ELECTRO-ENCEPHALOGRAPHY IN CASES OF MENTAL DISORDER

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The value of electro-encephalography as an aid to the study and diagnosis of nervous diseases is now accepted. The most valuable results have been obtained in cases of organic disease of the brain, particularly in space-occupying lesions and in epilepsy, but considerable attention has also been paid to the changes occurring in cases suffering only from mental disorder. The chief contributors to this subject are listed in the bibliography.

The earliest claims were that certain classes of psychotic patients exhibited significant variations in the normal brain rhythms (Lemere, 1936), but these claims did not bear the test of statistical analysis. Later, certain workers considered that, in schizophrenia particularly, true abnormalities were present from which the condition of the patient could be inferred, and a measure of these abnormalities was introduced, called the delta index (Hoagland, Rubin, and Cameron, 1936). Again, further work showed that these abnormalities were illusory and that many of them were indeed artefacts, due to involuntary or uncontrollable movements, particularly of the eyes (McMahon and Walter, 1938). This matter of spurious or artificial disturbances is a particularly important one in the electro-encephalogram of mental patients, since by the very nature of the complaint complete co-operation may be lacking, and the usual request for quiet may be positively disobeyed. For this reason, the more severe cases may never be examined, and should the presence of artefacts not be suspected, an apparent correlation between the patient's condition and fluctuations in the record may give the illusion of a true electro-encephalographic discovery.

As many workers have pointed out, the absence of a strict pathological classification of mental disorder makes infinitely more difficult any interpretation or comparison of electrical records. It is quite possible that a group of, say, 50 "schizophrenic" patients in one hospital may contain a number of people who in another centre would have attached to them quite different clinical labels, and there is no doubt that this diversity of psychiatric vocabulary is responsible for many anomalies and paradoxes.

It is doubtful, therefore, whether in the present condition of the subject

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and of the medical world, any attempt at a more detailed theoretical analysis is worth while from any point of view, but it was considered most important to decide whether electro-encephalography of patients in a mental hospital was likely to be of real practical value. Such a study implies no assumptions about the nature of the disorders studied, nor of the true classifications of the records obtained, but, bearing in mind the great saving of time achieved by electro-encephalography in other conditions, it was thought posssible that a similar facilitation of preliminary diagnosis, and possibly some clarification of prognostic probability, might result from the examination of patients as a routine procedure.

Owing to difficulties of transport imposed by the national situation, the number of patients included in this study is only a fraction of what had been hoped, but they represent a cross-section of a mental hospital population, no attempt being made to select " interesting " cases, the only selection operating being that the patients had to be reasonably clean and co-operative, so that the journey from one hospital to the other could be made without danger to themselves or others.

Seventy-two patients were examined, and these were classified as follows:

Epileptics	18
Catatonic schizophrenics	6
Non-catatonic schizophrenics	16
Manic-depressives in mania	2
Manic-depressives in depression	10
Involutional melancholia and depression	14
Cerebral atrophy	3
Organic cerebral lesion	1
Psycho-neuroses	2

The patients were all examined lying down in a lighted room in a relatively quiet atmosphere. The examination in each case lasted about a quarter of an hour, and the effects of opening and closing the eyes, mental activity, and over-breathing were tested in as many of the patients as were sufficiently co-operative.

The apparatus used was a three-channel amplifier driving Grass ink writers, the time constant of the amplifiers being of the order of one second, and the background noise small enough to permit detection of potentials about five microvolts in size. The recording speed was 1·5 centimetres per second.

Classification of the records was on a very broad basis; since it was desired to know merely whether or not a significant abnormality was present, the records were called either normal, abnormal or doubtful. For the purposes of this study, the criterion of abnormality was the presence in the record of potential variations having a frequency of less than 7 per second and an amplitude greater than about 20 microvolts. In more co-operative subjects this

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criterion could be made more precise, and more detail could be taken into account, but the presence of uncontrollable artefacts was so common that any attempt at quantification seemed unjustifiable, and the advantage of a simple classification of this sort is that the number of doubtful cases can be greatly reduced, although at the expense, perhaps, of precision.

The aim of the study, it may be repeated, was to test the usefulness of the method as a routine aid to the clinical psychiatrist, rather than to study the nature of the conditions included in the population.

The results of the investigation are set out in Table I, and may be briefly described as follows :

Out of the 72 patients, 18 (or 25 per cent.) gave definitely abnormal records, and 3 were doubtful. Of the abnormal records, 12 were from epileptics, 2 from catatonic schizophrenics, 3 from cases of cerebral atrophy, and 1 from a case of extensive cerebral haemorrhage. No abnormalities were discovered in the non-catatonic schizophrenics, the manic-depressives, the involutional depressives, or the psycho-neurotics.

As a first approximation, therefore, it is clear that electro-encephalography serves to sift out from a population of mixed mental patients the majority of the epileptics, and probably nearly all of those with organic changes in the cerebral cortex. It reveals nothing in the depressed or non-catatonic schizophrenic patients, and shows peculiar irregular disturbances in certain of the catatonic patients.

The abnormal records may be considered in groups according to their clinical classification.

1. *The epileptic group.*—All the epileptics examined were suffering not only from convulsions, but from some disturbance of mind or behaviour as well. Most of those giving abnormal records had regular fits, while those with normal records either had fits infrequently, or had only a remote history of convulsions.

TABLE I.

Diagnosis.	Electro-encephalograms. Normal.	Doubtful.	Abnormal.	Total.
Epilepsy	5	1	12	18
Schizophrenia : Catatonic	3	1	2	6
Non-catatonic	15	1	—	16
Manic-depressives : Mania	2	—	—	2
Depression	10	—	—	10
Involutional and other depressives	14	—	—	14
Cerebral atrophy	—	—	3	3
Organic cerebral lesions	—	—	1	1
Psycho-neuroses	2	—	—	2
Totals	51	3	18	72

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It may be noted that the proportion of abnormalities is about the same as that obtained with any population of people complaining of fits of various sorts.

Fig. 1 shows at "A" a tracing obtained from a case of simple depression exhibiting a normal alpha rhythm, and at "B" a record from one of the epileptic patients. This shows a fairly well localized delta rhythm, characteristic of this condition between attacks, and is representative of the group. The important feature of the record is that the slow delta waves are

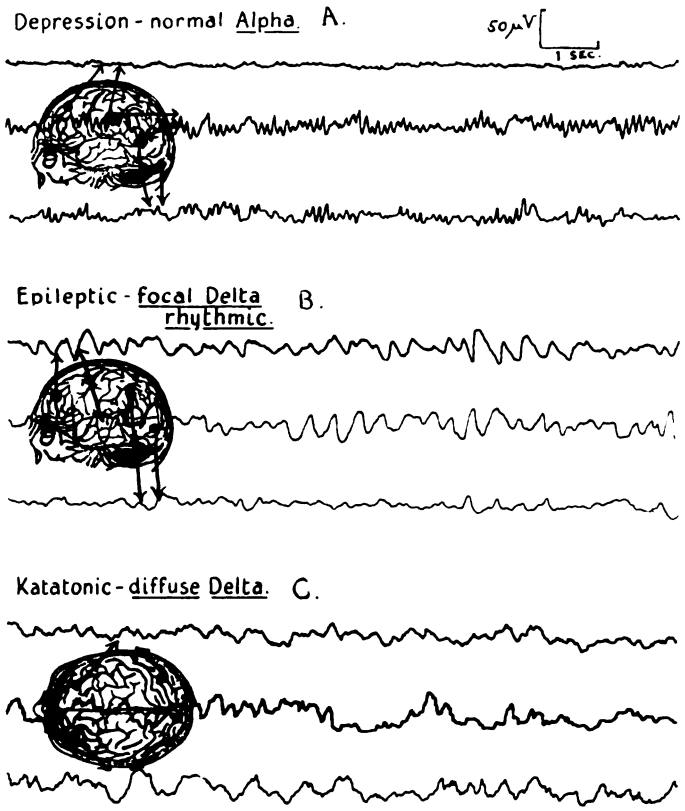


FIG. 1.—Examples of three types of electro-encephalogram found in the series of mental patients. A shows a normal alpha rhythm from the post-central region, B shows a slow delta focus in the superior frontal region, pathognomonic of epilepsy, and C shows random discharges at various frequencies from a patient described as a hyperthyroid catatonia.

rhythmic and give an appearance, as it were, of spontaneity, and this record should be compared and contrasted with those in the other figures, since it is possible, from the degree of development of rhythm of the slow discharges, to differentiate between an epileptic record and one from a patient suffering from other types of cerebral disturbance.

Several workers in this field have commented upon the superficial resem-

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blance between epileptic electro-encephalograms and those from certain schizophrenics, and have suggested (Gibbs and Lennox, 1938 ; Davis, 1940) that the resemblance between the two classes of electro-encephalogram may indicate some relation between the clinical or pathological features of the two conditions.

In the group of patients studied for this work, very little true resemblance was found between the epileptic and the schizophrenic records. Indeed, the only two schizophrenics who gave abnormal tracings would never have been considered epileptic if the analysis had been done blind, and it seems doubtful whether the comparison of epilepsy and schizophrenia on the basis merely of electro-encephalographic records can have any validity. The appearance of slow waves in an electro-encephalogram may be taken as diagnostic of cerebral abnormality, but a slow potential change in itself is entirely non-specific, and the degree of rhythmicity must be taken into account when any comparison is made between records.

In this connection it may be remarked that the characteristics of the recording system are of the greatest importance, since if the time constant of the amplifiers is too short, or if a tuned amplifier is used, a relatively arrhythmic slow potential change may appear on the record with an exaggerated degree of rhythmicity. It is by no means certain that all investigators have observed these two precautions.

For the mental hospital psychiatrist, differentiation between extremes should not be difficult, but there are many cases in which the only complaints or symptoms upon which a classification can be based are interpretable in a number of ways. For example, a patient known to have periods of unaccountable or violent behaviour may be suffering from a true periodic catatonic excitement, or from some form of epileptic equivalent, and obviously the treatment of the patient will depend entirely upon which of these alternative diagnoses is finally accepted. It is in such cases as these that electro-encephalography can be of particular value, especially in young people, since it is becoming clear that a large proportion of cases of severe behaviour disturbance in children are associated with abnormal electro-encephalograms, and the probability of an epileptoid aetiology. In several cases in this series, diagnostic information of this type was actually obtained, and in one patient with a definitely abnormal electro-encephalogram, who had been clinically classified as a schizophrenic, the induction of convulsions by the electrical method was followed by two spontaneous fits, suggesting very strongly that the electro-encephalographic abnormality indicated something like an epileptic pathology.

The effect of various sorts of treatment upon these different groups is an important and very involved matter, which is now the subject of a special study, and this will not be discussed at any length here. It would seem probable that, as several American workers have conjectured, convulsive therapy may be counter-indicated in any case whose electro-encephalogram shows slow waves of any sort.

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Another point of interest is that if voluntary over-ventilation is performed as a part of the routine examination, the effect is found to be very much more dramatic in the epileptic patients, while the few abnormalities found in other groups are scarcely affected by the alkalosis. It is true that such patients do not co-operate with any enthusiasm, but, even allowing for the smaller degree of ventilation, there seems a strong likelihood that the slow epileptic rhythms are augmented in some almost specific way by a decrease in hydrogen ion concentration, however this effect may be mediated.

2. *Schizophrenics.*—Out of all the schizophrenic patients examined, only two gave records which were definitely outside the normal range, and one of these is shown in Fig. 1, " C." There are irregular potential changes at several

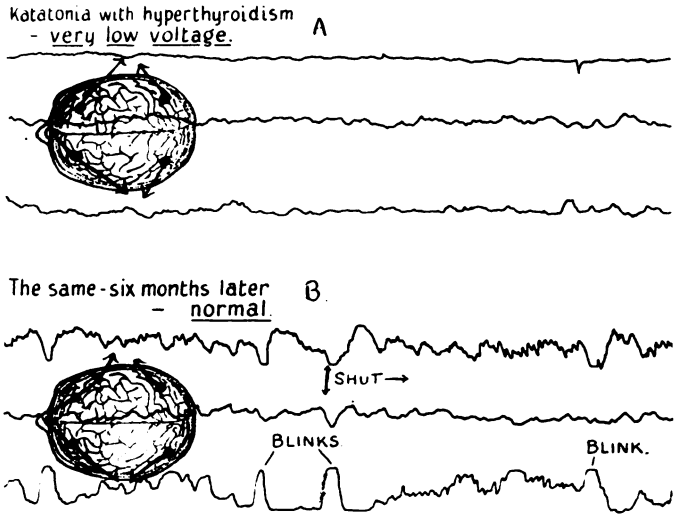


FIG. 2.—A, An extremely low voltage record from a patient described as hyperthyroid catatonia. B, The same six months later, showing normal rhythms and potential.

frequencies from all areas. The two hemispheres are poorly synchronized, and neither opening and closing the eyes nor over-breathing had any visible effect upon these potentials. The patient from whom the record was taken was by no means a simple case. She was a girl of 20, with a history of hyperthyroidism, and just before admission to the mental hospital she had been operated on and a large proportion of her thyroid had been successfully removed. Immediately after the operation she had developed marked mental disturbances of a catatonic type, and when examined was in a state of stupor, but could be stimulated sufficiently to open and close her eyes and to overbreathe to a moderate extent. Her impedance angle (Brazier, 1931–38) was also done, and this was very high up in the hyperthyroid range, indicating that even after her sub-total thyroidectomy she was still suffering from some degree of thyroid over-function. Some months after the examination she recovered

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entirely, spontaneously, and returned to work. She had sufficient insight to be thoroughly frightened of hospitals and could not be induced to return for another electro-encephalogram, but her behaviour is said to be entirely normal.

The other abnormal record was from a patient suffering from an acute schizophrenic illness, who was in a state of profound stupor with waxy flexibility, and his condition remains unchanged.

The striking difference between these two catatonic cases and the others who were in the schizophrenic group, but not catatonic, may be significant as indicating a true sub-group among the schizophrenics, and it is hoped to investigate this more closely. Indeed, this investigation was planned some time ago, but, as so often occurs, immediately the decision had been taken no catatonic patients could be discovered.

The three normal catatonic electro-encephalograms were from patients with a more long-standing illness, and this again should be borne in mind in interpreting the results.

The record classed as doubtful in this group is shown in Fig. 2 at "A," and is characterized merely by the absence of any regular rhythm and even of the usual random potential changes. It can be described merely as a very low voltage record. This patient was also catatonic and had signs of hyperthyroidism, but had not been operated on, and she also recovered spontaneously and returned to her home. When examined six months later as an out-patient she gave an entirely different record, shown in Fig. 2 at " B." Here are seen normal random potential changes, a certain amount of alpha rhythm when the eyes were shut, and artefacts due to blinking of the eyes. There is no obvious explanation for this change, nor for the difference between this record and that in Fig. 1, " C." They may represent different stages in the same illness, or it may be that in spite of the superficial clinical resemblance the conditions were really entirely different. Unfortunately it has not been possible to collect more data, as such cases are rare. These findings should be compared with the report by Hemphill (1942), suggesting the existence of such a group of hyperthyroid schizophrenics, among which were the two patients discussed in this series.

3. *Depressives and melancholics.*—Since no abnormalities were found among these patients, it is sufficient to comment that artefacts are extremely common in this category. It may be a pure coincidence, but it is among these patients that the greatest success is obtained with convulsion therapy.

4. *Organic cases.*—In these patients various types of abnormality were discovered. Two examples are shown in Fig. 3, "A" and " B." The patient who gave the tracing at Fig. 3 "A" was suffering from some cerebral degenerative disease, the exact nature of which cannot be decided until autopsy, but it is interesting to note that her early symptoms were those of a confusional psychosis, and this group may be considered a very important one, in that differentiation between a purely mental disorder and one

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associated with organic cerebral changes is not easy in the early stages of the disease, as is also the case, of course, with expanding lesions, so that electro-encephalography may make a very important difference to the patient's treatment and ultimate fate. Fig. 3 " B " was taken from a patient, aged 43, who had had a stroke two years previously, resulting in a right-sided palsy and motor speech defect. He had become deeply depressed and later mute, resistive, and suicidal. At the time of examination he was beginning to recover slightly,

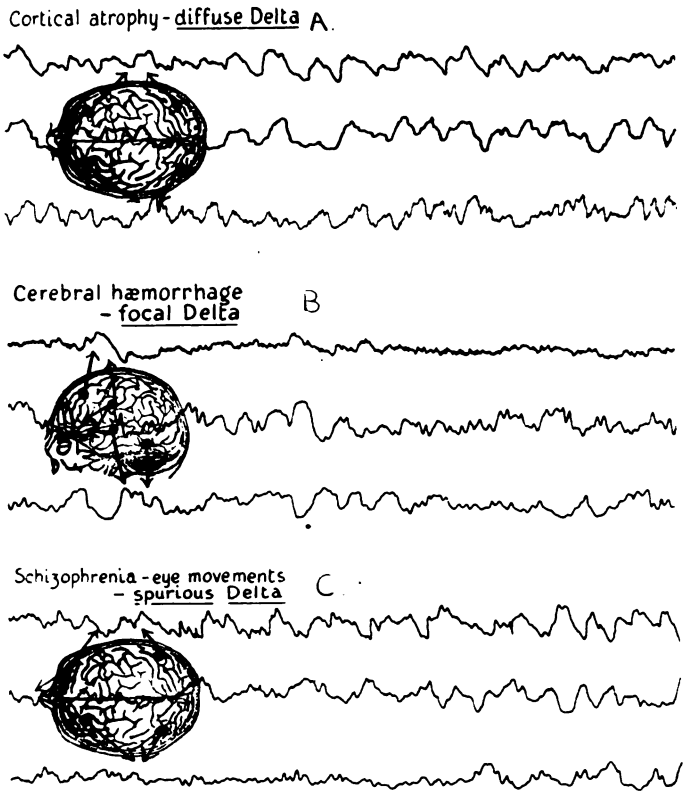


FIG. 3.—A, Diffuse delta discharges associated with cortical atrophy and indicating progressive interference with cortical function. B, A focal delta discharge in the left fronto-temporal region, suggesting local damage and correlating with the patient's clinical history. C, Spurious delta-like waves originating actually from movements of the eyeball and exactly simulating a focal cerebral abnormality.

and has since made good progress. The electro-encephalogram demonstrates the presence of a localized area of cortical damage correlating well with the neurological signs, and there is a real possibility that this rather unusual persistence of electro-encephalographic abnormality for two years after a vascular catastrophe may partly account for his very serious mental reaction to his misfortune, for it would indicate that the area of damage was even greater than the neurological signs would suggest.

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Fig. 3 " C " shows a record from a schizophrenic patient in a state of mild excitement. The slow potentials shown are due entirely to involuntary movement of the eyes, consisting of a very slight tremor of the eyeball, scarcely visible by direct examination. The electrode in the right frontal position has been moved forward specially to exhibit these artefacts. It is of the greatest importance to notice that no amount of inspection of the record could possibly enable an investigator to decide whether the potentials were true or false, as it is only by knowledge of the conditions under which the record was taken and by really painstaking localization of all potential changes that artefacts such as these can be controlled or eliminated. If only one recording channel had been available, it would have been almost impossible to decide whether the potentials in this case were cerebral or ocular in origin, and, whenever an apparent abnormality is discovered in the frontal regions, most particularly in patients of the type discussed here, the onus of proving the cerebral origin of the potentials rests in each case on the investigator.

Discussion.

It will be noted that no mention has been made of percentages, and it is certainly unfortunate that the number of patients investigated is too small to permit of any statistical analysis. Another possible source of error is that while these investigations were going on there were fairly regular air attacks in progress, and it is by no means beyond the bounds of possibility that this unusual excitement may have had some effect, both upon the mental state of the patients in the hospital and upon the type of patient admitted during that period. Certain differences between the results obtained in this investigation and those reported by workers elsewhere may be accounted for in this way.

Since the purpose of this investigation was rather to test the validity of method as a clinical aid than to investigate the nature of the conditions themselves, the description of the tracings has not been particularly detailed. There were, for example, several cases in which the alpha rhythm was either unusually slow or abnormally persistent, and these are well worth studying in themselves. (Compare Davis, 1940, MacMahon and Walter, 1938.) But these variations cannot yet be considered in any sense pathognomonic, and are therefore not of any very great assistance to the clinician.

o records were seen of the type described by Davis (1940) as " choppy," and the reason for this is still obscure. The absence of such records in this series may be accounted for by differences in the time constant of the recording apparatus used, since Davis's amplifiers apparently had a much shorter time constant than those employed for this study. The potentials appearing in Davis's record as " choppy " may really have been slower and smoother, but truncated by the short time constant of the coupling condensers.

The records showing variable slow rhythms in the schizophrenic patients

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are presumably in the same class as those described by Davis as " dysrhythmic," and the cause for these variable slow changes will be discussed in the next paragraph. It would be wrong to draw any sweeping conclusions from this study, owing to the small numbers in each group, but the results of the examinations prove at least that time spent in electro-encephalography of mental patients is by no means wasted, from the point of view either of the patient or of the psychiatrist, and the brief descriptions of one or two special cases presented here may provide some picture of the sort of help which can be given by electro-encephalography. As an epilogue, some suggestions will be made as to the interpretation of the records in the more difficult cases, but these will be of a somewhat technical nature, and those for whom Ohm's Law is but a pre-medical memory will find little of interest beyond this point.

Assuming that the epileptic records are in no way different from those obtained from other groups of epileptics, and that the records obtained from organic cases also require no special consideration in this survey, we are left with the peculiar tracings given by certain of the schizophrenic patients, and these certainly require an explanation and may suggest a hypothesis.

If these records were presented to someone experienced in electro-encephalographic interpretation without any account of the patient or the recording conditions, the description given of the records would most likely be merely " high voltage " in the case of Fig. 1, " C," and " low voltage " for Fig. 2, "A." That is to say, the potential changes differ not qualitatively but quantitatively from the normal ; it is as though Fig. 1 " C " had been taken with considerably increased amplification and Fig. 2 "A" with the gain greatly reduced. Both records could be mimicked by merely changing the position of a pointer on the apparatus, whereas the records from the epileptic and organic cases could not. What is the simplest explanation for this appearance ? It is well known that the potentials from the cortical neurones are greatly attenuated by the tissues which intervene between the brain and the electrodes on the scalp. These tissues are, of course, in three main groups : the meningeal envelopes of the brain, the skull, and the tissues of the scalp. All these various tissues, and of course the brain itself, have differing electrical resistances, and the degree of attenuation of the brain potentials depends upon the relative value and distribution of these resistance elements. Many attempts have been made to analyse the nature and effect of this resistance network, and it is comforting at least that at the frequencies involved in electro-encephalography only the resistance need be considered, since the capacitative properties of the tissues have a negligible effect at these frequencies. But even the ohmic resistance network is extremely complex, and its effect upon the potential gradients in the head is very hard to predict. When recording with an amplifier, a high resistance between the source of potential and the amplifier input has relatively little effect upon the apparent size of the potential recorded, but a resistance across the amplifier input has a very marked effect,

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particularly in the scale of resistances encountered on the head—that is, of the order of thousands or tens of thousands of ohms. In practical terms, the resistance between the scalp and the brain does not greatly affect the size of potential led off from the scalp, but the resistance between the recording electrodes—which is composed not only of the skin, but also of all the deeper tissues as well—has a very great and variable effect upon the potential reaching the amplifier. There is no simple way of measuring the values of resistance in the different parts of this resistance network, and the simplest explanation of any marked change in electro-encephalographic potentials—as apart from the appearance of entirely strange rhythms—is that the anatomical resistance has changed in such a way as either to attenuate or to amplify the potentials reaching the scalp from the brain.

Now it is well known that a schizophrenic in some sort of catatonia exhibits peculiar and as yet unaccountable changes both in metabolism and in anatomy. Moreover, in the case from which the record in Fig. 1 " C " was taken, the patient was actually markedly hyperthyroid, a condition characterized by prominent changes in the superficial tissues. The simplest explanation which can be put forward for the records obtained in such cases is that some disturbance of water and ionic balance has occurred in some or all of the tissues between the brain and the electrodes, leading in some cases to an increase in the apparent size of the brain potentials, in others to a decrease. Experiments are now in progress to check this hypothesis by direct measurement, and it is hoped to present material at a later date which will throw light on its validity. At present it seems a reasonable conjecture that unless entirely different rhythms are detected, the appearance of very large or very small potentials is due to changes not directly connected with the bio-electrical properties of the central nervous system.

Summary.

1. Electro-encephalograms have been taken of 72 patients suffering from a variety of mental disorders.

2. Definite abnormalities were found only among the epileptics, catatonic schizophrenics, cerebral atrophies, and in one case with an organic cerebral lesion. No true abnormalities were seen in non-catatonic schizophrenics, nor in depressive conditions.

3. The particular value of electro-encephalography in mental patients seems to be the diagnosis of latent epilepsy, and in discrimination between organic and purely mental disorders.

4. It is suggested that the peculiar appearances of certain schizophrenic records may be due to changes in the electrical resistance of the tissues between the scalp and the brain.

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REFERENCES.

BERGER, H. (1931), *Arch. Psychiat. Nervenkr.*, **94**, 16.
Idem (1933*a*), *ibid.*, **98**, 232.
Idem (1933*b*), *ibid.*, **99**, 555.
Idem (1937*a*), *ibid.*, **106**, 165.
Idem (1937*b*), *ibid.*, **106**, 576.
Idem (1938), *ibid.*, **108**, 407.
BRAZIER, M. A. B. (1933), *Lancet*, ii, 742.
Idem (1936), *Endocrinology*, **20**, 621.
DAVIS, P. A. (1940), *Amer. J. Psychiat.*, **96**, 851.
DAVIS and DAVIS (1939), *ibid.*, **95**, 1007.
GIBBS, F. A., GIBBS, E. L., and LENNOX, W. G. (1938), *ibid.*, **95**, 255.
HEMPHILL. R. E. (1942), *J. Ment. Sci.*, **88**, 1.
HOAGLAND, H., RUBIN, M. A., and CAMERON, D. E. (1936), *J. Psychol.*, **3**, 513.
Idem (1937*a*), *Amer. J. Physiol.*, **120**, 559.
Idem (1937*b*), *Amer. J. Psychiat.*, **94**, 183.
Idem (1938), *Med. Rec.*, April 6, p. 293.
JASPER, H. H., FITZPATRICK, C. P., and SOLOMON, P. (1939), *Amer. J. Psychiat.*, **95**, 835.
LEMERE, F. (1936), *Brain*, **59**, 366.
MACMAHON, J. E., and WALTER, W. G. (1938), *J. Ment. Sci.*, **84**, 781.
RUBIN, M. A. (1940), *Amer. J. Psychiat.*, **96**, 861.
TRAVIS, L. E., and MALAMUD, W. (1937), *ibid.*, **93**, 927.

https://doi.org/10.1192/bjp.88.370.110 Published online by Cambridge University Press