Changes in the Electro-encephalogram in Minimal Cerebral Dysfunction

A CONTROLLED STUDY OVER 8 MONTHS

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SUMMARY

Electro-encephalograms (EEGs) of 35 children at a centre for remedial education and 35 age- and sex-matched normal controls at a private school were recorded on two occasions, with an 8-month interval, during which the minimal cerebral dysfunction (MCD) group received specialised remedial instruction, and the control group normal classroom schooling. The EEGs of each group were compared both before and after the 8-month period. The results of previous investigations showing that children with MCD have a significantly higher incidence of EEG abnormalities of a slow wave type, were confirmed. Further, the MCD group differed from the control group on a number of measures related to alpha activity, and showed a significantly greater subcortical excitability. Right posterior EEG dysfunctions were implicated in a significantly higher proportion of the MCD group, and appeared to be related specifically to reading disability. Differences between control and experimental groups were reduced after the 8-month period between EEGs, suggesting that a process of normalisation was operative in the MCD children.

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Previous studies have indicated a high incidence of electro-encephalographic abnormalities in children with minimal cerebral dysfunction. Procedural inadequacies, however, detract from the value of several of these investigations. Paine,[1,2] Paine et al.[3] and Kenny and Clemmens[4] all failed to employ control groups, while Capute et al.[5] used imperfectly matched control and MCD groups.

Tuller and Eames,[6] in a sample of only 7, found tentative evidence of a relationship between the locus of electro-encephalographic dysfunction and the reading disability in children. They suggest the need for further investigation of language disability, using the bipolar recording technique. This would enable more precise localisation of electro-encephalographic abnormalities associated with language disability by the determination of phase reversals, than is possible with the monopolar technique frequently employed in electro-encephalographic studies in the USA. In addition, a study by Behrens[7] indicated that the EEG

may reflect changes over a period of time in the cortical electrical activity of children with MCD.

Finally, it would appear that investigations of the EEG and MCD have concentrated, without exception, on the abnormal electrocortical activity associated with this syndrome. It is not improbable that the activity of the brain assessed as falling within the range of normality, may show more subtle changes related to MCD.

I attempted to avoid the procedural inadequacies of previous investigations of the EEG in MCD by using a control group of normal children age- and sex-matched with those in the MCD group. The bipolar technique of recording was employed for the detection of possible localised cortical effects related to MCD, and changes in the EEG were measured over a period of 8 months. Differences in the normal electrical activity of the cortex between control and MCD groups were also considered.

SUBJECTS

Subjects in the experimental (MCD) group were selected according to the definition of Clements.[8] The disadvantages of a broad definition of MCD, and the need for a taxonomy for this group of dysfunctions have been discussed by Walzer and Richmond.[9] It is not my intention to become embroiled in the semantic controversy surrounding the concept of MCD. The orientation adopted by Walzer and Richmond[9] would appear to be applicable in the present instance. Briefly, they suggest that dysfunctions of the central nervous system result in primary disorganisation, which influences the developmental reaction to the environment, thus producing atypical patterns of behaviour. In the present study the end-result of this process was used as the criterion, namely enrolment due to parental or teacher anxiety, or both, in a school applying remedial education techniques.

MCD Group

Subjects in the MCD group were 35 children (23 males and 12 females) in full-time attendance at a centre for remedial education, the majority having been enrolled for between 1 and 3 years. Initial referral to the centre was for specific reading, writing or spelling problems in 11 cases, and in the remainder because of prolonged non-achievement without obvious cause at a conventional school. Admissions to the centre were made according

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to assessments by teachers, occupational therapists, psychologists and neurologists at the centre. All MCD subjects had full-scale IQs greater than 80, with the exception of one, an Italian immigrant, whose full-scale score was depressed by a low and almost certainly invalid verbal score, resulting from his inability to understand and speak English. This subject's performance IQ was, however, 87. Full-scale IQs for the experimental group ranged from 80 to 126 (mean 101,56; SD 11,98) excluding the subject just mentioned. Thirty-two subjects were tested on the South African Individual Scale, and 3 on the Merrill-Palmer Scale. Subjects were aged 6 years and 7 months to 13 years (mean 9,7 years; SD 21,02 months) when the EEG was first recorded. They were aged 7 years and 4 months to 13 years and 7 months (mean 10,41 years; SD 20,93 months) on the second occasion of EEG recording. Details of pre-, peri- and postnatal histories were obtained for MCD subjects when these were available. Three subjects were born after difficult pregnancies, 12 had complications involving the perinatal period, and 10 reported relatively serious accidents or illnesses (excluding the common childhood diseases) in the postnatal period.

Control Group

The control group comprised 23 males and 12 females attending a private (non-state-financed) primary school. Full-scale IQs for 20 of this group ranged from 95 to 143 (mean 118,56; SD 12,15) on the Junior and Intermediate versions of the South African Group Test. IQs were not available for the remainder of this group. No control subject was reported to show any evidence in this classroom situation suggestive of a learning disability, and the subjects for whom IQ scores were available scored on average at a superior level on the test administered. Each MCD subject was individually matched as far as possible for age and sex with a control subject. The latter ranged in age from 6 years and 8 months to 12 years and 11 months (mean 9,8 years; SD 21,55 months) on the first occasion of EEG recording, and 7 years and 4 months to 13 years and 4 months (mean 10,47 years; SD 21,4 months) on the second occasion. Control subjects were presumably not aware of, and were not asked for, details of pre- and perinatal histories. Four reported relatively serious illnesses or accidents in the postnatal period.

Control and MCD groups did not differ significantly in respect of age at the 5% level on either the first (t =0,045) or second (t = 0,141) occasion of EEG recording. IQ differences between the groups were significant (t = 5,01) at less than the 1% level.

PROCEDURE

EEG Recording

EEGs were recorded in both groups on two occasions, with an intervening period of 8 months. Recordings with 5 different bipolar montages of electrodes placed according to the ten-twenty system[10] were made on an 8-channel

portable Galileo E8b electro-encephalograph. All subjects hyperventilated according to standardised procedure for 3 min. Photic stimulation was applied to all subjects in the control group on both testing occasions, but to only 25 MCD subjects on the first, and 30 on the second occasion of testing because of technical difficulties.

EEG Analysis

All recordings were analysed by eye by the same electro-encephalographer with the aid of a millimetre cursor. Adherence to school schedules and staff shortages extended the testing of both groups to a period of almost 2 years, and EEGs were analysed for each group as they became available. The electro-encephalographer was therefore aware of the group designation of each EEG and, although he attempted an objective analysis, the possibility of unconscious bias cannot be excluded.

EEGs from each group were compared on 41 measures of normal activity (predominantly relating to alpha activity) and indices of cortical dysfunction on each occasion of testing. Both sets of EEGs were rated independently and blindly by two experienced electro-encephalographers for improvement, deterioration or 'no change' during the 8-month interval between recordings.

Other Indices of Change

Changes in the behaviour, personality and emotional characteristics and scholastic performance of children in the MCD group during the interval of 8 months between EEG recordings, were rated by their teachers on an 11-point scale.

RESULTS

Student's t-test[11] was used to assess the significance of control and MCD group differences on EEG measures scored on a continuous scale on each occasion of recording. Other EEG measures, scored discretely, were examined for group differences in incidence on each occasion of recording, using chi-square in contingency table form.[11]

Group differences were considered significant if at the 5% level or less. Findings are presented in Tables I-IV.

TABLE I. INCIDENCE OF NORMAL AND ABNORMAL EEGs IN CONTROL AND MCD GROUPS ON FIRST AND SECOND TESTS

	First* testing		Second** testing	
	MCD	Control	MCD	Control
Moderately and severely abnormal EEGs	28	6	25	4
Normal and questionably normal EEGs	7	29	10	31

In each group N= 35.
* χ^2 = 27,68; (P <0,01).
** χ^2 = 25,96; (P <0,01).

TABLE II. MEAN CONTROL AND MCD GROUP ABNORMA-LITIES DURING REST AND HYPERVENTILATION ON THE TWO TESTS

	MCD		Control		
	Mean	SD	Mean	SD	t
Rest abnormality:					
1st testing	1,60	0,50	0,47	0,60	8,42*
2nd testing	1,21	0,61	0,43	0,54	5,63*
Hyperventilation abn.:					
1st testing	1,27	0,45	0,66	0,77	4,00*
2nd testing	1,14	0,51	0,66	0,61	3,56*

In each group N = 35.
* $(P < 0,01)$.

The results of former investigations[4,5,12] suggesting the association of a high incidence of abnormal EEGs with the symptom constellation of MCD were confirmed, in spite of the procedural inadequacies of some of the studies previously mentioned. Eighty per cent of the MCD group had abnormal or severely abnormal first EEGs, 71,4% had abnormal second EEGs. Respective figures for the control group were 17,7% and 11,4% (Table I). These group differences were significant $(P < 0,01)$. In addition, the EEGs of subjects in the MCD group were rated as significantly more abnormal $(P < 0,01)$ during both rest and hyperventilation than those of the control subjects on both recording occasions (Table II).

Confirmation of the results of Behrens,[7] Paine et al.[8] and Capute et al.[5] indicating a high incidence of both theta and delta activity in MCD children, was also obtained. The most common EEG abnormality in the MCD group was theta (first EEG) and delta (both first and second EEGs) activity. Further, this group had a significantly higher incidence $(P < 0,01)$ of both theta and delta activity on the occasions specified than the control group (Table III). This suggests that a defect in cortical maturation may be associated with MCD, supporting the observations of Critchley[13] and the findings of Satterfield.[14] The association of latent epileptogenic abnormalities and MCD in some cases is suggested by the higher incidence of paroxysmal activity (first EEG) and of sharp wave and spike activity (both EEGs) in the MCD group (Table III). Others[1,3,5] obtained similar results. Finally, it appears that the EEGs of subjects with MCD may reflect a higher level of subcortical excitability than those of normal children of the same age and sex. The MCD group had a significantly greater response to hyperventilation (first EEG) and more abnormal responses (first and second EEGs) than the control group (Table IV). They also displayed more augmentation of activity slower than 7 Hz in response to photic stimulation and hyperventilation (first EEG), and of paroxysmal activity in response to photic stimulation (first EEG) than the control group (Table III).

The MCD group had a significantly higher incidence $(P < 0,05)$ of focal EEG abnormalities than the control group on both occasions of recording (Table III). This is in contrast to the results of Capute et al.[5] who obtained a low incidence of focal abnormalities in their MCD sample of 53. A detailed analysis of all cases displaying evidence of localisation of EEG dysfunction, including those of borderline significance, showed that the right posterior quadrant was implicated in 15 MCD and 3 control subjects $(\chi^2 = 4,06; P < 0,05)$ on the first, and 18 MCD and 3 control subjects $(\chi^2 = 9,308; P < 0,01)$ on the

TABLE III. SIGNIFICANT DIFFERENCES IN INCIDENCE OF EEG MEASURES IN CONTROL AND MCD GROUPS ON FIRST AND SECOND TESTS

Condition	Variable	MCD		Control		Chi Square
		Present	Absent	Present	Absent	
	Theta (1)	32	3	22	13	8,102**
	Delta (1)	32	3	22	13	8,102**
	Delta (2)	24	11	11	24	9,657**
	Focal (1)	14	21	6	29	4,48 *
Rest	Focal (2)	17	18	9	26	3,916*
	Paroxysmal (1)	7	28	1	34	5,081*
	Sharp wave and spike (1)	19	16	7	28	8,811**
	Sharp wave and spike (2)	18	17	9	26	4,884*
	Asymmetry and asynchrony (1)	6	29	0	35	6,563*
Augmentation by photic stimulation	<7 Hz activity (1)†	9	16	5	30	3,844*
	Paroxysmal (1)†	4	21	0	35	6,000*
Augmentation by hyper-ventilation	Eeta (1)†	1	34	7	28	5,081*
	<7 Hz activity (1)†	34	1	28	7	5,081*
Photic stimulation	Subharmonics (1)†	6	19	1	34	6,326*
	Subharmonics (2)‡	2	28	9	26	4,169*

* $(P < 0,05)$.
** $(P < 0,01)$.
(1) Indicates first EEG examination.
(2) Indicates second EEG examination.
† Technical difficulties prevented the administration of photic stimulation to 10 MCD subjects on the first test.
‡ Technical difficulties prevented the administration of photic stimulation to 5 MCD subjects on the second test.

TABLE IV. CONTROL AND MCD GROUP SCORES ON NORMAL EEG MEASURES ON FIRST AND SECOND TESTING OCCASIONS

Measure		MCD		Control		
		Mean	SD	Mean	SD	t
Mean alpha frequency (Hz)	(1)	9,407	1,198	9,507	0,905	0,388
	(2)	9,329	1,043	9,386	0,809	0,252
Mean alpha amplitude (μV)	(1)	38,771	12,697	41,371	11,757	0,876
	(2)	38,857	9,862	41,429	12,454	0,944
Alpha index (0 - 4)†	(1)	2,343	0,954	2,829	0,878	2,184*
	(2)	2,400	0,868	2,857	0,833	2,215*
Alpha organisation (0 - 3)†	(1)	1,286	0,436	1,657	0,444	3,484**
	(2)	1,300	0,657	1,700	0,496	2,834**
Alpha frequency range (0 - 5)†	(1)	0,786	0,768	1,643	1,060	3,820**
	(2)	0,771	0,647	1,229	0,669	2,863**
Number of alpha components	(1)	1,943	0,860	2,571	0,728	3,252**
	(2)	1,971	0,736	2,543	0,805	3,054**
Response to hyperventilation (0 - 3)†	(1)	1,457	0,498	1,143	0,682	2,170*
	(2)	1,414	0,579	1,229	0,614	1,284
Hyperventilation recovery	(1)	17,571	8,732	17,514	22,538	0,014
time (sec)	(2)	15,943	10,068	16,286	11,361	0,132

* $P<0,05$.
** $P<0,01$.
(1) Indicates the measurement made on the first test.
(2) Indicates the measurement made on the second test.
† Represents the upper and lower limits of the measure.
N = 35 in both groups.

second occasion of testing. As 11 of the MCD children with right posterior abnormalities on first EEG test were referred to the centre for remedial education specifically for reading difficulties, or had a reading age more than one year retarded in relation to chronological age at the time reading ability was tested, this may provide evidence for Tuller and Eames's[6] contention that parieto-post-temporal dysfunction (in this case specifically in the right hemisphere) is related to reading disability.

Significant MCD and control group differences in incidence and magnitude of measurements of both normal and abnormal EEG activity (Tables I - IV) were found during the first and second occasions of EEG recording. However, group differences were reduced, both in number and in size of difference, on the second occasion. Further, no 'new' variables were added to those that differentiate significantly between the groups on the second occasion of recording. This suggests that the MCD group tended to approach closer to the normal control group in terms of cortical electrical activity during the 8-month period between EEG recordings. Behrens[7] described a similar tendency in his MCD group, after periods between EEG tests of 6 - 24 months, and suggested that 'the changes in the EEG characteristics encompassed by this study indicate an apparent trend towards normalisation'.

Although an apparent over-all tendency towards normalisation of the EEG was apparent in the MCD group, individual cases showed improvement, deterioration or 'no change' in EEG characteristics between tests. The ratings of these changes by two independent electro-encephalographers were compared with each other and with teachers' ratings of changes in behavioural, emotional and personality characteristics in the MCD group during the same period. Ratings of changes in control EEGs were also made. Agreement between judges in respect . of ratings of change in EEG characteristics was significant ($P<0,01$), but low (0,432 for the MCD, and 0,488 for the control group). Very little agreement was found between EEG ratings of change and the ratings of teachers of behavioural, emotional and personality tendencies. This provides some support for the views of Freeman[15] who expressed reservations regarding the validity of the EEG, particularly in the field of remedial education. However, the difficulties involved in the analysis of the EEGs of children have been pointed out by Vizioli,[16] Torres and Blaw[17] and Fish,[18] among others, and formal specification of EEG criteria of change would undoubtedly increase reliability. Behrens[7] has indicated that individual EEG change in MCD children may have some prognostic significance in relation to performance on cognitive tests and further research along these lines may prove fruitful.

A detailed comparison of the EEGs of MCD and control groups in respect of measures of alpha activity, revealed interesting and statistically significant differences (Table IV). Group differences in alpha measures were consistent in that they appeared on both occasions of EEG recording. The MCD group displayed a lower index of alpha activity, a less organised alpha, a smaller alpha frequency range and a lesser number of components in the 8-13 Hz band than the control group. Thus, there would appear to be some relationship between MCD and less organised, less variable alpha activity, with a more restricted range of frequencies in the 8-13 Hz band, a reduced number of alpha components and lesser over-all amount of alpha activity. It is of interest that, as early as 1953, Walter[19] suggested a greater variation in the EEG frequency

spectrum among his 'more brilliant colleagues' than among his 'duller patients' This observation was not subsequently upheld by Ellingson *et al.*[20] in a group aged 19 - 40 years, but the present finding suggests that further investigation in a younger group presenting the MCD constellation may prove worth while.

The findings of this investigation do not allow any firm decision to be made as to whether the majority of MCD cases have an underlying disorganisation of electro-cortical function or a disruption of tissue. The process of EEG normalisation seen in this study may provide evidence for the former view. However, bilateral anatomical anomalies of the parietal lobe have been seen at the postmortem examination in a child with marked reading disability.[21] The distinction between functional and organic disorganisation may, in any event, be somewhat artificial in the present context, although treatment procedures would undoubtedly benefit if such a distinction were validly possible.

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