A Comparative study of P300 and Cognitive ability in Adolescents with and without significant perinatal history

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Abstract

Background: The P300 component of the event-related potential (ERP) is a well-established neurophysiological variable of cognitive processing, reflecting attention allocation, stimulus evaluation, and working memory updating. Perinatal complications may adversely affect neurodevelopment and cognitive functioning during adolescence.

Objective: To evaluate P300 and cognitive ability index in adolescents with and without significant perinatal history.

Methods: A comparative cross-sectional study was conducted among adolescents aged 10–19 years to examine the relationship between cognitive ability and auditory P300 event-related potentials (ERPs) in individuals with and without a significant perinatal history. Participants were categorized into two groups based on documented perinatal factors such as prematurity, low birth weight, birth asphyxia, neonatal intensive care unit (NICU) admission, or other neonatal complications. Cognitive ability was evaluated using a standardized cognitive assessment scale. Auditory P300 responses were recorded using the auditory oddball paradigm wherein P300 latency was measured and analyzed in relation to cognitive ability scores.

Results: Adolescents with a significant perinatal history showed longer P300 latency than those without such a history. Cognitive ability assessment revealed reduced cognitive functioning. Furthermore, a significant negative correlation was found between P300 latency and cognitive ability scores, suggesting that longer neural processing times were associated with lower cognitive performance value.

Conclusion: The findings of this study indicate that P300 latency is associated with cognitive ability suggesting alterations in neural information processing and cognitive performance during adolescence. Early identification of these neurocognitive changes may help in developing timely interventions to improve long-term outcomes.

Keywords: P300 Event-Related potential, cognitive ability, adolescence, significant perinatal history

Introduction

The recording of evoked electroencephalographic (EEG) potentials is one of the neurophysiological techniques that have been employed extensively in recent years to study the brain systems involved in information processing and perception. Because they offer a direct measure of brain activity linked to attention, stimuli assessment, memory, and decision-making processes, event-related potentials (ERPs) have become one of the most useful methods for researching cognitive function [1 ,2,3,4].

The P300 (P3) wave is one of the ERP elements that has been examined the most. An oddball paradigm is commonly used to elicit the P300 by presenting infrequent target stimuli among a sequence of frequent non-target or standard stimuli [5]. About 250–350 milliseconds after a target stimulus are presented, it manifests as a positive deflection in the EEG waveform and is often most noticeable over the Centro-parietal scalp areas [6]. The P300 has been extensively utilized as an objective neurophysiological indicator of cognitive functioning due to its strong correlation with cognitive processes [5,7]. P300 latency is considered an indicator of the speed of stimulus evaluation and cognitive processing. Consequently, alterations in P300 characteristics have been used to assess cognitive impairments associated with various neurological and psychiatric disorders [5,6,7,8].

Age and cognitive development have been shown to affect P300 parameters in a number of studies. P300 latency gradually decreases and cognitive processing efficiency increases as a result of the central nervous system's continuous maturing during childhood and adolescence [9,10]. These results provide credence to the use of P300 as a sensitive instrument for examining cognitive development and pinpointing variables that could affect adolescent neurocognitive functioning.

The Cognitive Ability Test (CAT-GMLB).

Adolescents' cognitive capacities were evaluated using the Cognitive Ability Test (CAT-GMLB), which was

created by Ms. Bindya Lakhan and Dr. Madhu Gupta. It is a general intellectual measure designed to evaluate, reasoning, attention, perception, tasks. The CAT-GMLB, which consists of a number of objective items given in an orderly fashion, is suitable for use in both educational and therapeutic situations [20].The responses were scored using established scoring procedures, and the raw results were converted into cognitive ability scores using the manual's normative data. Higher scores on the CAT-GMLB reflect higher cognitive functioning and more intellectual ability [20].

Method

Procedure

The ethical committee of the Institute of Medical Sciences at Banaras Hindu University approved the current cross sectional observational study, which was conducted in the Department of Physiology, IMS, BHU, Varanasi. Eighty patients who consented to participate in the study were split into two groups: group A, which had no significant prenatal history, and group B, which had a significant prenatal history each comprising of 40 individuals each. The subjects were selected from Inter College, Varanasi, studying in senior secondary class. After having consent from the college, parents, and students in the age group of 10 to 19 years (early adolescents 10 to 14 years and late adolescents 15 to 19 years) having both genders, male and female, were considered for the study based on the inclusion criteria (Adolescents aged 10–19 years, history of significant perinatal risk factors, able to understand and follow instructions, written informed consent from parents/guardians and assent from participants) and exclusion criteria (Neurodegenerative disorders, Hearing impairment, Use of ototoxic or sedative medications, Sleep disorders, Psychiatric disorders, Lack of parental consent).

Tools used

P300 recording

Auditory P300 event-related potentials were recorded using a computerized evoked potential system under standardized laboratory conditions. Participants are comfortably lying on a bed in a quiet room and instructed to remain relaxed and attentive throughout the procedure. P300 waveforms were acquired using a dual-channel device (NEUROSTIM-NS2, Medicaid system). An auditory oddball paradigm was employed, in which frequent (1000 Hz) and rare target (2000 Hz) tones were presented binaurally through headphones at an intensity of 80 db. The target stimuli were randomly interspersed among the frequent stimuli, and participants were asked to mentally count the rare tones. Electrodes were placed with Cz as the active electrode, M1 and M2 as reference electrodes, and Fpz as the ground electrode. Before electrode placement, the scalp was cleaned to reduce impedance and ensure optimal signal quality. P300 latencies were measured and analyzed as indices of cognitive processing and attentional function.

Statistical analysis

Cognitive ability scores and P300 latency (ms) were compared during all procedures using a paired t test, as data was parametrically distributed, and the level of significance was determined at $p< 0.05$.

Results

The results are organized according to the study objectives and include descriptive group comparisons and correlation analyses.

Table 1: Showing cognitive ability score and P300 latency (ms) mean differences in both groups

Groups	Mean ± S.D		p value
	Cognitive Ability Test Scores	P300 latency	
Control	25.97 ± 4.79	291.39± 46.33	< 0.001
Case	17.3 ± 3.15	327.17± 28.04	

Note: ($p < 0.05$)

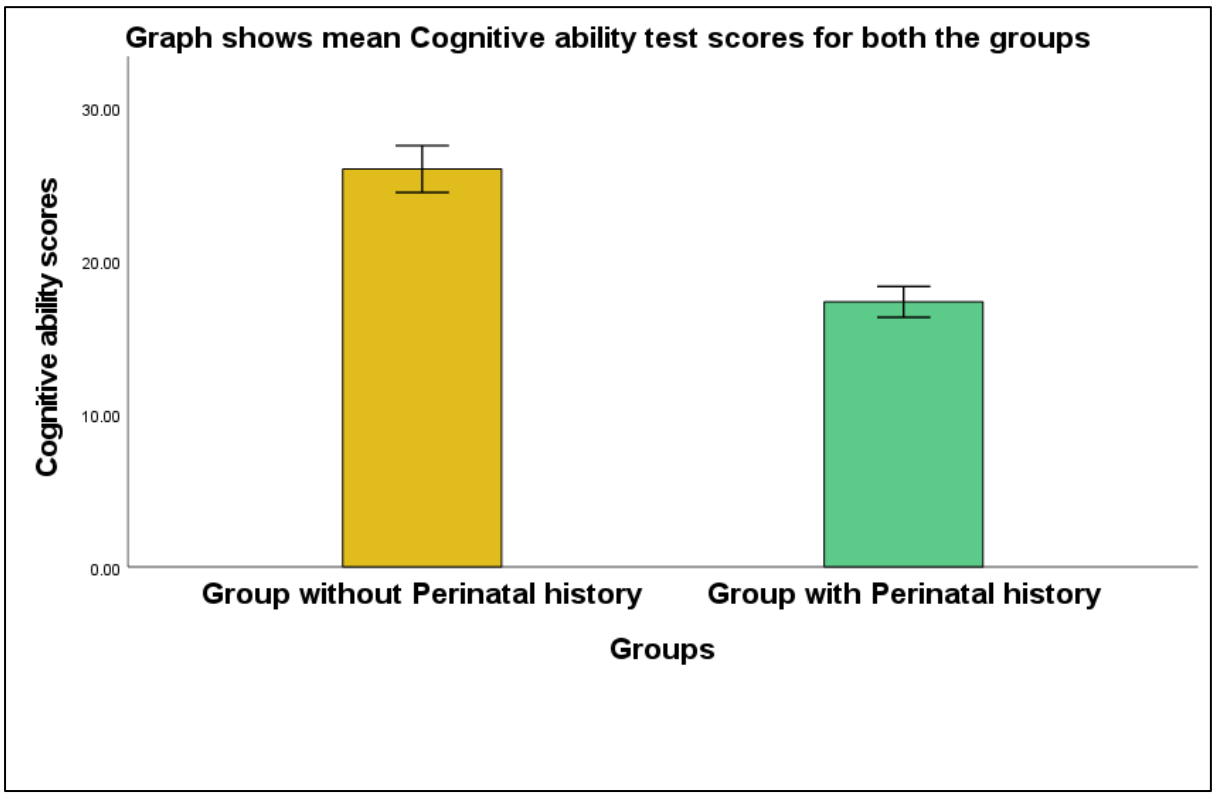

Figure 1: Shows mean difference of CAT scores among two groups under study.

From the above Figure, we get the comparison of mean cognitive ability scores between the two groups. The mean cognitive ability score in the control group was 25.97 ± 4.79, whereas the case group demonstrated a significantly lower mean score of 17.3 ± 3.15. Statistical analysis was performed using the independent samples t-test, which revealed a highly statistically significant difference between the two groups (**= $p < 0.001$). The mean difference between the two groups was 8.67 points, indicating that adolescents in the control group performed substantially better on the cognitive ability assessment compared to those in the case group. The obtained p-value suggests that this difference is unlikely to have occurred by chance.

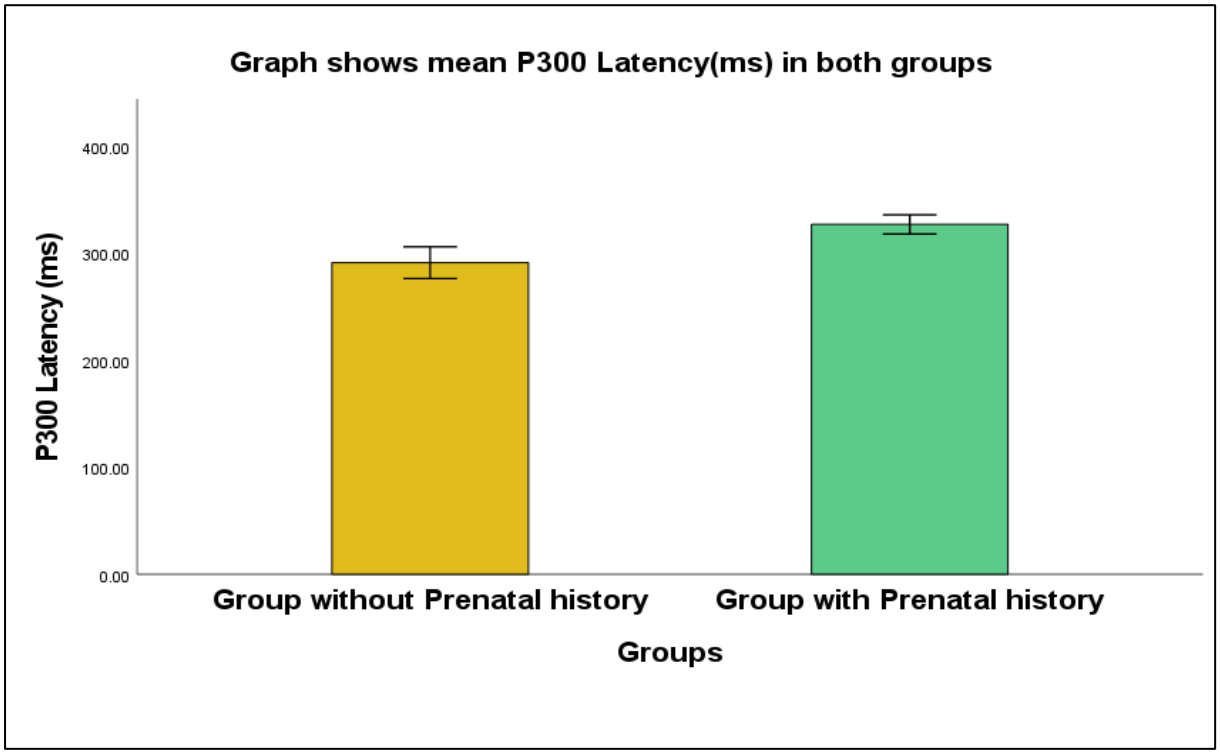

Figure 2: Shows mean difference of P300 latency (ms) among two groups under study.

Similarly, the mean P300 latency (ms) in the control group 291.39 ms , whereas the case group demonstrated a significantly higher P300 mean scores of 327.17 ms. Statistical analysis was performed using the independent samples t-test, which revealed a highly statistically significant difference between the two groups (**=$p < 0.001$) indicating the difference is unlikely to have occurred by chance.

Table 2: Pearson Correlation coefficient (r) between P300 latency and cognitive ability score in adolescents without significant perinatal history.

Variable	P300 latency	Cognitive ability score
P300 latency	1	-0.28*
Cognitive ability test scores	-0.28*	1

Note: *p < 0.05

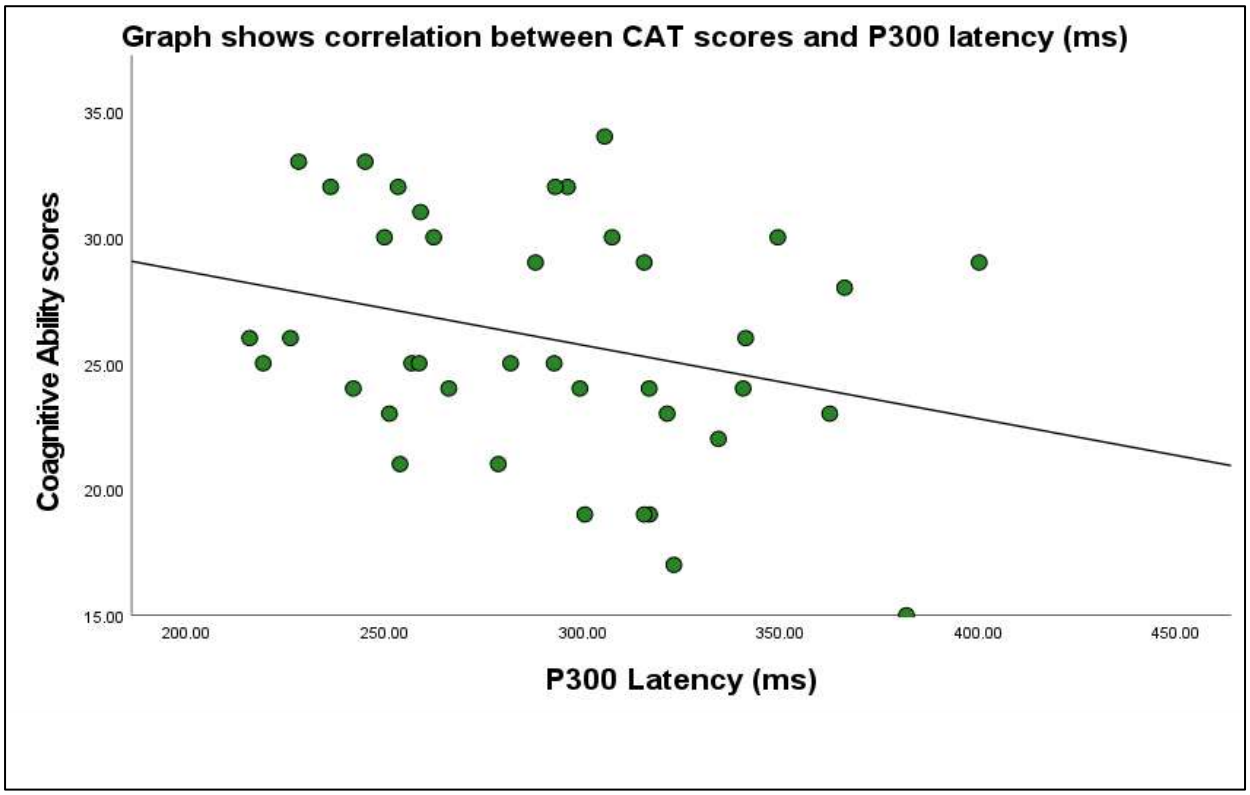

Figure 3: Showing Scatter plot illustrating the relationship between P300 latency (ms) and cognitive ability scores in adolescents without perinatal risk factors

Above figure represents the correlation between P300 latency and cognitive ability scores in adolescents without significant perinatal history. Pearson's correlation coefficient (r) was used to determine the relationship between variables. A statistically significant negative correlation was observed between P300 latency and cognitive ability scores ($r = –0.28$, $p < 0.05$). This indicates that higher cognitive ability scores were associated with shorter P300 latency values.

Table 3: Pearson Correlation coefficient (r) between P300 latency and cognitive ability score in adolescents with significant perinatal history.

Variable	P300 latency	Cognitive ability score
P300 latency	1	-0.36*
Cognitive ability test scores	-0.36*	1

Note: *p < 0.05

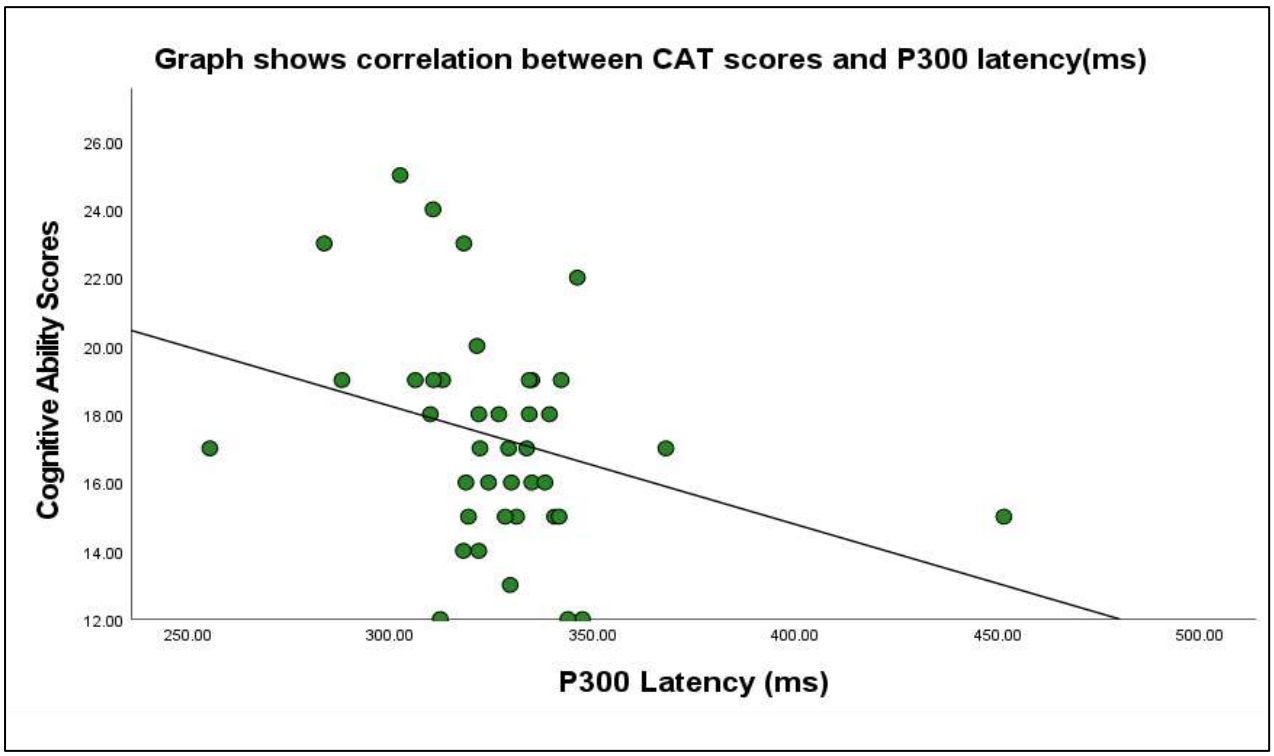

Figure 4: Showing Scatter plot illustrating the relationship between P300 latency (ms) and cognitive ability scores in adolescents with perinatal risk factors

The above figure revealed that P300 latency had a significant negative association with cognitive ability scores (r = -0.36), using Pearson's correlation coefficient (r) to determine the relationship between variables. This indicates that adolescents with significant prenatal history having higher latencies showed comparatively reduced cognitive abilities.

Discussion

The present study compared cognitive ability scores between adolescents with and without a significant perinatal history. The findings revealed a highly significant difference between the two groups, with adolescents in the control group demonstrating substantially higher cognitive ability scores than those with perinatal risk factors. Cognitive abilities continue to develop throughout adolescence alongside ongoing maturation of the brain, including synaptic pruning, increased myelination, and strengthening of neural networks [11]. Adolescents with a significant perinatal history showed lower cognitive ability scores, which may reflect alterations in neurodevelopmental processes involved in attention, working memory, executive functioning, and information processing [12]. Any disruption during the perinatal period may therefore influence later cognitive outcomes [13,14]. The findings are consistent with previous studies reporting lower cognitive performance among individuals exposed to adverse perinatal conditions compared with their typically developing peers. Earlier research has suggested that prematurity, low birth weight, birth asphyxia, and other perinatal complications can contribute to long-term neurodevelopmental vulnerabilities, resulting in reduced cognitive efficiency and academic performance [15].

Furthermore, longitudinal studies have demonstrated that early biological risk factors can have persistent effects on intellectual functioning, executive abilities, and learning outcomes throughout childhood and adolescence [16,17]. The significantly lower cognitive ability scores observed in the present study support this evidence and highlight the potential long-term impact of perinatal adversity on cognitive development.

The present study also revealed that correlation between P300 latency and cognitive ability scores among adolescents without a significant perinatal history were shown to have significant moderate negative association indicating higher cognitive ability scores are generally linked to shorter P300 latencies in neurologically healthy teenagers without a major prenatal history, indicating more effective brain information processing and quicker stimulus assessment processes [3,18,19]. On the other hand, significant associations between between P300 latency and cognitive ability suggests faster brain information processing is linked to improved cognitive performance regardless of early biological risk, according to the observed moderately negative connection between P300 latency and cognitive capacity in both teenagers with and without significant prenatal history. The idea that P300 latency acts as an electrical indicator of cognitive processing effectiveness is supported by this finding.

The use of standardized cognitive tests in conjunction with an objective electrophysiological measure (P300 latency) to provide a thorough assessment of cognitive processing is one of the strength of the study. Additionally, by including adolescents with and without a substantial prenatal history, the association between brain processing speed and cognitive capacity across various developmental backgrounds could be examined.

The study posits certain limitations as the observed relationships cannot be causally inferred due to the cross-sectional methodology. Purposive sampling and the comparatively small sample size may restrict how far the

results may be applied. Furthermore, significant confounding variables such as parental education, socioeconomic traits, and environmental impacts were not completely taken into consideration.

Conclusion

P300 latency and cognitive capacity were found to be significantly and moderately negatively correlated in both teenagers with and without a substantial prenatal history. The results show that shorter P300 latencies are linked to higher cognitive performance, which reflects faster neuronal information processing and increased cognitive efficiency. Regardless of perinatal background, the existence of this association in both groups implies that P300 latency may function as a reliable electrophysiological marker of cognitive function. Additionally, the strong correlation highlights P300 latency's potential value as a non-invasive biomarker for evaluating adolescents' cognitive processing effectiveness. To further understand the impact of prenatal variables on neurocognitive development and the predictive validity of P300 measurements over the lifespan, future longitudinal research with bigger sample sizes are required. These findings emphasize the importance of early identification, developmental monitoring, and timely interventions to optimize cognitive outcomes in at-risk populations

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