

THE OBJECTIVE STUDY OF MENTAL IMAGERY.

I. PHYSIOLOGICAL CONCOMITANTS.

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ALTHOUGH much work has been done on the physiological concomitants of affective states, nothing is known of any objective bodily changes accompanying thought processes, and yet the most superficial observation of lip, facial and eye movements, of unconscious gesture and restlessness furnishes indications of some of the more obvious somatic accompaniments of non-emotional mental activity.

The present paper represents the introduction to an objective study of mental imagery. The attempt has been made, by recording the respiratory movements and cortical potentials, to correlate these observations with an independent evaluation of the form of imagery used. The type of imagery of our subjects has been elicited by a very simple questionnaire, which has frequently been performed modified to suit the mental capacity and powers of introspection of individuals.

In a paper published in 1929 Antonovitch and Golla called attention to the connection between respiratory rhythm and the type of imagery involved in thought processes. They were convinced that the extraordinary sensitiveness of the respiratory mechanism to affective states made it very desirable that the subjects should be unaware that their respirations were being recorded if a true record of the global respiratory movement was to be obtained.

With this object in view they used a plethysmograph in the form of a large wooden case in which the subject sat with only the head outside, and the neck was rendered in airtight connection with the aperture in the lid by an inflated rubber collar. The apparatus communicated with a recording plethysmograph of four litres capacity by a very wide tube; and the whole apparatus—which, of course, recorded the total respiratory volume—was so designed as to offer practically no resistance, and was of sufficient sensibility to register the heart-beats.

The apparatus was so arranged that it was possible for the subjects to accept the suggestion that it was designed for heat recording, and the attention was thus diverted from the respiration.

As a result of these experiments it was found that there were two types of habitual respiration, approximately equally distributed among normal members of both sexes.

The irregular respiratory type was found in subjects with predominantly auditory imagery; the regular type in subjects with predominantly visual imagery.

It was thought that irregularity of respiration was the objective sign of laryngeal movements accompanying verbal kinaesthetic imagery.

For purposes of the present investigation, in which regularity and depth of respiration are the only factors considered, it was found possible to dispense with the plethysmograph in favour of a rubber sac, slightly inflated, and suitably adjusted to the thorax recording through a Marey capsule. The subjects sat upright, and in order to distract attention from the breathing, those who showed any curiosity were told that a record was being made of the pulsation of the heart.

For a limited number of experiments respiration was electrically recorded simultaneously with the electroencephalogram.

In spite of the fact that in the original paper by Golla and Antonovitch it had been noted that a distinction could be made between people whose auditory imagery consisted mainly of sound, and those in whom the sound image was accompanied by kinaesthetic sensations in the vocal organs, the full importance of this was not

recognized at the outset of the investigation. It was thought that primary distinction between regular and irregular breathers was between those who used visual and those who used verbal imagery, but this was later found to be erroneous; the real distinction is between those with only sensory imagery and those in whom a vocal kinaesthetic component is present.

In order to elicit the prevalent mode of imagery of the subjects they were asked to perform the following tasks:

- (1) A simple sum in mental arithmetic.
- (2) To "see" some person or place they knew well.
- (3) To "think over" to themselves the story of Red Riding Hood; (certain subjects who could not recall this story were asked to "think over" what they knew of the events that took place at Dunkirk).
- (4) To "think over" their plans for some definite day (e.g. the following Sunday).
- (5) To "think over" the arguments for or against some abstract proposition such as "honesty is the best policy" or "the existence of free will."
- (6) To "recall" the sound of the National Anthem as played by a military band, and the sound of other people's voices.
- (7) To repeat the Lord's Prayer to themselves.

It was found that in some subjects visual imagery played a preponderatingly important part in the execution of all these tests. Even in test (5), which was expected to evoke verbal imagery, pronounced visualists either saw the arguments written down or else they saw concrete illustrations of the argument, e.g. a dishonest man being sent to jail. Similarly when asked to recall the sound of the band, a visual image would accompany the sound, and the Lord's Prayer would be seen in the Prayer Book instead of being repeated verbally.

Yet other subjects varied their imagery according to the task in hand; in some visual imagery was replaced by verbal imagery for certain tasks, notably mental arithmetic and the abstract argument. Some subjects confessed to using both visual and verbal imagery concomitantly, though usually they used visual imagery alone in task (2), in which they were only asked to visualize. The vividness of the visual image and the extent to which it was employed varied considerably in these subjects. In some the image was clear, vivid, easily elicited, and usually preceded or occurred simultaneously with the verbal image; in others it was faint, fragmentary, fleeting, and usually followed the verbal image.

Finally there were those in whom the visual imagery was either very faint or absent altogether, but who used verbal imagery for all the tests 1-5 and who, in test 6, were only able to hear the tune if they sang it or hummed it to themselves.

When further enquiries were made into the nature of the verbal imagery it was found that those who were only conscious of an auditory sensation were in most cases capable of vivid visualization, whilst those whose verbal imagery had a kinaesthetic component were in most cases deficient in the power of visual imagery.

Furthermore, these subjects with auditory imagery but without consciousness of laryngeal movements were also found, like the visualists, to be regular breathers, whilst those with auditory-kinaesthetic imagery were irregular, thus further strengthening the viewpoint advanced by Gollà and Antonovitch that the irregularity of the breathing is due to the restricted articulatory movements which occur in these people.

It was felt that these differences in the mode of imagery would probably be associated with differences in intellectual aptitude and in temperament. Further studies are being made in order to determine whether this is actually the case.

In view of the fact that the interpretation of colour and kinaesthesia plays such an important part in the Rorschach test, it was felt that this test, which is also one of the best character tests we yet have, would be particularly suitable for this purpose.

It is also interesting that in the evaluation of his findings Rorschach made use of the colour-movement ratio to determine the introversive or extratensive tendencies of his subjects, those with many colour responses being extraverts and with many movement responses introverts. Rorschach claimed that the movement responses were conditioned by the subject's own kinaesthesia, and that genuine movement responses did not occur unless this kinaesthetic element was present.

Now it is an interesting fact that if we take our two groups of regular and

irregular breathers, the former group are attending to sensations apparently originating outside themselves, while their regular breathers, on the other hand, are undoubtedly attending to sensations originating within themselves. It seems possible, therefore, that the regular breathers will be found to be predominantly extratensive and the irregular breathers introversive. It will be remembered, however, that Jung found he had to enlarge his classification of introversion and extraversion, and it is almost certain that other forms of kinaesthetic imagery must be included before this problem can be satisfactorily investigated.

Too little attention has hitherto been paid to the role of kinaesthesia in intellectual processes, though the recent work by Lowenfeld on the creative activity of blind or nearly blind children, and the relation of their art to that of primitive man and the child, suggests that it is an extremely important factor. It is also significant that Rorschach associated the kinaesthetic element with creative imagination.

About 60 subjects in the present series had electroencephalographic and respiratory tracings taken and were investigated with regard to their imagery. For various reasons the group is not large enough for the results to be treated statistically, the various sub-groups being too small to yield indisputable correlation. Nevertheless the results lend confirmation to the view, already expressed by Golla and Antonovitch, and confirmed by Patterson and Wittkower, that persons with only sensory imagery, either visual or auditory, are regular breathers, while those whose imagery has a kinaesthetic component are irregular. The respiratory tracing gives no definite evidence of the presence or absence of visual or auditory imagery; it merely reveals whether or no any vocal kinaesthetic imagery is present. If the respiratory tracing is regular, the subject may be using either visual or auditory imagery or both simultaneously, while if the tracing is irregular, vocal kinaesthesia is almost certainly present, but no indication is given as to whether or no visual imagery is also present. In some people who are capable of both visual and vocal kinaesthetic imagery, the fact may be revealed if they can evoke a visual image independently of a verbal one; in these cases the record becomes regular when visual imagery alone is used, and irregular when a vocal kinaesthetic image either accompanies or replaces it. This also was found by Golla and confirmed by Patterson.

The numerical results of our observations on the relation of imagery to respiratory rhythm deal with 98 subjects (61 males and 37 females).

For our present inquiry we have considered that we can most usefully classify the habitual imagery in two types—those who are able to satisfy the examiner that they use laryngeal kinaesthetic images, and those who do not. Both types may use visual and auditory imagery.

The type using laryngeal kinaesthetic imagery is predominantly dependent on auditory images, and those without laryngeal kinaesthetic imagery use predominantly visual imagery. It is proposed to deal with the relation of auditory to visual imagery in subsequent communications.

Of the 61 males, 25 had a regular respiratory rhythm, and of these only two used laryngeal kinaesthetic images; 36 males had irregular respiratory rhythm and of these 32 used laryngeal kinaesthetic imagery.

Of the 37 females, 20 had regular respiration and none of them used laryngeal kinaesthesia; 17 had irregular respiration and 11 of these used laryngeal kinaesthetic imagery.

When, in 1935, Adrian and Matthews confirmed Berger's discovery of the alpha rhythm, they described it as "disappointingly constant." Having in mind the infinite variability of the human intellect, an experimenter would hope to find some dramatic fluctuation in cortical potentials; to be faced with an electrical rhythm even more slow and constant than any developed by the simplest tissues was certainly disappointing to the early workers. Attention therefore shifted gradually from these normal rhythms to the more dramatic phenomena associated with epilepsy and cerebral disease.

The main harvest in the clinical field has now been reaped, and interest is beginning to return to the more subtle variations on the normal theme. Two main difficulties are encountered in the study of normal electro-encephalographic records: Firstly, any correlative information which is needed about the subject's state of mind and mental dynamics depends upon his introspective skill, and the untrustworthiness of information so obtained is well known to everyone. Secondly, the records themselves (which are, of course, tracings representative of voltage

against time) are of a form and frequency which defy accurate analysis. Numerous attempts have been made to devise some scheme whereby the alpha rhythm records could be described quantitatively so as to avoid such terms as "large," "irregular" or "persistent." Since none of these methods have proved of very lasting value there would be little profit in describing them in detail. It is sufficient to note that they all involve either a most tedious examination of the record or the inclusion of artefacts and spurious potentials in the analysis.

When this study was begun it was hoped to avoid such complications by adopting as simple a classification as possible, and up to a point the results have been satisfactory.

As a working hypothesis it was assumed that alpha records fell into three main groups:

(a) Those in which the alpha rhythm was extremely small (below 10 microvolts maximum), and in which for this reason the effect of opening and closing the eyes or of any such stimulus was invisible on the record.

This type of record was called "M," standing for minus.

(b) The next type is that in which a clearly visible rhythm of the usual size (that is from 10-50 microvolts) is present when the eyes are shut, and is blocked or greatly attenuated either by opening the eyes or by mental exertion of a fairly vigorous type. This type is called "R" for responsive.

(c) The last category contains those records in which an alpha rhythm of average size is present to an equal extent at all times, whether the eyes are open or shut, and irrespective of the degree of mental activity of the subject. In such records of course the delivery of stimuli is invisible, as in the "M" type, but for the opposite reason, that the rhythm is present at all times.

This type has been called "P" for persistent.

This classification takes no account of the actual frequency of the rhythm or of its form and focus. It may be called a "fundamental" classification, since it depends upon the way in which the alpha rhythm is affected by a change in physiological function. It is arbitrary also, designed rather to be tested than to mould results into its form, and it is based to a large extent upon the hypothesis that the alpha rhythm itself is a sign of inactivity in the visual association areas of the cortex—a hypothesis which may be only partly true.

The virtue of the system is that very little more time need be spent in examining the records than is usual, since it is necessary only to discover to what extent stimulation by vision or intellectual problems affects the record.

Casual observations made from clinical material before this study was commenced in earnest, strongly suggested that the type of record might be connected with the habitual imagery form used by the patient. It was suspected that people who make great use of visual imagery at all times are likely to make greater use also of their visual association areas than those in whom the visual imagery is less customary or less vivid. This type of subject would be expected to have a small alpha rhythm even in the most placid conditions. Conversely, those whose imagery was more predominantly auditory or kinaesthetic would presumably make less use of their visual association cortex, which would accordingly be left free to develop its alpha rhythm at all times and the record would be classed as "P." Between these two extremes would be those who were able to make use of visual images when necessary but were not continually, so to say, at their mercy, and in whom closing the eyes would produce an immediate relaxation of the visual integrative mechanism.

The examination was accordingly made of 60 normal subjects, as nearly as possible unselected and without any clinical symptoms of complaint.

These were all subjected as well to the inquiry into their habitual imagery, and various tests were made, as described above in this paper, to supplement their introspective data.

The records were taken under uniform conditions with a four-channel ink-writing electro-encephalograph. It was impossible to ensure complete isolation of the subject from stimuli, but the noise level did not fluctuate appreciably from day to day.

The records were taken for about a quarter of an hour for each subject and the effect of opening and closing the eyes was tested repeatedly. Whilst the eyes were closed, simple sums were given to the subjects to be done with the eyes closed, and

the effect of this upon the record was noted. A number of different test problems were tried, but the most consistent results were obtained by giving a series of multiplication sums, starting with extremely easy ones, and working up to something a little bit too difficult for the comfort of the subject in question.

In "M" subjects no effect was visible of course, and in the "P" group also the criterion of persistence was that no amount of inspection would show when the problem was being solved or when the eyes were open, when the signals indicating these events were concealed from the examiner.

Of the two extremes—that is "M" and "P"—quite good correlation was obtained with imagery types and there were no really glaring exceptions.

The possibility of unconscious bias on the part of the observer was reduced by keeping the results of the E.E.G. unknown to those conducting the imagery tests and vice versa.

The anomalies occurred in the "R" group, and in those few whose records seemed to fall on the border-lines between the different categories.

The statistical results of the first tests are shown in Table I.

It was seen that the number of cases in the middle range is too great to permit any confident correlation. The absence of pure visual imagery types from the "P" group and of auditory kinaesthetic types from the "M" group indicates that there is some foundation for the assumption made.

It would appear to be possible that in this preliminary study the electro-encephalogram enables us to differentiate these types of behaviour. In the "P" group occur those whose preoccupation with verbal and kinaesthetic imagery is such that the opening of the eyes does not in itself constitute an adequate stimulus to activate the mechanism dealing with the integration of visual imagery and perception. In the "M" group this mechanism continues its activity when the eyes are shut, because in such subjects all mental activity is carried out with the aid of visual imagery.

In the mixed group one would appear to have a complex of at least two factors, one of which is concerned with visual perception and the other with visual imagery. In the former group the opening of the eyes initiates cortical activity, whilst in the other group activity may result from any mental effort initiating visual imagery.

The "P" group show predominantly irregular respiration characteristic of auditory kinaesthetic imagery. The "M" group show predominantly regular respiration characteristic of visual imagery.

The correlation of these electro-encephalographic results with the records of the respiratory rhythm affords indirect evidence in favour of this hypothesis.

TABLE I.

TABLE I.—*The Correlation Between Imagery Type and Electro-encephalogram.*

	V.	V. A.-k.	A.-k. V.	A.-k.	
"M"	13	9	—	—	22
"R"	—	12	15	—	27
"P"	—	3	6	2	11
	13	24	21	2	60

V. Number of subjects with "pure" visual imagery. V. A.-k. Number of subjects with predominantly visual imagery but mixed with auditory-kinaesthetic. A.-k. V. Number of subjects with predominantly auditory-kinaesthetic imagery but mixed with visual. A.-k. Number of subjects with "pure" auditory-kinaesthetic imagery.

TABLE II.—*The Correlation Between Sex and Electro-encephalogram.*

	Male.	Female.	
"M"	12	14	26
"R"	31	14	45
"P"	12	4	16
	55	32	87

M. Number of subjects with records of the minus type (see text). R. Number of subjects with records of the responsive type. P. Number of subjects with records of the persistent type.

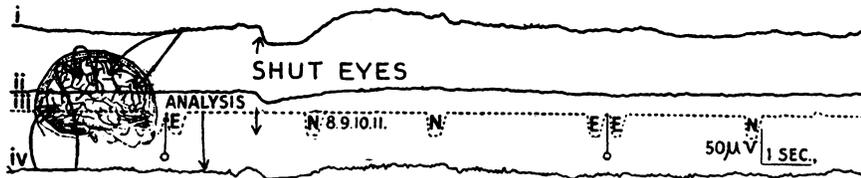


FIG. 1.—Electro-encephalograms from a subject of the "M" type. From above downwards: i, Fronto-vertical lead; ii, vertico-parietal lead; iii, analysis of iv, the parieto-occipital lead. In the analysis the small double downward deflections ("E") mark the divisions between summation epochs, each epoch being of 10 seconds. The analysis concerns the portion of record corresponding to the epoch. The single downward deflections ("N") mark off the normal alpha frequency band from the abnormal low and high frequency bands. In this case there is no alpha activity and the analysis shows only the signal marks. Compare with Figs. 2 and 3, which show humps in the normal band referable to the energy in the alpha frequencies. (Further description in text.) Electrode positions, time and voltage scale apply to all figures.

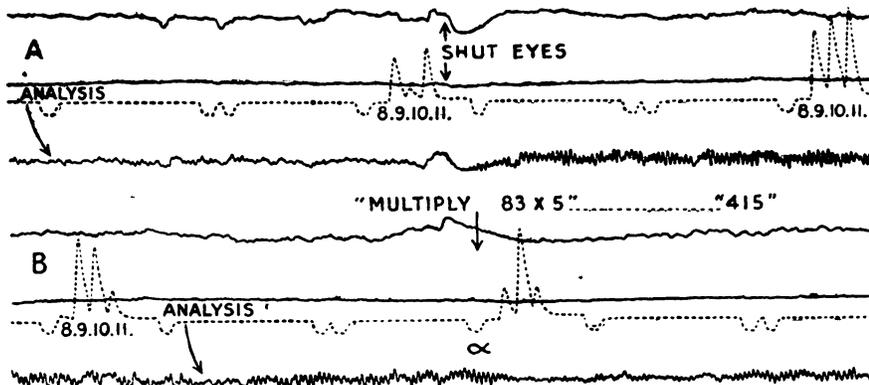


FIG. 2.—Electro-encephalograms from a subject of the "R" type. A. The effect of shutting the eyes. B. The effect of mental arithmetic. Note that the analysis shows the appearance of a large amount of energy in the alpha band when the eyes are shut. There is conversely a considerable diminution during mental effort, in spite of the inclusion in the same epoch of a large burst at 9 cycles per sec., just before the sum was given (marked "α")

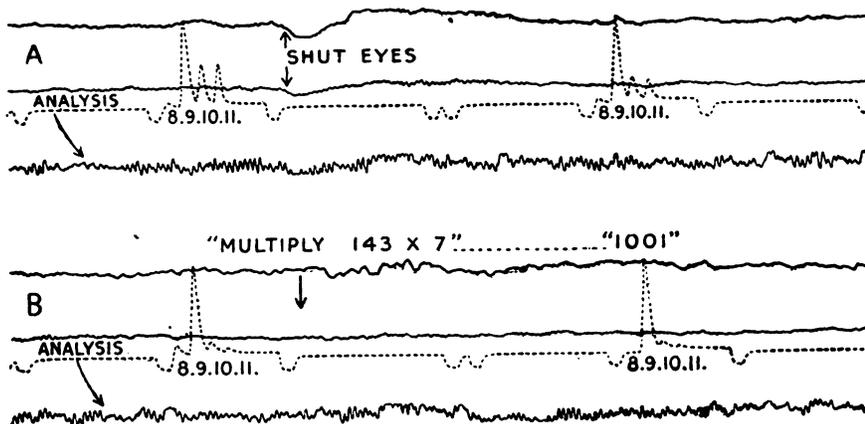


FIG. 3.—Electro-encephalograms from a subject of "P" type. A. Note the absence of any effect when the eyes are shut. B. Mental effort does not appreciably diminish the alpha energy.

It is proposed in subsequent communications to make an intensive study of the relations between various forms of mental imagery and the electrical activity of the cortex.

The investigations will be conducted on a few subjects chosen so as to exhibit extreme forms of habitual imagery, and possessing sufficient intelligence and power of introspection to be reliable witnesses.

An intensive survey of the imagery habitual to a large number of psychotics has been initiated, with the object of discovering if there be any obvious relation between habitual imagery and the form of mental derangement. The studies on respiratory rhythm made at the L.C.C. Central Pathological Laboratory by Patterson and Wittkower are suggestive in this connection.

When these results had been collected a further correlation was noticed (Table II). There appears to be a slight but definite connection between the sex of the subject and the electro-encephalogram. The proportion of women having records of the "P" type is considerably smaller than of men; the proportion of "R" types is slightly smaller among women than among men, and the proportion of "M" types is slightly higher among women than among men.

The numbers are certainly small, but they are larger than in Table I because not all of those in this table have yet been fully studied as to their imagery. With less than several hundred subjects there may still be a possibility that the apparent correlation is due to chance, but the probability is that sex is connected in some way with electro-encephalographic type.

Very broadly stated, the relationship is that women tend to have less in the way of alpha activity than men, and this suggests that women make fuller use of their visual association areas than men do in the conditions of the examination. This may be due to a real inborn sex difference, or to a difference in education, or to a different attitude to the examination, or to some unintentional selection of subject types. These possibilities remain to be investigated, as does the similar correlation which must exist between sex and the other processes studied in this investigation.

Work is in progress on the relation between imagery and personality. For this purpose the Rorschach test has proved to be of great utility. The influence of the habitual form of imagery used on the performance in the various types of intelligence tests is being investigated at the Burden Institute in collaboration with Dr. Price of the Stoke Park Colony. The validity of such tests as a measurement of intelligence will obviously bear a very direct relation to their applicability to persons using all forms of imagery.

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APPENDIX ON A NEW METHOD OF ELECTRO-ENCEPHALOGRAPHIC ANALYSIS.

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In the first few cases examined, the electro-encephalograms were studied in the ordinary way, that is, by inspection of the trace, and the figures given in the table were obtained by this method. It became apparent however that something more was wanted; some method whereby the qualitative impression of "responsiveness" or "persistence" could be translated into a more quantitative form. Of the methods available the only one in the least suitable is that developed by Grass (1938), in which a separate film record is made and run through a standard wave analyser at 100 times the speed at which it was taken. This record is spliced end to end so as to create a continuous function of a form susceptible to Fourier transformation, and the resulting transform gives in effect a frequency spectrum of the record, in which the ordinates are energies and the abscissa is a frequency scale.

The drawback of this method is that a special record must be taken for each analysis and the result is obtained only after processing of this record, which takes several minutes at least. Moreover, a considerable length of record is required, and changes which occur in the course of a few seconds would inevitably be missed, while the effect of transient artefacts and other spurious potentials is hard to detect and allow for.

A method has now been developed to overcome these difficulties—a series of tuned reeds energized by the output from the electro-encephalograph. These reeds act as frequency splitters, since each is tuned to a frequency in the band to be studied. In the complete instrument there will be 20 such reeds, covering the stretch from 1 to 20 cycles per second. In the equipment for this study only four were in use, resonating at 8, 9, 10 and 11 c.p.s., thus covering the normal alpha band. Their damping and sharpness of resonance are adjusted so that the coverage is correct for the frequency scale. Each reed is provided with a fine steel contact wire, which dips in and out of a mercury cup when the reed vibrates, but is just out of the mercury when the reed is at rest. In series with this mercury-reed contact is a high resistance, a source of EMF and a condenser. When the reed is vibrating the contact is made for a length of time, depending upon the amplitude of the vibration and upon the total number of vibrations performed in a specified time. The condenser connected to the reed is therefore charged up to a potential which is a function of the total duration of the contact time, and therefore of the amount of energy at the frequency of the reed during the specified time. A motor driven rotary switch connects an amplifier to each condenser in turn, and this amplifier drives a wide-arc recording pen across the surface of the paper on which the original electro-encephalogram is at the same time being traced. For the purposes of this study the summation epoch was chosen to be 10 seconds, and two banks of condensers are used to provide a storage register for each epoch. While one bank is connected to the reed system the other is being scanned by the motor-switch, and the pen is tracing a diagram of the charges acquired during the previous 10 seconds. At the end of the epoch the motor-switch switches the condenser banks over, so that the other bank is now scanned while the first is receiving a fresh set of charges. The pen is set back from the direct recording pens so that the analysis diagram is traced above the record to which it actually applies—that is, the stretch which was vibrating the reeds and being analysed in the previous epoch.

The details of design are fairly intricate and the adjustment is quite critical, but the effect is that each 10-second stretch of record has traced over it a histogram of its spectrum, and the shift of energy from one band to another and the quantitative rise and fall of general energy level is permanently recorded without dependence upon the opinion of the investigator. The reason for any particular spectrum can be found by referring to the record below the analysis curve, which is drawn in red ink to distinguish it from the direct record.

Although the method is still experimental, results already obtained both on normal and clinical material suggest that it may have great value. It has a similar relation to the direct record as spectroscopic analysis has to ordinary chemical methods. It is possible, for example, to analyse a record in which the brain potentials are entirely obscured by interference of one sort or another, much as a trace of haemoglobin can be detected in a dilute and impure solution of doubtful origin. In the same way rhythmic potentials can be discerned in subjects whose direct records seem entirely featureless—for example, those classed as "M." This can be done by greatly increasing the amplification, so that, although the direct record seems a meaningless jumble of irregular oscillations, the analyser shows a perfectly clear distribution of energy, characteristic of the type and responding to physiological stimuli. The possibilities and limitations of this device are yet to be defined, but it seems likely to prove the key to some, at least, of the more subtle problems raised by applied electrophysiology.

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