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ORIGINAL ARTICLE

Auditory Event-related Potentials in Children With Attention Deficit Hyperactivity Disorder☆

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Key Words
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Background: Recording of event-related potentials (ERPs) from the scalp is a noninvasive technique reflecting the sensory and cognitive processes associated with attention tasks. Attention deficit hyperactivity disorder (ADHD) is a disorder involving deficits in attention and behavioral control. The aim of this study was to investigate the difference in ERPs between normal children and those with ADHD.
Methods: We examined 50 children with ADHD and 51 age-matched controls. All children with ADHD met the full criteria for ADHD according to Diagnostic and Statistical Manual of Mental Disorders, fourth edition (DSM-IV). The auditory oddball paradigm was applied, and event-related long-latency components (N1, P2, N2 and P3) from Fz, Cz and Pz were measured in each test subject.
Results: Children with ADHD showed a significantly longer latency and a lower amplitude of P3 compared to normal control children ($p < 0.01$). Delayed N2 latency at the Pz electrode was shown in children with ADHD compared to normal controls ($p < 0.01$). No differences in other ERP indices were found between children with ADHD and controls. When divided into four age groups, the latency of P3 was significantly increased in all age groups and a significantly smaller amplitude in P3 over the central region was found in children with ADHD > 10 years of age ($p < 0.05$).
Conclusion: We found that the endogenous ERPs (P3 and N2) were significantly affected in children with ADHD, compared to exogenous ERPs (N1 and P2). Increased latency of P3 suggests a slower processing speed, and decreased P3 amplitude is interpreted as disruption of inhibitory control in children with ADHD. These results indicate a neurocognitive abnormality in ADHD, as presented by a reduction in ERP response.

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1. Introduction

The recording of event-related potentials (ERPs) from the scalp is a noninvasive technique providing information regarding neural activity associated with sensory, cognitive, attention and decision-making processes.[1] ERPs have been used as an electrophysiological tool for studying neural bases of cognitive activities and in clinical applications for patients with psychopathological and neurological diseases, disorders of learning and attention, dementia, and other cognitive deficits.[2]

Attention deficit hyperactivity disorder (ADHD) is characterized by developmentally inappropriate attention, behavioral and cognitive impulsivity, and restlessness.[3] Evidence has shown that ADHD is associated with a deficit in response selection, motor adjustment, and inhibition of prepotent responses.[4] A variety of studies of children with ADHD have reported abnormalities in visual, auditory, and alternating visual and auditory ERPs.[5]

Abnormalities in auditory ERP waves are a reflection of tasks associated with selective attention and the categorization of stimuli involved in cognitive functions.[6,7] Studies on ERP have identified N1 and P2 components in response to frequent tones and P3 components in response to rare tones.[8] P3, namely the P300 wave, is a late positive waveform occurring with a latency of approximately 300 milliseconds or more after an infrequently presented target stimulus (so-called "oddball paradigm"). P3 is thought to be an endogenous potential generated in the medial cortical or subcortical region,[2,9] sensitive to the delivery of task-relevant information requiring a decision or response from the participant. Research has shown that P3 is also a presentation of an updating of working memory.[10] Understanding alterations of the ERPs in ADHD children helps to take into account their cognitive control processes and pathophysiology.

Many investigations into attention and cognition have conducted analysis of ERPs, and P3 responses are the most widely investigated waveform. As mentioned by Barry et al,[5] the most common ERP-related discovery associated with ADHD is a significant reduction in the amplitude of P3 during the performance of oddball tasks. The results concerning latency in P3 with regard to ADHD have been mixed.[11] Changes in other ERP waveforms such as N2, P2 and N1 have not been thoroughly studied in children with ADHD. The results of behavioral performance have been inconsistent when reported by measurements of reaction time, total hits, and false alarms.[12,13]

Behavioral studies of children of various ages have shown the importance of age with respect to the regulation and direction of attention.[13,14] Age-dependent changes in the ERPs of normal children have been reported in several studies.[15,16] Some reports have found that the age specificity of lower P3 amplitude in ADHD patients exists mostly in children,[6,13] but not in adolescent subjects.[6,17] Age effect should be considered in studies of the ERP in children with ADHD.

In Taiwan, changes in ERP waveforms in children with ADHD have rarely been reported.[18] The aim of this study was to investigate the differences in ERP responses, focusing on the differences in the latencies and amplitudes of P3, N2, P2 and N1 among children with ADHD and normal children between 6 and 13 years of age. Furthermore, the subjects in this study were divided into different age groups to evaluate the developmental effects of age on ERPs in children with ADHD.

2. Materials and Methods

2.1. Subjects

The ADHD group consisted of 50 children, aged 6—13 years old (42 boys and 8 girls) and recruited from our outpatient clinic. Children were divided into four age groups for testing: (1) 6—7 years; (2) 8—9 years; (3) 10—11 years; and (4) 12—13 years. All children with ADHD completed both the parents and teacher versions of the Child Activity Checklist in Chinese[19] with their scores over P85 (85 percentile). The teacher version of the Child Activity Checklist included children's behavioral control in general, during classroom, in groups, and responses to teachers such as "staying in seat according to classroom rules", "complying with usual request or direction of teachers", and school performance. The parents' version of Child Activity Checklist included behavior control and attention at home or other daily activity such as "interrupting another person's conversation or activity", or "unable to stick with one game or toy".

All children with ADHD met the full criteria of ADHD according to Statistical Manual of Mental Disorders, fourth edition (DSM-IV; American Psychiatric Association, 1994).[20] Of 50 children who were diagnosed with ADHD, 48 (96%) had combined-typed ADHD and two had predominantly inattentive type of ADHD. Full-scale Wechsler Intelligence Scale for Children (WISC) IV in children with ADHD was 80 or higher. A detailed history and physical and psychiatric examination were conducted, and the diagnosis was confirmed by a child psychiatrist, and none of the children were taking any medication. The patients with Tourette's syndrome, seizure disorders, learning disabilities, autism, Asperger diseases, mental retardation, and other psychotic disorders were excluded.

A comparable age- and sex-matched control group of 51 children aged 6—13 years old (40 boys, 11 girls) was assembled from patients who had previously visited our outpatient clinic suffering from various acute illnesses or for health examinations unconnected with neurological or psychiatric illness. Subjects with hearing problems were also excluded. Informed consent was obtained from participants' parents or guardians in accordance with the requirement of the ethics boards of the Cathay General Hospital (CGH-CT9762) and Cheng-Hsin General Hospital (CHGH-IRB-165-98-49).

2.2. Methods

The subjects were tested in a relaxed sitting position with their eyes closed in a silent room after cleaning the skin and scalp. Bioelectrical signals were measured by placing a surface electrode (plate-shape electrode, 11 mm in diameter; Dantec Electronics A/S, Skovlunde, Denmark) along the midline frontal (Fz), central (Cz) and parietal (Pz) region, according to the 10—20 international system of EEG