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Associations Between P300 Latency and Reaction Time on Event-Related Potentials in Children with Varying Levels of Fluid Intelligence

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Abstract: Assessing cognitive abilities is crucial in educational contexts to inform student selection processes. Presently, academic metrics are widely used for grading, evaluation, selection and placement decisions. This study investigates the correlation between P300 latency, reaction time, and fluid intelligence in children, utilizing Raven's Standard Progressive Matrices (RSPM) for intelligence measurement. Participants were divided into two groups based on their RSPM scores, reflecting "high mental abilities" and "average mental abilities." We hypothesized that children with higher RSPM scores would demonstrate shorter P300 latency and faster reaction times, indicative of more efficient cognitive processing. Electrophysiological data were collected through Event Related Potentials (ERPs), specifically analyzing the P300 component. Results confirmed that higher intelligence is associated with shorter P300 latencies and faster reaction times, supporting theories of neural efficiency and cognitive speed's role in intelligence. This study enhances understanding of the neurophysiological correlates of intelligence in children and informs educational strategies tailored to individual cognitive profiles.

Keywords: Raven Standard Progressive Matrices; intelligence; highly intelligent children; P300 latency; reaction time; neural efficiency hypothesis

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1. Introduction

Fluid intelligence is often used to forecast children's potential and ability for academic success [1]. Evaluating fluid intelligence requires intentional mental operations to solve new problems that cannot be tackled through simple memorization. Moreover, the link between fluid intelligence and learning ability as an indicator of mental capacity implies possible applications in educational methods [2]. Intellectually gifted children are believed to have more efficient neural functions, enabling them to excel in basic cognitive tasks compared to their average peers, as well as demonstrate superior performance on cognitive control tasks, involving executive and inhibition control [3]. Therefore, intelligence can serve as a predictor of children's cognitive control performance [4]. Raven's Standard Progressive Matrices (RSPM), a non-verbal measure of fluid intelligence, evaluates the ability to deconstruct problems into manageable sub-problems, address these sub-problems and reason abstractly. Raven's tests are among the most widely used assessments of fluid intelligence [5–7]. The RSPM is a visual neuropsychological test where the correct answers are identified by recognizing sameness, symmetry, and analogy, as well as analyzing form, color, and linear slope. Visual processing for this test occurs in the visual association areas, such as Brodmann's

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areas 18 and 19. It is proposed that one stream of information for object identification travels downward from the occipital cortex to the temporal lobe, while another stream for spatial aspects and movement moves upward to the parietal lobe. Consequently, the functioning of the visual association areas is believed to impact RSPM performance [8].

Neuroimaging research has proposed two main theories regarding the anatomical and functional aspects of human fluid intelligence. Jung and Haier's [9] Parieto-Frontal Integration Theory (P-FIT) suggest that general intelligence is significant, because it involves multiple brain areas. Specifically, it has been proposed that after sensory information is processed by the temporal and occipital lobes, it is transferred to the parietal cortex for extraction. The frontal cortex is believed to play a crucial role in solving specific cognitive tasks, while the anterior cingulate is thought to be involved in selecting responses [10].

The alternative theory regarding intelligence, based on research using Positron Emission Tomography (PET), is the neural efficiency hypothesis. Haier et al. [11] suggested that with practice, glucose metabolism decreases in various brain regions. These findings suggest that more intelligent individuals tend to concentrate their brain activation on areas relevant to the task, while less intelligent individuals exhibit more widespread brain activation. The theory is explored through various neuropsychological methods, including electroencephalography, which assesses brain activation and event-related synchronization or desynchronization of EEG brain activity [12].

Event-related potentials (ERPs) represent a non-invasive electrophysiological method for gathering data on brain activity associated with cognitive information processing. ERPs reflect the average electrophysiological response to a presented stimulus. When stimuli are attentively processed and a specific target stimulus is consciously detected, a distinct P300 component appears in the ERP as the third positive deflection [13]. ERPs have been suggested as the most suitable method for investigating correlations between brain electrical activity and the dynamic processes of cognitive stimuli [14]. The P300 component of ERPs is extensively studied and is thought to reflect higher-level cognitive information processing and attentional mechanisms involved in contextual evaluation when focusing on specific stimuli [15].

The latency of the P300 component is believed to reflect advanced cognitive functions such as categorization and sensory assessment, serving as a temporal indicator of brain activity that enhances the efficiency of attention allocation and updates working memory processes [2]. Additionally, speed of cognitive processing is mirrored in the P300 waveform, with longer P300 latency generally indicating slower cognitive processing, often associated with cognitive impairments [2]. Furthermore, the P300 waveform reflects the speed of cognitive processing. Longer P300 latency is generally indicative of slower cognitive processing and is associated with various cognitive impairments [16]. Moreover, the P300 appears to be associated with learning and memory abilities, as tasks involving memory recall and new learning have presented significant correlations between P300 responses and task performance [17].

The relationship between P300 latencies and intelligence is particularly relevant in educational contexts because P300 latencies have been shown to reflect cognitive processing efficiency, which is often linked to intelligence and, consequently, to academic performance [18]. Shorter P300 latencies generally indicate faster cognitive processing, which can enhance learning, problem-solving, and information retention—skills crucial for academic success. By correlating P300 latencies with intelligence measures, educators and psychologists can gain insights into a student's potential cognitive strengths or challenges, allowing for more tailored educational support and interventions [19,20]. Walhovd and Fjell [21] reported that individuals with higher cognitive abilities exhibited shorter P300 latencies, implying that neural processing speed is tied to intelligence and learning ability. Similarly, Polich [22] found that the P300 component is sensitive to cognitive capacity, with shorter latencies linked to higher cognitive functioning, suggesting that P300 latency could serve as an objective neurophysiological indicator of intellectual capacity that correlates with educational outcomes. Moreover, it is essential to understand cognitive processes like attention and decision-making, which can be assessed through measures such as reaction time. This indicator is closely tied to intelligence, a key predictor of academic success that may exhibit varying influences across different educational levels [23].

P300 latency and reaction time are essential for delineating students' cognitive profiles, enabling the design of interventions aimed at enhancing learning and memory in contexts requiring elevated cognitive speed and attentiveness. The relationship between intelligence and academic performance, substantiated through systematic reviews, highlights a diminishing influence of intelligence as students advance in their education [24]. Integrating basic cognitive measures with intelligence constructs a solid framework for educational psychologists and neuroeducators [25]. This integration not only deepens our comprehension of cognitive dynamics within educational environments but also supports the customization of educational strategies to individual cognitive abilities, thereby optimizing educational outcomes. Employing insights from research on intelligence and cognitive metrics enables educators to develop interventions that are attuned to the varied cognitive needs of students, fostering more effective educational outcomes [26].

Several studies have employed P300 latency within an oddball task to evaluate intelligence [20,27–30]. It is proposed that individuals with higher mental abilities will exhibit faster P300 latency compared to their peers with typical mental abilities. These findings indicate that individuals with higher intelligence possess superior cognitive processing capabilities and more effective attentional mechanisms, supporting the mental speed theory of intelligence [20,30–32]. Yet, the association between intelligence and P300 latency in other tasks appears less consistent. For instance, in the Sternberg memory [33] scanning task and in response-conflict tasks [34,35] contradictory results have been reported. Regarding the associations between intelligence scores and reaction time in oddball (target) stimulus, research data seem more consistent. Evidence corroborates that individuals with higher intelligence exhibit faster information processing, as evidenced by their consistently shorter reaction times in simple cognitive tasks, as outlined in a meta-analysis [36]. Individuals with higher intelligence demonstrate shorter reaction times compared to the control group, indicative of their superior attention abilities, memory capacity, and interest in the task at hand [37].

Although prior research has explored the relationship between intelligence and either P300 latency (e.g., [21,31]) or reaction time (e.g., [36,37]) in isolation, no known studies have concurrently investigated these metrics within the context of intelligence categorization. This combined approach offers a more integrative perspective on cognitive processing speed and attentional dynamics. Additionally, while much of the existing work on P300 latency and reaction time has concentrated on adult populations (e.g., [11,22]) or mixed-age groups, the current study focuses specifically on children, emphasizing developmental processes and providing insights into cognitive profiles during critical educational stages. Moreover, this research seeks to directly correlate Raven's Standard Progressive Matrices (RSPM) scores with both P300 latency and reaction times. Whereas previous studies have typically examined these variables independently or in connection with general intelligence measures (e.g., [9,29]), the present study fills a gap by linking specific fluid intelligence scores to both electrophysiological and behavioral indicators. This study represents a foundational effort to analyze P300 latency and reaction times among two groups of children with different intelligence levels, aiming to establish correlations with their RSPM scores.

The primary objective of this study was to compare electrophysiological brain activity among children grouped according to their cognitive abilities, categorized as "high mental abilities" and "average mental abilities" based on their RSPM classification. Building on prior research involving highly intelligent participants and their average peers (e.g., [20,37,38]), the first hypothesis posits that children identified as "highly intelligent" or "average intelligence" using RSPM scores will demonstrate shorter P300 latency. The second hypothesis suggests that participants within these groups will exhibit shorter reaction times. Furthermore, the third hypothesis implies that measurements of (a) P300 latency and (b) reaction time will display negative correlations with RSPM scores across the two groups.

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2. Materials and Methods

2.1. Participants

Twenty-two male students aged from 10 to 12 (mean age = 11.33, SD = 1.03) years participated in the study. Specifically, there were twelve right-handed children that scored highly in RSPM (M = 137.33 SD = 11.65). Twelve right-handed children participated in the third group with average score in RSPM (100.33 SD=3.50). The selection of children for each group was based on their performance in the Raven's Standard Progressive Matrices (RSPM). None of the participants had previously been assessed in mental ability or electrophysiologically. Furthermore, none of them had any psychopathological disorder, learning difficulties, developmental disorders, or significant visual or hearing impairments as evidenced by the interviews of children and parents. All participants were recruited from primary schools. Initially in the recruitment phase teachers were interviewed. We specified that all participants had good academic performance. These children were administrated the Raven Standard Progressive Matrices by a licensed psychologist [39]. Another psychologist interviewed their parents. According to the scores obtained on the RSPM the two groups were formulated. After the selection the EEG recordings were administrated. It is worth noting that all participants' parents/guardians were required to sign the consent form allowing their child to participate in the research. Finally, all human data included in this manuscript were obtained in compliance with the Helsinki Declaration and the guidelines of the Internal Research Ethics Committee (EHDE) protocol (code 227092023).

2.2. Electrophysiological Assessment

2.2.1. Electrode Placement and Data Recording

ERPs were recorded using Ag-AgCl electrodes placed at 15 sites in accordance with the 10-20 International System [40]. The ground electrode was placed at the nasion, and all channels were referenced to linked mastoids. Electrode impedance was maintained at <5 kΩ. Recordings were made at a sampling rate of 256 Hz, with a bandpass filter set between 0.16 Hz and 70 Hz. EEG data were segmented into epochs spanning 200 ms pre-stimulus to 800 ms post-stimulus

2.2.2. P300 Component Detection

The P300 component latency was measured for both target and non-target stimuli across all channels. The P300 waveform, identified by its long positive peak occurring 250-500 ms after the N200 waveform, was visually inspected for accurate detection. This visual inspection allowed for adjustments to ensure that high-frequency noise or unreliable data did not affect the measurements. If a reliable P300 peak was not observed, the data for that ERP were marked invalid [41].

2.2.3. Data Preprocessing and Artifact Removal

To ensure high-quality data, trials were excluded if the voltage exceeded 70 μV in any of the 15 channels (excluding EOG) or if participants provided incorrect responses. Baseline correction was applied using the 200 ms pre-stimulus period, and epochs were averaged separately for target and non-target stimuli. Only children with at least 30 artifact-free trials for both target and non-target conditions were included in the analysis. Recordings were conducted in a soundproof room to avoid external interruptions [42–44]. This precise methodology ensured reliable electrophysiological measurements and established correlations between cognitive ability and P300 latency.

2.3. Implementation

All children who took part in the study underwent the RSPM scale to assess their nonverbal IQ. Ten-year-olds administered the first version of the scale, comprising 30 logical sequence designs with the final part missing, which they were required to complete. Children aged 11 to 12 received the

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second version of the scale, which includes three subcategories (A, AB, and B), each containing 12 designs and six suggested answers. Participants were instructed to select the answer that logically completes the pattern. The scale was completed by all participants at the Digital Neuropsychological Assessment Laboratory of the University of Thessaly, in a dedicated research space. A psychologist was present to provide instructions and adhere to the timing specified in the test manual.

2.4. Statistical Analysis

Initially, descriptive statistics were calculated to summarize the participants' demographic and clinical characteristics. The Kolmogorov-Smirnov test was used to assess the distribution of the data, confirming its adherence to normality. Subsequently, one-way ANOVA was employed to investigate differences in P300 latency between children with high and average mental abilities. To account for multiple comparisons across 15 Electroencephalographic (EEG) sites, a Bonferroni correction was applied. Additionally, ANOVA was used to compare reaction times between the two groups. Effect sizes were calculated and reported using Cohen's d [45] to quantify the magnitude of the observed differences. Finally, correlation analyses were conducted to examine the relationship between P300 latency and the children's scores on Raven's Standard Progressive Matrices (RSPM).

3. Results

One-way ANOVA compared the results of children with high mental abilities against children with average mental abilities. Descriptive statistics analyzed mean scores and standard deviations of P300 latency measured at 15 scalp sites (e.g., Figures 1 and 2) and Cohen's d-effect sizes were calculated. Table 1 presents the mean scores, standard deviations, statistical significance, and effect size of P300 latency from all recorded brain areas.

Table 1. Descriptive Statistics, ANOVA Results, and Effect Sizes for P300 Latencies Between Children with High and Average Mental Abilities.

Electro/ Encephalographic Sites	P300 Latency of Children with high mental abilities	SD	P300 Latency of Children with average mental abilities	SD	F	p	Cohen's d
Fp1	304.48	6.21	316.58	3.46	34.80	<0.001	2.41
FPz	305.44	7.64	318.41	4.63	25.33	<0.001	2.05
Fp2	307.55	6.33	320.53	5.92	26.89	<0.001	2.12
F3	307.00	7.14	326.65	7.56	42.84	<0.001	2.67
Fz	307.87	6.05	325.53	2.21	90.16	<0.001	3.88
F4	313.15	10.31	336.38	1.99	58.74	<0.001	3.13
T3	306.28	10.03	329.00	4.82	50.03	<0.001	2.89
T4	308.32	11.85	325.85	2.45	25.16	<0.001	2.05
C3	306.78	13.10	330.45	6.37	31.67	<0.001	2.30
Cz	311.69	15.84	337.53	3.22	30.65	<0.001	2.26
C4	317.77	9.41	338.19	2.89	51.63	<0.001	2.93
P3	309.51	10.04	329.96	5.21	39.19	<0.001	2.56
Pz	311.98	14.98	336.37	5.45	28.10	<0.001	2.16
P4	313.39	17.56	339.68	3.67	25.79	<0.001	2.07
Oz	316.91	10.38	337.87	5.71	37.58	<0.001	2.50

All children's P300 latency was presented statistically significantly shorter according to their scores in RSPM. In more detail all participants with high mental abilities presented shorter P300 latencies in comparison to children with average mental abilities. Furthermore, Cohen's d values (ranged from 3.88 to 2.05) are substantial, suggesting large effect sizes in the differences between the two groups of participants.

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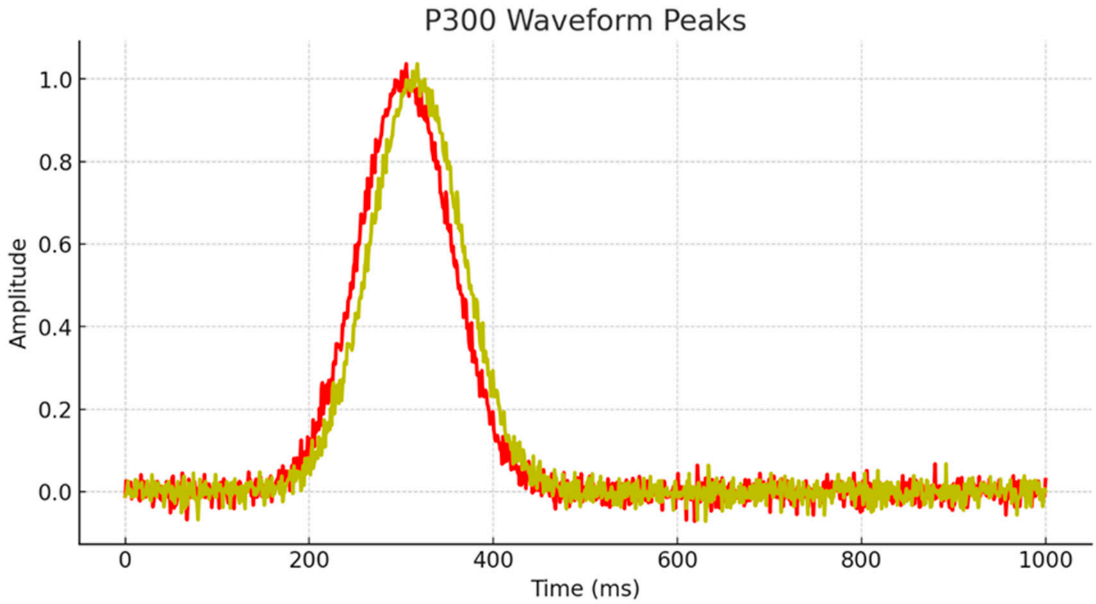

Figure 1. P300 latency was measured from the left prefrontal lobe (FP1). The red line represents the P300 waveform from children with high cognitive abilities and the yellow line indicates the P300 waveform from children with average cognitive abilities.

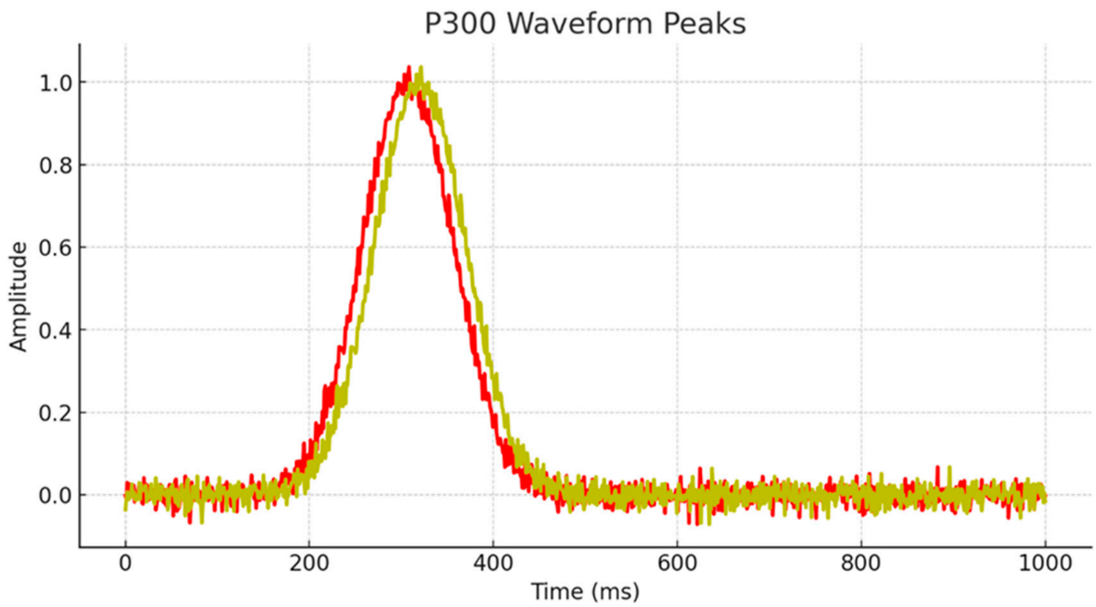

Figure 2. P300 latency was measured from the right prefrontal lobe (FP2). The red line represents the P300 waveform from children with high cognitive abilities and the yellow line indicates the P300 waveform from children with average cognitive abilities.

Bonferroni correction analysis employed to evaluate the significance of the observed effects across 15 electroencephalographic sites where *p*-values were calculated to assess the likelihood of observing the data under the null hypothesis. Table 2. presents the *p*-Values for Statistical Analysis across 15 electroencephalographic sites

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Table 2. p-Values across15 electroencephalographic sites.

Electro/ Encephalographic Sites	Lower Bound (p)	Upper Bound (p)
Fp1	6.17×10^{-6}	9.26×10^{-5}
FPz	4.87×10^{-5}	7.30×10^{-4}
Fp2	3.37×10^{-5}	5.05×10^{-4}
F3	1.39×10^{-6}	2.09×10^{-5}
Fz	3.07×10^{-9}	4.61×10^{-8}
F4	1.19×10^{-7}	1.79×10^{-6}
T3	4.28×10^{-7}	6.42×10^{-6}
T4	5.07×10^{-5}	7.60×10^{-4}
C3	1.17×10^{-5}	1.75×10^{-4}
Cz	1.45×10^{-5}	2.18×10^{-4}
C4	3.34×10^{-7}	5.02×10^{-6}
P3	2.66×10^{-6}	3.99×10^{-5}
Pz	2.55×10^{-5}	3.83×10^{-4}
P4	4.36×10^{-5}	6.54×10^{-4}
Oz	3.60×10^{-6}	5.40×10^{-5}

Table 2. Presents the statistical significance across all electroencephalographic sites, supporting the overall validity and reliability of the findings. The lowest p-value was observed in Fz (3.07×10^{-9} to 4.61×10^{-8}), indicating the strongest effect. Similarly, electroencephalographic sites demonstrated significant effects, with the upper bound of p-values ranging up to 7.60×10^{-4} in T4. These results suggest statistical evidence across all tested electroencephalographic sites.

Next the analysis focused only on reaction time of children with high mental abilities in comparison to children with average mental abilities. It is worth to remind that all participants were Participants were instructed to press a button detecting the target stimulus (oddball) as quickly and accurately as possible. Table 3 presents the mean scores, standard deviations, statistical significance, and effect size of reaction time from the two groups of participants.

Table 3. Mean scores, standard deviations, significance and Cohen's d of reaction time for children that participated in each group of mental abilities.

Reaction Time	High Mental Abilities		Average Mental Abilities				
	M	SD	M	SD	F	p	Cohen's d
	319.70	6.54	352.30	11.76	70.42	<0.001	3.43

As depicted in Table 3, all children with high mental abilities exhibited statistically significant shorter reaction times compared to children with average mental abilities. Additionally, Cohen's D was suggested as high.

In addition, a Spearman's rho correlation analysis was conducted to examine the associations between the latency of the P300 waveform and the RSPM scores of children across all 15 topographic brain areas. The results of the correlation analysis are presented in Table 4.

Table 4. Correlation analysis between P300 latency and RSPM scores.

Electro/ encephalographic sites	Correlation ϱ	Sign
FP1	-0.844	0.001
FPZ	-0.804	0.001
FP2	-0.742	0.001
F3	-0.862	0.001
FZ	-0.889	0.001
F4	-0.813	0.001
T3	-0.818	0.001
T4	-0.893	0.001
C3	-0.844	0.001
CZ	-0.865	0.001
C4	-0.770	0.001
P3	-0.853	0.001
PZ	-0.803	0.001
P4	-0.790	0.001
OZ	-0.781	0.001

The findings varied, ranging from ϱ=-0.742 (at FP_2 electrode site) to ϱ=-0.893 (at T_4 electrode site). The analysis revealed a strong negative correlation, indicating that higher RSPM scores corresponded to shorter P300 latencies.

The same statistical analysis was followed to calculate the correlation between reaction time and RSPM scores. A negative correlation (ϱ=-0.877) was found indicating that the higher RSPM scores correlate with shorter reaction time.

4. Discussion

The present study was conducted to compare the electrophysiological brain activity among children that were classified according to RSPM criteria as "high mental abilities", and "average mental abilities". The first hypothesis based on previous studies [20,27–30,37,38] compared the P300 latency between the two groups of participants. The expected shorter P300 latencies in children with high mental abilities in comparison to children with average mental abilities were supported by the findings of the present study. Specifically, children with higher mental abilities presented statistically significant shorter P300 latencies in all electroencephalographic sites in comparison to their average peers.

The shorter latency of P300 waveform that was presented in children with higher mental abilities in the present research and other studies (eg. [34,35]) possibly explains the higher cognitive abilities

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that are present in children according to more correct answers to RSPM. Specifically, important cognitive components of mental abilities are attention and memory for information processing [46]. Since the latency of P300 reflects the promptness of stimulus assessment and demonstrates the efficiency of cognitive functioning, it can uncover the aforementioned abilities [47]. Studies using P300 latency suggest that participants with more efficient memory abilities present significantly shorter auditory P300 latency [44]. Furthermore, it has been proposed that a longer latency of P300 indicates disorders in attention [46].

In general, it is suggested that longer P300 latencies indicate inferior mental performance [47]. These results verify our first hypothesis, as participants with higher mental abilities presented shorter P300 latency in comparison to children with average mental ability. These findings are consistent with the neural efficiency model. Moreover, studies have indicated that this efficiency is task-dependent, with greater differentiation between high- and low-ability individuals in tasks requiring complex cognitive processing [3]. The auditory oddball paradigm used in this study, which demands selective attention and rapid decision-making, appears to accentuate these differences, providing robust support for the theory.

The Bonferroni correction was applied to mitigate the increased likelihood of Type I errors arising from multiple comparisons across 15 EEG sites. By adjusting the significance threshold, this approach ensured the reliability and validity of the findings despite the high number of statistical tests conducted. The analysis identified significant differences in P300 latency between children with high and average mental abilities at all EEG sites, with p-values well below the adjusted threshold. The Fz site, which is linked to frontal cognitive functions, exhibited the most pronounced differences, suggesting that neural activity in this region plays a pivotal role in differentiating cognitive performance between the groups. Similarly, frontal and central regions such as F3, Cz, and C3 also showed notably low p-values, underscoring their involvement in key cognitive processes, including attention, memory, and executive function. These findings underscore the extensive neural differences in cognitive processing speed and efficiency between the two groups, offering additional support for the neural efficiency theory. They further highlight the practical relevance of P300 latency as a neurophysiological measure for identifying and understanding variations in cognitive abilities within educational and developmental frameworks.

The second hypothesis of this study arose from studies suggesting that children with higher mental abilities presents low reaction time and reporting that general intelligence and a wide range of RT tasks have been consistently reported with high-ability subjects displaying faster RTs than low-ability subjects [15,48–52]. The results of the present study assume that children with higher mental abilities presented statistically significant shorter reaction time in comparison to their average peers.

Shorter reaction time is possibly reflecting better memory and attentional functions, as it is proposed that the ability of children and adolescents with higher metal abilities to inhibit responses improves sufficiently as they answer with more confidence [53]. Moreover, reaction time is suggested that monitors the self-regulation abilities. Shorter reaction time may provide proof that highly intelligent children show better self-regulation abilities and strategies [4]. Taking together the electrophysiological findings and behavioral findings is further supported that highly intelligent children have more efficient and mature neural function in accomplishing cognitive processes [13,54].

Reaction time is another behavioral marker linked to neural efficiency. Faster reaction times in children with higher mental abilities, as observed in this study, further corroborate the neural efficiency hypothesis. The ability to rapidly detect and respond to stimuli requires efficient sensory processing and motor execution, processes facilitated by reduced neural "noise" and optimized cortical activation in individuals with higher intelligence [55]. This aligns with the broader literature suggesting that reaction time variability decreases with increasing intelligence, reflecting more consistent and efficient cognitive performance [36].

The reported Cohen’s d values for both P300 latency and reaction time are notably high, indicating that the differences observed between children with high and average mental abilities are not only statistically significant but also practically meaningful. These substantial effect sizes

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underscore the critical influence of cognitive differences on neural processing speed. Cohen's d serves as a valuable metric in this study, complementing the statistical significance of group differences by emphasizing the practical relevance of the findings. These large effect sizes highlight the broader implications of the results, particularly for understanding and fostering cognitive and educational development in children.

The third hypothesis of this study posited a correlation between (a) P300 latency and (b)reaction time with RSPM scores. Other study findings showed a positive correlation between P300 amplitude and RSPM scores and a negative correlation between P300 latency and RSPM scores. The analysis conducted in the present study postulated negative correlations between P300 latency and reaction time with RSPM scores across the two participant groups, presenting that higher intelligence scores are linked to shorter P300 latency and reaction time.

4.1. Psychoeducational Implications of the Study Using ERPs and RSPM Results in Identifying Children's Mental Abilities

The integration of P300 and RSPM in cognitive classification has significant psychoeducational applications. Using P300 latency and RSPM scores enables the early detection of giftedness, which is crucial for timely intervention and the provision of enrichment programs that cater to advanced learners [62]. Furthermore, by differentiating between high mental abilities and average mental abilities groups, educators can design individualized instructional strategies [63]. For example, children with shorter P300 latencies may benefit from accelerated curricula, while those with average latencies might require scaffolded learning experiences. It is worth noticing that longitudinal studies using P300 and RSPM can track cognitive changes over time, providing insights into the effectiveness of educational interventions and neurodevelopmental trajectories. The average approach of this study fosters a deeper understanding of how the brain function influences learning, encouraging evidence-based practices in classrooms. The combination of neurophysiological markers, such as the P300 waveform, and psychometric measures like RSPM represents a significant advancement in psychoeducational research and practice. By classifying children according to their intelligence, this methodology not only enhances our understanding of cognitive diversity but also informs educational policies aimed at fostering the potential of all learners [64]. As such, it exemplifies the translational value of neuroscience in addressing real-world educational challenges.

4.2. Limitations

When considering the findings of this study, several methodological limitations should be noted. Firstly, the participant pool was small because it was difficult to recruit a large sample of children with high scores on RSPM. The average age was kept low due to strict exclusion criteria. While a larger sample would have strengthened the study, the small sample size might have reduced the statistical power. Moreover, the use of the RSPM as the sole IQ assessment presents certain limitations, as it does not evaluate verbal intelligence. However, despite the limited number of participants, interesting results were found. Lastly, this study did not incorporate all ERP waveforms documented in literature. Instead, the study focused on the P300 waveform due to its frequent use in research related to cognitive abilities and its relevance in evaluating studies targeting higher cognitive functions.

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5. Conclusions

In conclusion, despite certain limitations, the findings of this study are consistent with previous research demonstrating shorter P300 latencies and faster reaction times in children with high intelligence. These results suggest enhanced cognitive processing speed, superior attentional and memory capacities, better inhibitory control, and more efficient neural functioning, all of which are likely to contribute to their superior cognitive performance and academic success. Furthermore, the observed associations between P300 latency, reaction time, and RSPM scores reinforce patterns reported in earlier studies. Participants in this study were categorized into two groups based on their fluid intelligence levels. The integration of P300 latency and reaction time metrics with RSPM scores in children aged from 10 to 12 years old underscores key developmental processes and offers valuable insights into cognitive profiles during a pivotal stage of educational development. Lastly, the findings of this study provide empirical support for the neural efficiency theory, highlighting its relevance in explaining cognitive differences in children. The integration of P300 latency and reaction time as markers of neural efficiency offers a valuable framework for understanding the neurophysiological underpinnings of intelligence. Future research should aim to explore these relationships longitudinally and across diverse populations to further elucidate the developmental and contextual factors influencing neural efficiency.

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Institutional Review Board Statement: All participants' parents/guardians were required to sign the consent form allowing their child to participate in the research. Finally, all human data included in this manuscript were obtained in compliance with the Helsinki Declaration and the guidelines of the University of Thessaly Internal Research Ethics Committee (EHDE) protocol (code 227092023).

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Conflicts of Interest: The authors declare no conflicts of interest.

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