Available online at www.sciencedirect.com
ScienceDirect
International Journal of Psychophysiology 67 (2008) 35–40
INTERNATIONAL JOURNAL OF PSYCHOPHYSIOLOGY
www.elsevier.com/locate/ijpsycho

EEG coherence in adults with Attention-Deficit/Hyperactivity Disorder

Adam R. Clarke [a,b,*], Robert J. Barry [a,b], Patrick C.L. Heaven [a], Rory McCarthy [c], Mark Selikowitz [c], Mitchell K. Byrne [a]

[a] School of Psychology, University of Wollongong, Wollongong 2522, Australia
[b] Brain & Behaviour Research Institute, University of Wollongong, Wollongong 2522, Australia
[c] Sydney Developmental Clinic, Level 3/9 Bligh St. Sydney 2000, Australia

Received 2 February 2007; received in revised form 2 October 2007; accepted 2 October 2007
Available online 10 October 2007

Abstract

Attention-Deficit/Hyperactivity Disorder (AD/HD) is the most common psychiatric disorder of childhood, but it is becoming increasingly more apparent that more than half the childhood sufferers will continue to manifest symptoms of the disorder as adults. While EEG coherence in children with AD/HD has been examined extensively, no studies have investigated coherence in adults with the disorder. This study investigated EEG coherence in adults with AD/HD. EEG was recorded from 18 adult males with AD/HD, and an age- and gender-matched control group, during an eyes-closed resting condition. Waveshape coherence was calculated for 8 intrahemispheric electrode pairs (4 in each hemisphere), and 8 interhemispheric electrode pairs, within each of the delta, theta, alpha and beta bands. A laterality effect was found for intrahemispheric coherence at long inter-electrode distances, with the AD/HD group showing reduced hemispheric differences in the delta band compared to the control group. In the alpha band, at short-medium inter-electrode distances, the AD/HD group also had lower coherences than the control group. The results suggest that theta coherence differences reported in children with AD/HD may be associated with hyperactivity, which is reduced in adults with AD/HD, while reduced alpha coherence could be associated with inattention, which remains in adult with AD/HD. Reduced delta coherence also appears to be an aspect of the disorder which may develop from later childhood into adolescence and adulthood.

Keywords: Attention-Deficit/Hyperactivity Disorder; AD/HD; Adults; EEG; Coherence

1. Introduction

Attention-Deficit/Hyperactivity Disorder (AD/HD) is one of the most common psychiatric conditions of childhood, affecting between 4% and 6% of school-age children (Lindgren et al., 1990; Pelham et al., 1992; APA, 1994). However, it is increasingly recognized that while AD/HD might have its origins in childhood, between 40% and 70% of those individuals with childhood AD/HD will continue to suffer the disorder as adults (Bellak and Black, 1992). This would mean that between 2% and 3% of adults have the disorder. However, even with this high level of psychopathology in adults, the disorder remains poorly investigated.

Research has shown that the behavioural profile AD/HD undergoes considerable change from childhood to adulthood. Hyperactivity, which is common in children with the disorder, reduces with increasing age whereas the inattentive and impulsive components of the disorder often remain (Hallowell and Ratey, 1994; Hechtman et al., 1984). This can mean that a child who meets the diagnostic criteria for the combined type of AD/HD (APA, 1994), may only meet criteria for the inattentive type in adulthood. AD/HD is widely accepted as resulting from a central nervous system (CNS) dysfunction, yet very little is known about developmental changes in brain function and the adult form of this disorder.

One measure that has been used to investigate CNS dysfunctions in children with the disorder is EEG coherence. EEG coherence is conceptualised as the correlation in the time domain between two signals in a given frequency band (Shaw,

* Corresponding author. Tel.: +61 2 4221 5775; fax: +61 2 4221 4163.
E-mail address: adam_clarke@uow.edu.au (A.R. Clarke).

0167-8760/$ - see front matter © 2007 Elsevier B.V. All rights reserved.
doi:10.1016/j.ijpsycho.2007.10.001

1981), providing information about the degree of functional connectivity between structures underlying the pair of electrodes used to calculate the coherence measure. With normal brain development, synaptic connections both proliferate and are destroyed over time, and this has been hypothesised to cause fluctuations in coherence (e.g., Thatcher et al., 1987; Thatcher, 1994). The increase in myelination with age has also been hypothesised as impacting on coherence (e.g., Barry et al., 2004).

A few studies have investigated the coherence of children with AD/HD using an eyes-closed resting condition. This is the dominant paradigm in coherence studies of children with the disorder. Montague (1975) found that hyperkinetic children had significantly elevated intrahemispheric coherences compared to controls. Chabot and Serfontein (1996) and Chabot et al. (1996) reported that children with an attention disorder had increased interhemispheric and intrahemispheric coherence in frontal and central regions although the studies do not stipulate in which bands these abnormalities were found. Barry et al. (2002) found substantial increases in theta coherence and reductions in alpha coherence for most interhemispheric and short distance intrahemispheric measures, with an alpha reduction also apparent at longer inter-electrode distances. Frontally, AD/HD children also had coherences elevated in the delta and theta bands, and reduced in the alpha band. Clarke et al. (2005) found that AD/HD children had lower theta coherences than controls at long inter-electrode distances, and reduced lateralisation at both long and short-medium inter-electrode distances. For interhemispheric comparisons, AD/HD children showed increased coherences in the frontal regions for the low frequency bands (delta and theta), and reduced coherences in the alpha bands in all other regions. In the central/parietal/occipital regions, interhemispheric coherences in the alpha band were again lower in AD/HD children than in controls. Collectively, these studies indicate the presence of substantial frontal lobe dysfunction, with increased slow wave coherence being found in several studies in children with AD/HD.

Only a few studies have investigated coherence differences between children with either the combined or inattentive types of the disorder, which are important as inattention is most likely to remain in adults with the disorder. From the existing literature inconsistent conclusions about the nature of the disorder, in the different subtypes, have been drawn. Barry et al. (2002) found intrahemispheric effects at shorter inter-electrode distances, with children with the combined type (AD/HDcom) having higher coherence levels in the theta and beta bands than children with the inattentive type of AD/HD (AD/HDin). AD/HDcom children also had higher frontal interhemispheric coherence than AD/HDin children in the delta and theta bands, as well as in the central/parietal/occipital regions, in the beta band. These differences were seen to support the view that AD/HDin children suffer similar, but less extreme, deviations from normality than AD/HDcom children. Similar results were found by Barry et al. (2006) in girls with the combined or inattentive subtype, where differences between subtypes seemed to mainly reflect differences in severity of the disorder rather than discrete components that could be linked to a particular component of the disorder. However, Barry et al. (2005) investigated developmental changes in boys between the ages of 8 and 12 years old, with a diagnosis of either AD/HDcom or AD/HDin. Boys with AD/HDcom had higher levels of short-range intrahemispheric coherences generally than did AD/HDin boys, and this difference reduced with age in the alpha and beta bands. With longer-range intrahemispheric coherences, a similar elevation in AD/HDcom boys was apparent in the beta band. AD/HDcom boys showed more consistent evidence of development than AD/HDin boys at lower frequencies, suggesting that the downturn in coherence in older children was mainly associated with AD/HDin children. With interhemispheric coherences, AD/HDcom levels were greater than AD/HDin in the theta band in frontal regions, and the beta band in central/parietal/occipital regions. In the central/parietal/occipital regions, AD/HDcom coherences were elevated at age 8, and levels in the two groups converged with increasing age in all bands. These results suggest the presence of differences in the nature and development of the impairments, rather than a simple increase with symptom severity in the subtypes.

To date there are no coherence studies of adults with AD/HD, and hence the aim of this study was to investigate whether EEG coherence differences could be found between adults with and without AD/HD. Due to known maturational changes in the symptom profile of people with AD/HD, it was hoped that EEG coherence components could be identified which may be relatable to the hyperactive and inattentive components of the disorder.

2. Method

2.1. Participants

Thirty six adult males between the ages of 18 and 26 participated in this study. Eighteen participants met criteria for AD/HD according to the DSM-IV (APA, 1994), and 18 were non-AD/HD controls. The AD/HD participants were all past patients of the paediatric practice of RM and MS, where they were assessed and treated for AD/HD combined type as children. The control group consisted of age-matched adults who were drawn from the local community. Informed consent was obtained from all participants prior to inclusion in this study.

Inclusion in the AD/HD group was based on published criteria for the diagnosis of AD/HD in adults (Adler and Cohen, 2004; Montano, 2004; Fargason and Ford, 1994) which requires the determination of AD/HD during childhood, and the existence of AD/HD symptoms in adulthood which is determined by a clinical interview and AD/HD rating scales. All participants in the AD/HD group had a confirmed diagnosis of AD/HD combined type as children and met criteria for AD/HD as adults which was determined in a second assessment at the time of testing. The second assessment included a clinical interview, an assessment of IQ, reading ability, current AD/HD symptoms, depression level, and general mental health status. The Conners Adult AD/HD rating scale was also used to determine the presence of AD/HD symptoms, with a *T*-Score of greater than