.16        | 6.40±3.91            |         |
| Fz              | 4.56±2.51        | 6.07±6.59            |         |
| N2              |                  |                      |         |
| Cz              | 7.34±3.46        | 7.81±4.50            | 0.06    |
| Pz              | 6.21±3.51        | 9.26±8.39            |         |
| Fz              | 7.85±2.82        | 13.22±11.25          |         |
| N3              |                  |                      |         |
| Cz              | 5.59±4.91        | 7.80±7.32            | 0.106   |
| Pz              | 5.29±3.92        | 5.57±6.90            |         |
| Fz              | 8.56±5.86        | 11.28±11.00          |         |
| P3              |                  |                      |         |
| Cz              | 15.82±7.88       | 11.14±10.95          | 0.337   |
| Pz              | 18.51±8.41       | 12.19±11.69          |         |
independent of stimulus modality. The P300 wave is one of the cognitive components of the ERP frequently used to investigate attention and cognitive processes. In the present study, since P300 is prolonged in children with borderline intelligence there seem to be primary disturbance of selective attention contributing to less efficient cognitive process in this group. The connection between slow speed of processing and impairment in executive functioning has been reported in various populations. In the present study, the ERP amplitudes were not significantly different in the two groups. No significant differences in amplitude and latency of N100 between normal and poor readers were reported by Bernal et al. However, N200 to frequent stimuli and P200 to both frequent and infrequent stimuli were of higher amplitude in poor readers than in normal children. No difference between groups in P300 latency and amplitude was found in their study. They suggested that poor readers use more attentional resources in the components occurring before P300 to both frequent and infrequent stimuli then the normal children. P300 amplitude indicates the amount of difficulty encountered in differentiating target from nontarget stimuli in the “oddball” paradigm of the ERP. The lack of significant P300 amplitude differences between the control and the children with borderline intelligence in our study suggest that there were no deficits in the allocation of processing resources to task-relevant stimuli during the auditory oddball paradigm.

The above findings indicate that brain systems that are important for stimulus discrimination and using cognitive representation to guide cognition and behavior are impaired in children with borderline intelligence. Due to the small number of subjects recruited, these results may not reflect the true variability of neurophysiological variables in the general population. The authors plan to further extend the study by recruiting more cases and conducting follow-up evaluations of all the recruited subjects.

ACKNOWLEDGMENT

We are grateful to Dr. Pushplata, Psychologist, Amar Jyoti School, Delhi for conducting the psychological evaluation of our subjects. We are also grateful to Amar Jyoti Institute, Delhi, for their full co-operation during the study. We would like to thank Mr. Manjhi for the technical assistance.

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How to cite this article: Vaney N, Khaliq F, Anjana Y. Event-related potentials study in children with borderline intellectual functioning. Indian J Psychol Med 2015;37:53-7.

Source of Support: Nil, Conflict of Interest: None.