ELECTRO-ENCEPHALOGRAPHY.

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THE history of electro-encephalography contains both triumphs and disappointments. The most profound of the disappointments is the relative failure to elucidate any of the important problems which concern the psychiatrist. It was hoped that some real electro-physiological alteration would be seen in patients whose mental condition suggested something bordering on the organic, but the negative findings even in the most profound mental disorders are almost as striking as if they were positive. Before considering the published work it would be well to review in a few words the nature and significance of electro-encephalographic records.

The fundamental axiom of electro-physiology is that all excitable tissue is capable of generating small electric currents, whose direction is such that the inside of the cell concerned is electro-negative to the outside world. This has been shown to be true for all nervous tissue, cortical neurones included, and it is therefore perfectly reasonable that the human cortex should produce electric currents of one sort or another. The size of these currents is, however, at no time very large, and when, as in the brain, the active tissue is surrounded by a majority of inactive cells and connective tissue, its feeble electric activity is dissipated in its immediate surroundings, and the amount of current or voltage remaining for the electro-physiologist is very minute indeed; moreover, in the case of the brain the intervening tissues of the head attenuate these currents still further, so that in order to detect the spontaneous electrical activity of the brain from the outside of the scalp, great amplification and sensitive recorders must be used. If the form and frequency of the brain potentials were such as are seen in the peripheral nervous system it is doubtful whether we should ever be able to study them at all. The typical nerve action potential lasts about $\frac{1}{1000}$ second and in normal conditions appears in volleys, sometimes synchronized, more often not, so that a record may often resemble closely the fundamental electrical "noise" which is the background to physical existence. The brain, however, does not appear to be so restricted in its behaviour; its electrical activity has large rhythmic components which stand out clearly against a background of jumbled action potentials and artefacts, like the note of a whistle above the murmur of a busy street.

It is because of this rhythmicity in its electrical behaviour that the electrophysiology of the brain can be studied at all without surgical aid, but it means also that we are liable to neglect potential changes which lack a rhythmic character, and in doing this we may be missing facts of the greatest importance. Electrical rhythmicity has an unfortunate physiological correlation; far from being action potentials, the electrical rhythms of the brain would be more truly described as "inaction" potentials, since they are seen most clearly

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when the part of the brain concerned is at rest. We are, therefore, constrained to studying what may be called the negative properties of the brain rather than its positive ones, which still elude us. The same condition applies in other fields, for it is easy to show by extirpation that a part of the brain had fulfilled some function, but it cannot be demonstrated by replacement that such function can be restored. An answer can be got by subtraction, but its accuracy cannot be checked by addition.

The significance of this situation in neuro-psychiatry is that the more subtle the disorder, the more slight the electro-encephalographic changes are likely to be, and the detection of minute and transient changes of rhythm is one of the most difficult tasks both for the standard apparatus and for the eye of the observer. This accounts for the contradictions and vacillations of opinion, which are the most prominent features of the literature. The earliest report on the electro-encephalogram in schizophrenia (Lemere, 1936) was that patients in this category showed less of the rhythmic alpha activity than normal patients. If this were true it would indicate an unusual degree of visual and mental activity—which is scarcely the most prominent feature of the schizophrenic condition. As a contrast it was claimed that manic-depressive patients showed an unusually large and regular alpha rhythm, suggesting an ability to disregard visual impressions and images, which again accords but ill with the conventional picture of the disorder. More lately a close resemblance has been claimed between schizophrenia and psycho-motor epilepsy on the basis of electro-encephalographic studies (Gibbs, Gibbs and Lennox, 1938). It is stated that—"On the basis of statistical, therapeutic and electrical evidence we believe that any relationship between epilepsy and schizophrenia is positive rather than negative. We believe that some of the clinical boundary lines which delimit different disorders characterized by recurring psychic or psychomotor symptoms are artificial, and are of secondary importance compared with classification based on physiological pathology." This bold and revolutionary belief, intriguing though it is, is contrary not only to the majority opinion of clinical observers, but also to most electro-encephalographic experience. In a later publication Gibbs (1942) amends the earlier claim and says "electro-encephalography cannot . . . at present be used to diagnose manic-depressive psychosis, schizophrenia, feeble-mindedness, migraine or psychoneurosis." More recently in a routine survey of mental hospital cases, Walter (1942) reported: "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." From these few examples, which are representative of the whole literature, it is clear that no consistent or diagnostic features are found in the electro-encephalograms of psychiatric material.

This failure does not mean that the story is finished, however, but only that the easy successes in the first years of electro-encephalography have led to a certain impatience with anything but the most striking records. It is a fact which many observers have commented on after taking a few thousand records, that the eye becomes so practised in detecting the grosser abnormalities and

the more dramatic accompaniments of organic cerebral disease that it passes without question variations of a more subtle nature, and indeed the appetite for recording flags without the stimulus of an occasional " spike and wave " from a *petit-mal* or a focal delta rhythm from a cerebral tumour. All the more creditable therefore are the efforts of those who have attempted to reveal significant variations in the normal rhythm too slight for the unaided eye.

In one of her last papers Pauline Davis (1942) adopted a classification of records into three main types with the hope of obtaining some quantitative data on the relation between mental disorder and the normal features of the EEG. Her conclusions are too complex and technical to be summarized here, but the general impression is that some relationship may exist between the mental state and history of a patient and the fine structure of the EEG. Davis was not able to confirm the presence of slow or delta waves as a diagnostic feature in schizophrenic records. Her main contribution is the description given to certain records as " choppy," signifying apparently the presence of irregular higher frequency components in the record. This " choppy " activity was found in 61 per cent. of 126 schizophrenics as compared with 39 per cent. of 81 manic-depressives. Davis regards the " choppy " activity " as indicating primarily over-stimulation or irritation of the cortex which is due to unsynchronized activity within the central nervous system." She suggests that this " might account for apparent early deterioration in schizophrenics as a secondary effect of prolonged or continuous over-activity." In those of her patients under 40 years of age 47 per cent. of the schizophrenics but only 3 per cent. of the manic-depressives showed this " choppy " activity.

In collaboration with Sulzbach, Davis " demonstrated the occurrence of ' choppy ' activity with the appearance of schizophrenic-like symptoms " during the administration of mescaline. Davis concludes that " the EEGs clearly demonstrate that the condition is *primarily* not one of physiological sluggishness."

These findings, though very suggestive, have unfortunately not been confirmed by other workers, and there is one important objection to the optimistic conclusions reached by Davis. This is the general one that components of the EEG having frequencies above 20 c/s are very difficult to distinguish from artefacts due to muscle action potentials, particularly with ink-recording oscillographs, which tend to smooth out higher frequencies or to convert them into small oscillations at the natural frequency of the recording pen. In a condition like schizophrenia, where disturbances of muscle tone are conspicuous enough to lead to a catatonic rigidity or flexibility, an unusual degree or quality of muscular activity is to be expected, even when its mechanical effects are not obvious, and it remains to be proved that Davis's " choppy " activity is not muscle action potentials.

A similar criticism has been made (MacMahon and Walter, 1938) of the reported delta waves in schizophrenics, which in most cases can be traced to artefacts due to ocular movements of the rhythmic type common in mental disorder.

It will be realized that this question of artefacts is of primary importance

in recording from mental patients, and it is a matter which has received inadequate attention by many workers. Walter (1942) pointed out that the magnitude of potentials led off from the scalp depended, among other things, upon the electrical resistance of the brain itself and of the intervening tissues. Since quite gross changes are known to occur in the superficial tissues of schizophrenics (Hemphill, 1942), it is quite possible that some of the variations in voltage which have been described as characteristic of this condition may actually be due merely to variation in superficial electrical resistance.

Another attempt to "quantify" the EEG is that of Rubin (1938, 1939, 1940). He uses the conception of "per cent. time alpha" as a measure of the amount of alpha rhythm in a given record. This quantity is computed by measuring the percentage of two consecutive metres of record occupied by the alpha rhythm, which is taken to be at least three consecutive alpha waves. By recording from seven different points on the scalp in succession using an "indifferent" electrode on the mastoid process, Rubin was able to plot the *per cent. time alpha* against the position of his electrode, and he displays curves showing that the two hemispheres are symmetrical in normal people, but asymmetrical in certain cases with cerebral atrophy revealed by air replacement. Unfortunately another serious criticism can be made of this work. In his normal records Rubin demonstrates two peaks of *per cent. time alpha*, one in the parieto-occipital region and one in the frontal region. This would imply that alpha activity is as common in the frontal lobes as in the occipital, which is not the case. Simple experiment shows that when an "indifferent" electrode is placed on the mastoid process and another in the frontal region, the alpha rhythm will be picked up not by the frontal electrode, but by the mastoid one, which is of course nearer to the alpha focus than is the frontal electrode. That is to say, the "indifferent" electrode is not "indifferent" at all. Another criticism, not so serious, is that Rubin used ten-cycle filters "to make analysis easier." Since these filters would tend to produce a ten-cycle rhythm when receiving a transient or aperiodic input, the amount of alpha rhythm recorded would not necessarily be a true representation of the actual alpha activity. Yet another criticism can be made relating to a record in Rubin's paper showing a "psycho-motor seizure"; the transient potentials in this record are identical with those seen from eye movements, and it seems extremely probable that they are due to the rhythmic ocular tremor already referred to, particularly since his electrodes were on the forehead of the patient.

Since it would seem necessary to abandon hope that any specifically abnormal features are likely to be discovered in the EEGs of mental patients (compare Finley and Campbell, 1941), the physiological significance of the "normal" rhythms must be carefully considered. There is no doubt that the alpha rhythm itself contains much more of interest than was at first supposed. In the first place, since it is usually localized to the visual association areas of the cortex and may respond to both mental and visual stimuli, it must be considered one of the few direct methods of studying cortical physiology. It has been shown that the dominant frequency of the alpha rhythm correlates well with the basal metabolic rate, with the oxygen consumption of the brain and with the blood-sugar level (Lennox, Gibbs and Gibbs, 1938). There is an

inverse correlation over a certain range with the CO_2 content of the jugular blood (Gibbs, Williams and Gibbs, 1940), and a rather irregular and puzzling relationship to intellectual level (Rahm and Williams, 1938).

Apart from these biochemical relationships, Jasper and Shagass (1941) have shown that the inhibition of the alpha rhythm by visual stimuli may be conditioned to previously inert stimuli, and that this conditioning obeys all the laws laid down by the Pavlov school. They remarked that this conditioning of the alpha response is one of the most satisfactory methods for studying the formation and function of conditioned reflexes in man, the limitations being only that the subject should happen to be one of those with a large and regular alpha rhythm.

The variation implied in the last paragraph is another of the important aspects of brain electro-physiology. In a recent paper Golla, Hutton and Walter (1943) have suggested that before any general statement can be made either about the alpha rhythm or the functions with which it is connected, the basic meaning of individual variations must be understood. As a preliminary classification they assumed that the EEGs of normal persons could be divided into three main groups: those with no appreciable alpha rhythm, even with the eyes shut and the mind at rest; those with an alpha rhythm only with the eyes shut and the mind at rest; and those with an alpha rhythm persisting even with the eyes open and the mind active. They found a correlation between the type of EEG and the type of habitual imagery used by the persons in solving mental problems. Those addicted to intense visual imagery tended to have the least alpha rhythm, and those unaccustomed to visual imagery were those in whom the alpha rhythm persisted. The responsive alpha subjects had mixed imagery.

The picture suggested by the brief outline above has great width and perspective, but the details are blurred and the true nature of the subject is still in doubt. Considering how poorly the simplest normal record is understood and how little has yet been done in connecting brain electro-physiology with character, mood and environment, it is scarcely surprising that disorders of the highest nervous function have proved so elusive and controversial: it may be in place here to mention that in their investigation of alpha types and imagery Golla, Hutton and Walter used a new method of record analysis. As was pointed out by Grass and Gibbs (1938), analysis of the electro-encephalogram into its component frequencies may be expected to yield information of a different order of importance from that obtained by ordinary methods. The ingenious analytical machine constructed by Grass performs such an analysis and has already given dramatic results. The Grass method, however, involves taking a special record on film and the analysis is not available for some time. In the method developed by Walter (1943*a* and *b*) a similar frequency analysis is performed automatically every ten seconds and the result of this is traced directly on the original record, so that the various components can be detected with a very short delay, and changes in the brain rhythms can be watched as conditions are varied and as the subject's mood changes.

The results obtained with this apparatus are already promising, but their relation to typical and individual variation is still to be worked out. One

interesting point is that there is absolutely no correlation between physique and EEG type.

It is clear that sub-classification of " normal " records will be necessary and possible, and that correlation of the record with changes in the environment, both external and internal, will be essential before much further progress can be made.

This is particularly evident in studying cases of " psychopathic personality." Hill and Watterson (1942) found that in persons in this category who commit acts of violence the proportion of " abnormal " EEGs is unusually high. Harty, Gibbs and Gibbs (1942) consider the same to be true of psychopaths generally. The " abnormality " in such cases is, however, quite often an elusive one. This was dramatically illustrated by a case of matricide reported recently by Hill, Sargant and Heppenstall (1943). In this case the EEG showed little or no abnormality when the blood-sugar level was above 100 mgm. per 100 c.c., but when this was reduced to 80–90 mgm. per 100 c.c. various types of abnormality appeared—asymmetry of the two hemispheres, a 4–6 c/s rhythm in the right frontal lobe and a greatly increased sensitivity to hyperventilation. Such extreme variations with slight blood-sugar changes is in itself pathological or at least extremely unusual, and it is generally considered (e.g. Gibbs, 1942) that reduction of the blood-sugar level to 50 mgm. per 100 c.c. is necessary before a normal record begins to show any change. In the case of matricide, Hill, Sargant and Heppenstall were able to detect a change in consciousness during combined slight hypoglycaemia and alkalosis—a fact of forensic importance which contributed considerably to the evidence presented as to the state of mind of the accused at the time the murder was committed. Such extreme cases are probably rare, but slighter degrees of hypersensitivity or lability of the cortex are quite common, and in fact there is a smooth gradation in the normal range from the people whose record remains " normal " in extreme conditions of alkalosis and hypoglycaemia until consciousness is lost, down to those in whom a very slight change in biochemical conditions can precipitate an electrical crisis almost indistinguishable from a larval epileptic attack. It must be remembered that the clinical distinction between normal and abnormal persons often rests upon whether or not the person has sought medical advice. Fluctuations in mood and conscious control subjectively quite tolerable to one person may seem most sinister and morbid to another. It is perhaps adventuring beyond the formal bounds of electro-physiology and medicine, but this question of an individual's own concept of his affective and intellectual behaviour may come to play an important part in the detailed interpretation of neurophysiological data. Introspection is the least reliable method of human study, but introspective information, taken at its face value and compared with the physiological and physical realities, may complete a picture otherwise vaguely limned. An instance of this is the effect of low oxygen concentration upon the human subject, who has no complete physiological mechanism to compensate for a brief and sudden deprivation of oxygen. At low oxygen tensions there is often a feeling of combined lassitude and well-being, of indifference and confidence. The EEG shows that in this condition the brain is already abnormal, and that the gap between this state and a total lapse of

consciousness is not wide, nor is the crossing of it attended by any subjective warning. Tolerance to low oxygen tensions and the symptoms associated with the state of strain vary greatly from one person to another. These variations are probably related to the EEG variations already mentioned, but those with the most labile EEGs are not always the first to exhibit loss of judgment and control.

Similarly there are epileptics with very frequent minor attacks who have learned to conceal and compensate for their frequent absences so well that their handicap is never detected by others, nor need they resort to medical aid until for some reason an EEG is taken and the characteristic waveform is revealed.

These simple examples point to a well-known but often conveniently forgotten axiom: The main feature of brain function is the enormous adaptability of its components. From the formation of a single conditioned reflex up to recovery from a hemiplegia, each element of the brain seems capable of a multitude of activities. Study of the number and interrelation of these activities is the basic problem of neurophysiology, and electro-encephalography is of unique importance only in so far as it contributes to that study.

A logical return to psychopathology may be made by way of childhood disorders. For some time the association between behaviour disorders and abnormal EEGs has been widely accepted. About 60 per cent. of "behaviour" cases give abnormal records, and of these a proportion—not agreed upon—are of the epileptic type. Electro-encephalography often reveals in children the presence of frequent minor attacks about which the child has never complained, accepting momentary blanks as a part of life. Similarly, epileptic equivalents, psychomotor attacks and occasionally post-epileptic automatism in children are occasionally the cause of inattentiveness in school, silly behaviour or even temper tantrums, all of which are complained of, not by the child, but by the teacher or parents. This state of self-ignorance may persist into adult life, accumulating neurotic features as the disability becomes more significant. The relation between the subjective appearance of such conditions and the type of EEG is an important subject for future study.

As well as the true epileptic records among behaviour problem cases, other types of abnormality have been described in such cases. The commonest is an unusual amount of activity in the 2–6 c/s band. In normal adults the amount of energy at these frequencies is very much smaller than in the 8–12 c/s alpha band, but in a proportion of "behaviour" children the energy in the lower frequencies is often higher than in the responsive alpha band. This would be a very significant observation if the EEG of normal children had been studied sufficiently. This is not the case, however; Hill has reported privately that in a group of normal children aged 14 to 17, 40 per cent. produced records of the low-frequency type, and that the response to voluntary hyperventilation was "abnormal" by adult criteria in the majority. This is similar to the observation of Brill *et al.* (1941), who also reported a significantly "higher" proportion of "abnormalities" among behaviour problem children.

In another communication Heppenstall and Hill (1943) stated that among head injury cases, more of those in whom the injury occurred in youth had

abnormal EEGs than of those who were hurt in later years. This suggests that the immature cortex may be particularly sensitive to environmental changes, such as occur during hyperventilation and after injury, and that the slow rhythms so common in behaviour cases may be rather an exaggeration of an immature type of activity than a specific abnormal rhythm.

In Hill's cases the correlation of the EEG was better with what may be called "personality age" than with chronological or mental age, and the suggestion is that the essential *immaturity* of the aggressive psychopath and of the "behaviour" child with temper tantrums is associated with a real developmental failure in the nervous system.

The logical conclusion is that records of the non-specific slow-rhythm type should be classed as "immature" rather than abnormal, but the sub-classification of such records is very difficult without a quantitative analytic aid, and the future of this branch of the subject depends directly upon the technical developments in this direction.

From all the above contributions it will be seen that the EEG can offer no short cut to accurate diagnosis and prognosis in psychiatry. Often the clinical picture is complicated by the EEG result, and when attempts are made to combine electrical with psychological statements, profound confusion is usual. If psychology is a science, it is unique among sciences, since it embodies neither laws nor units; similarly, unless electro-encephalography is quantitative, it cannot claim to be more than a technical luxury. The lowest common multiple of the two subjects is higher than either separately, but it is rarely relevant.

Treatment.

The treatment of mental disorders has changed greatly in the last years, emphasis being laid on physical and physiological methods. Induced convulsions have been studied by several workers. Cook and Walter (1938), Rubin and Wall (1939) recorded during cardiazol seizures and published records showing the close electrical resemblance between these and spontaneous epileptic convulsions. Cook and Walter found that toward the end of the fit, slight muscular movements persisted when the EEG had become quite flat, while Rubin and Wall disagreed with this. The view of Cook and Walter was upheld by the experiments of Löwenbach and Lyman (1940) on electrically induced convulsions in the rabbit. The latter form of induction evokes discharges again identical with those of an essential epileptic fit (Golla, Walter and Fleming, 1940).

The EEG between convulsions has also been studied (Finley and Lesko, 1941). When treatment is given very frequently, a slow rhythm tends to persist and is correlated with some degree of mental confusion. This can be used to assess the frequency of treatment which a given patient can stand. The effect of induced convulsions upon the EEG is very variable, however. In one case of chronic schizophrenia who received 120 convulsions in the course of six months, the EEG remained entirely normal and the mental state unchanged, but in others only a few convulsions are necessary to evoke some degree of abnormality and confusion. This shows that the effect of induced

convulsions must depend not only upon their number and frequency, but also upon the innate character of the patient's brain. The factor of age is also present—young patients are more likely to become confused and electrically abnormal than older ones. The question whether the temporarily abnormal EEGs sometimes found in convulsive therapy patients indicate some organic cerebral damage has not yet been answered. Smith, Hughes, Hastings and Alpers (1942) state that in cats "subjected to similar dosage" of electrical shock punctate haemorrhages are found in the brain, and there is a possibility that the transient effect of such haemorrhages is responsible for the EEG observations. The invariable disappearance of the mental and electrical disturbances is quite consistent with such an explanation, but does not demand it. The electrical dosage was relatively much higher in the animal experiments, and it is hard to decide what would be a truly equivalent condition to human electric convulsion therapy. There is no evidence that any serious damage results from induced convulsions, and the dearth of autopsy records, though it may tantalize the experimenter, satisfies the patients and confirms at least the safety of the method.

Löwenbach and Stainbrook (1942) have made the interesting suggestion that the prognosis is actually better in cases showing confusion after treatment, because, being less well orientated, they need help to find their bearings again, and this situation offers a very favourable opening for psychotherapy. If this is the case the EEG may be of considerable value in determining the correct moment to initiate psychotherapy.

The infantile regression in the Rorschach response after a convulsion, also reported by Löwenbach and Stainbrook, suggests that the EEG abnormalities may again be in the nature of "immaturities" rather than abnormalities. Speculation along these lines regarding the nature of mental disorder and reasons for the effectiveness of shock therapy are intriguing, but would lead to remote regions of metaphysics.

The action of other therapeutic agents, such as insulin and amytal, have been studied, but nothing relevant to psychiatric problems has emerged. Selection of treatment on the basis of patients' EEGs has been proposed by Lemere (1939), but this does not promise well, since the basic prediction is that violent methods such as convulsion therapy would make depressives and melancholics worse and schizophrenics better. The other suggestion, that those with slow rhythm records are less likely to benefit from convulsions, is more reasonable and is supported by experience (cf. Walter, 1942*a*).

A use of electro-encephalography so far little developed is for distinguishing hysterical and functional signs and symptoms from organic ones. Lundholm and Löwenbach (1942) find that the alpha rhythm in hypnosis and hysterical blindness behaves exactly as it does in normal people, that is, the *suggestion* of light and dark has no effect on the rhythm, whereas true light and dark have the usual effect. This is the opposite result from the original report of Loomis, Harvey and Hobart (1936), and agrees with the author's own findings (Walter, 1938). Similarly Lemere (1942) found no indication of insensitivity to light in hysterically blind patients, though the alpha rhythm was prominent when the eyes were closed. This indicates that the anaesthesia of hysteria is

a disorder between the visual association areas and still higher centres of consciousness and perception. As a practical application, the blocking of the alpha rhythm by physical stimuli and mental alertness can be of definite value as a signal of responsiveness at the half-way house of central integration.

In conclusion, the contact between electro-physiology and mental medicine has been intermittent and sometimes harmful to both, but the value of the results has steadily risen. Reasonable optimism suggests that differentiation between neurosis, psychosis and organic disorders will be perfectly possible by electro-encephalography when the new techniques are perfected and combined with a rational understanding of the more subtle variations of biochemistry and personality. Investigations of this type are far more intricate than the mere inspection of a strip of record, and it is possible that the old enemy of the classroom, mathematics, may rear its hoary head. If scepticism is the obligation of a scientific worker, his privilege is to confound his unbelief.

REFERENCES.

BRILL and SEIDEMANN (1941), *Amer. J. Psychiat.*, **98**, 250.
BRILL, SEIDEMANN, MONTAGUE and BAKER (1942), *ibid.*, **98**, 494.
COOK and WALTER (1938), *J. Neurol. Psychiat.*, **1**, 180.
DAVIS, PAULINE (1942), *Am. J. Psychiat.*, **99**, 210.
FINLEY and LESKO (1941), *Amer. J. Psychiat.*, **98**, 185.
FINLEY and MACFIE CAMPBELL (1941), *ibid.*, **98**, 374.
GIBBS, F. A. (1942), *J.A.M.A.*, **118**, 216.
Idem (1942), *J. Nerv. and Ment. Dis.*, **96**, 439.
Idem, WILLIAMS, and GIBBS (1940), *J. Neurophysiol.*, **3**, 49.
Idem, GIBBS, E. L., and LENNOX, W. G. (1938), *Amer. J. Psychiat.*, **95**, 255.
GOLLA, HUTTON and WALTER (1943), *J. Ment. Sci.*, **89**, 216.
GOLLA, WALTER and FLEMING (1940), *Proc. Roy. Soc. Med.*, **33**, 261.
GRASS and GIBBS (1938), *J. Neurophysiol.*, **1**, 521.
HARTY, GIBBS and GIBBS (1942), *J. Nerv. and Ment. Dis.*, **96**, 435.
HEMPHILL (1942), *J. Ment. Sci.*, **88**, 285.
HEPPENSTALL and HILL (1943), *Lancet*, **244**, 261.
HILL, SARGANT and HEPPENSTALL (1943), *ibid.*, **244**, 526.
HILL and WATTERSON (1942), *J. Neurol. Psychiat.*, **5**, 47.
JASPER and SHAGASS (1941), *J. Exper. Psychol.*, **28**, 373.
LEMERE, F. (1936), *Brain*, **59**, 366.
Idem (1942), *J.A.M.A.*, **118**, 884.
LENNOX, GIBBS and GIBBS (1938), *J. Neurol. Psychiat.*, **1**, 211.
LOOMIS, HARVEY and HOBART (1936), *Science*, **83**, 240.
LÖWENBACH and STAINBROOK (1942), *Amer. J. Psychiat.*, **98**, 828.
LÖWENBACH and LYMAN (1940), *J. Neurol. Psychiat.*, **3**, 336.
LUNDHOLM and LÖWENBACH (1942), *Charac. and Pers.*, **11**, 145.
MACMAHON and WALTER (1938), *J. Ment. Sci.*, **84**, 781.
RAHM and WILLIAMS, A. C. (1938), *Psychiat. Quart.*, **12**, 230.
RUBIN (1938), *J. Psychol.*, **6**, 325.
Idem (1939), *Proc. Soc. Exper. Biol. Med.*, **40**, 153.
Idem (1940), *Amer. J. Psychiat.*, **96**, 861.
Idem and WALL (1939), *J. Neurol. Psychiat.*, **2**, 107.
SMITH, HUGHES, HASTINGS and ALPERS (1942), *Amer. J. Psychiat.*, **98**, 558.
WALTER, W. GREY (1938), *J. Neurol. Psychiat.*, **1**, 359.
Idem (1942*a*), *J. Ment. Sci.*, **88**, 110.
Idem (1942*b*), *ibid.*, **88**, 306.
Idem (1943*a*), *ibid.*, **89**, 222.
Idem (1943*b*), *Electronic Engineering*, June, p. 9.