HANDBOOK OF ELECTROENCEPHALOGRAPHY AND CLINICAL NEUROPHYSIOLOGY

EDITOR-IN-CHIEF A. REMOND

VOLUME 6

The Normal EEG Throughout Life

EDITOR: G. C. LAIRY

Hôpital Henri-Rousselle, Paris (France)

PART A

The EEG of the Waking Adult

EDITORS: G. E. CHATRIAN and G. C. LAIRY

University of Washington School of Medicine, Seattle, Wash. (U.S.A.) and Hôpital Henri-Rousselle, Paris (France)

ELSEVIER

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Editor-in-Chief: **Antoine Rémond**
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A great need has long been felt for a Handbook giving a complete picture of the present-day knowledge on the electrical activity of the nervous system.

The International Federation of Societies for EEG and Clinical Neurophysiology is happy to be able to present such a Handbook, of which this is a small part.

The decision to prepare this work was made formally by the Federation at its VIIth International Congress. Since then nearly two hundred specialists from all over the world have collaborated in writing the Handbook, each part being prepared jointly by a team of writers.

The Handbook begins with an appraisal of 40 years of achievements by pioneers in these fields and an evaluation of the current use and future perspectives of EEG and EMG. The work subsequently progresses through a wide variety of topics—for example, an analysis of the basic principles of the electrogenesis of the nervous system; a critical review of techniques and methods, including data processing; a description of the normal EEG from birth to death, with special consideration of the effect of physiological and metabolic variables and of the changes relative to brain function and the individual's behaviour in his environment. Finally, a large clinical section covering the electrical abnormalities in various diseases is introduced by a study of electrographic semeiology and of the rules of diagnostic interpretation.

The Handbook will be published in 16 volumes comprising 40 parts (about 2500 pages altogether). For speed of publication most of the 40 parts will be published separately and in random order.

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PART A

THE EEG OF THE WAKING ADULT

Editors: **G. E. Chatrian and G. C. Lairy**
University of Washington School of Medicine, Seattle, Wash. (U.S.A.) and Hôpital Henri-Rousselle, Paris (France)

Collaborators:

C. J. Blanc, *Paris (France)*

J. R. G. Carrie, *The Methodist Hospital, Texas Medical Center, Houston, Texas (U.S.A.)*

G. E. Chatrian, *University of Washington School of Medicine, Seattle, Wash. (U.S.A.)*

M. Dongier, *Allan Memorial Institute, Montreal, Quebec (Canada)*

J. D. Frost, Jr., *Physiology Department, Baylor College of Medicine, Houston, Texas (U.S.A.)*

G. F. A. Harding, *Neuropsychology Unit, University of Aston, Birmingham (Gt. Britain)*

J. R. Knott, *Boston University School of Medicine, Boston, Mass. (U.S.A.)*

W. Kuhlo, *Deutsche Klinik für Diagnostik, Wiesbaden (W. Germany)*

R. L. Maulsby, *Tulane Medical School, New Orleans, La. (U.S.A.)*

W. C. McCallum, *Burden Institute, Bristol (Gt. Britain)*

W. D. Obrist, *Duke University Medical Center, Durham, N.C. (U.S.A.)*

C. R. S. Thompson, *Applied Psychology Department, University of Aston, Birmingham (Gt. Britain)*

F. Torres, *University of Minnesota Hospitals, Minneapolis, Minn. (U.S.A.)*

W. Vogel, *Psychology Department, Worcester State Hospital, Worcester, Mass. (U.S.A.)*

Preface

After more than 40 years of experience of EEG in clinical diagnosis and research, it is of utmost importance to reconsider the problem of "the normal EEG", because of all the ambiguities of the definition of "normality".

There are two concepts of EEG normality, with very different practical consequences. One postulates a "normality of the EEG *per se*", based on descriptive criteria only. The use of EEG as a diagnostic tool is largely based on this concept. The other considers the record as normal, whatever its features, if it belongs to a normal subject. According to this concept, the EEG is mainly a research method. These two points of view overlap to some extent but do not coincide; one of the problems to be discussed here is, in fact, that of the margin of discrepancy between the "normal adult EEG" and the "EEG of the normal adult".

The concept of "EEG normality *per se*" results from statistical studies. In these investigations, the records of a large control population display certain common features, both positive (frequency, amplitude, topography, reactivity, etc.) and negative (absence of certain deviant patterns). Thereafter, through a procedure of oversimplification and generalization, these most common features (corresponding to the central part of the Gaussian curve) are emphasized to the exclusion of others and tend to become the only accepted criteria of normality. The descriptive criteria of EEG normality are in turn used to define a "normal" population, which is an example of the use of circular reasoning. The uncommon "variants", encountered in a small part of the same normal population, at the two ends of the Gaussian curve, are excluded or considered to be "abnormal".

The above approach has three main implications. First, this concept is static and does not reflect the biological plasticity of the human organism. Second, the descriptive criteria of EEG normality vary from one EEGer to another and from one laboratory to another. Negative criteria (absence of abnormalities) can be judged sufficient to define normality in a laboratory dealing with gross pathology, that is, to exclude with reasonable probability the hypothesis of an evolving cerebral lesion. Positive criteria are usually stricter when they are applied to the fields of psychopathology or psychology where the problem is to determine subtle individual variations than when they are used in neurologic diagnosis. Selection problems will necessitate criteria of their own. These considerations explain why the proportions of "normal EEGs" in "normal" groups reported in the literature vary according to the authors from 85 to 28%.

Last but not least, even with very strict criteria, descriptive EEG normality cannot be equated with physiological or psychological normality. A "normal" record is uncommon in acute brain pathology but is more frequently observed in chronic brain pathology and in psychiatric conditions. Therefore, a normal EEG alone does not imply physical or psychological normality. Conversely, an "abnormal" or "borderline" record is not always indicative of physical or psychological abnormality. These limitations must not be underestimated.

According to the concept that any EEG must be regarded as normal if obtained in a healthy subject, the significance of an EEG can only be understood by the clinical and psychological analysis of the subject, and thus necessitates defining normality on the clinical or psychological level. Here again, the criteria will differ according to the field of application: in gross pathology, normality will be assessed on negative data, *e.g.*, will be based on evidence of absence of illness, whereas in psychology, the notion of normality is often replaced by such concepts as level of integration, degree of adaptation, etc., which are in fact of greater value.

Thus what will be treated in the following Sections is not the "normal adult EEG" but rather the "EEG of the normal adult", whatever the difficulties in defining precisely such normality.

The results of statistical studies remain an essential reference. It is important to know the most common EEG features, and the neuronal systems responsible for them. So far, most data in this domain have been obtained primarily through conventional, visually analyzed EEGs. The utilization of more sophisticated techniques of data acquisition and processing is hoped to improve the accuracy of descriptions and measurement of the spontaneous and evoked EEG activities and will lead to more adequate models to account for their genesis.

Nonetheless, it is essential to define the intra-individual and inter-individual range of variability of the normal adult EEG. Intra-individual variability may be due to variations of both the internal milieu and the external environment, whereas inter-individual variability has been mostly related to psychological characteristics.

The intra-individual variability can be fairly accurately controlled or experimentally reproduced. Hence, EEG variations incident to homeostatic regulation and psychophysiologic states are analyzed in this Part, as well as those produced by such conditions as stress, fatigue, sustained attention, unusual environments, sensory deprivation, etc. The inter-individual variability related to physiological differences is a more speculative field of research. The numerous "static" studies of EEG and psychology proceed from different methodological approaches including: search for relationships between selected psychometric elements and EEG variables; variations of EEG patterns among socio-cultural or occupational groups; comparison between normal groups and mental patients. These studies have provided results and controversies.

This Part includes a review of the evolution of the EEG with aging, and the limits between phsyiological senescence and pathology of aging. At this stage of life organic factors might appear prevalent. However, one must keep in mind that the EEG might reflect a mode of adaptation to a changing way of life as well as the metabolic, vascular, and other changes. Hence, at all stages, the interplay between "static" characteristics and "dynamic" variations must be considered to interpret appropriately the EEG of a given individual, whose normality varies dynamically within a certain range rather than according to rigid quantitative parameters.

In summary, the main purpose of this Part is to present the complexity of the problem of normality rather than solve it.

The use of instrumental technique in medicine is generally expected to replace complex subjectively interpreted information with objective quantifiable data. Such a demand implies the existence of precise criteria of normality. In the field of EEG, these criteria must take into careful consideration the biological and psychological range of variation. The diversity of the EEG of so-called normal subjects transcends statistical norms and includes plasticity, adaptation and reversibility of induced changes in the internal milieu as well as in the environment. Thus it is difficult to define the so-called normal EEG, but it is only on this basis that the EEG can be of any diagnostic help.

A source of bias not to be underestimated is that the way each EEGer interprets an EEG record reflects his own philosophy, and at times this may influence the collection of data itself as well as their subsequent interpretation. Because of this, all authors quoting in their papers the terms "normal" and "abnormal" should be urged to define them as precisely as possible.

Section I. Typical Normal Rhythms and Significant Variants

A. INTRODUCTION

This Section of Part 6A of the Handbook offers a comprehensive account of present-day knowledge of EEG rhythms encountered in apparently normal waking adults. Individual Sub-sections are devoted to the alpha, beta and theta rhythms as well as to other EEG patterns less frequently observed and/or less widely known, such as the low voltage EEG, mu and kappa rhythms, slow posterior activities and lambda waves. Paroxysmal patterns encountered in apparently normal individuals are also treated in detail in view of their special diagnostic importance. General considerations on the physiologic and genetic bases of normal EEG rhythms and on the information derived from instrumental analyses of such rhythms conclude this Section.

A critical evaluation of normal EEG rhythms of human adults is frought with difficulties. Surprisingly few studies of carefully screened normal subjects, based on currently accepted criteria of EEG interpretation, have been conducted so far. Thus, a remarkable proportion of data on normal EEG rhythms analyzed in this Section of Part 6A is derived from examinations of patients suffering from neurological and/or psychiatric illnesses. It is difficult to compare the results of these studies because of a variety of factors including major dissimilarities between populations investigated, differences in instrumentation and technique, a lack of uniform quantitative criteria for the identification of these rhythms, the influence of various disease states and possibly the effects of drugs and/or other treatments. Hence, uncertainties persist as to the true incidence of certain patterns among normal adults and their relationships to age, sex and race among others. Claims of correlations between certain normal EEG patterns or combinations of patterns and psychological variables and personality traits of normal adults and subjects with psychiatric and neurologic disorders abound in the literature. However, statistical validation of these data often was not attempted or was inadequate. Moreover, most of the studies which benefited from sound statistical design offered little support to the existence of such relationships. Credible experimental models of the generation of EEG potentials in general are available as indicated in Sub-section K. However, little is known on the origin and significance of individual rhythms of the human EEG. Moreover, the cerebral origin itself of one of the rhythms under consideration, the kappa rhythm, has not been established beyond doubt as yet. However, a substantial body of data descriptive of the basic characteristics of normal EEG rhythms and their reactivity to various stimuli does exist. Of special interest are the psychophysiologic experiments aptly summarized in Sub-section B on the alpha rhythm. Genetic studies reviewed in Sub-section C attempt to explain some of the inter-individual variations of normal rhythms. Moreover, it appears reasonable to hope that computer techniques including those alluded to in Sub-section M will contribute in the future quantitative measures designed to decrease the subjectivity of our present appraisal of normal EEG rhythms.

B. THE ALPHA RHYTHM

1. Definition

Numerous definitions of the alpha rhythm have been given by various authors. That suggested by the Terminology Committee of the International Federation for Electroencephalography and Clinical Neurophysiology (Storm van Leeuwen *et al.* 1966) describes the alpha as a "rhythm, usually with a frequency of 8–13 c/sec in adults, most prominent in the posterior areas, present most markedly when the eyes are closed, and attenuated during attention, especially visual".

The precise lower and especially upper frequency of the alpha rhythm are somewhat arbitrary (Cobb 1963a). With advancing age, this frequency tends to decline, even in healthy adults. Obrist (1963) reported that two-thirds of 47 males over 65 years of age had posterior rhythms below 10 c/sec, *i.e.*, at least a full cycle below the average for young adults.

The amplitude of "normal" alpha rhythms is subject to wide variation. Berger (1929) stated that voltages ranged from 15 to 20 μV. Cobb (1963) indicated that the amplitude of this rhythm "usually ranges from 0 to 40 or 50 μV in the individual record, and maximum peak-to-peak amplitudes of over 100 μV are uncommon in the adult". Simonova *et al.* (1967) reported that adults displayed alpha rhythms below 20 μV in 28% of cases, rhythms of 20–60 μV in 66% and over 60 μV in 6% of subjects.

2. Discovery and principal features of the alpha rhythm

The alpha rhythm of the human EEG was the principal electrical activity observed by Hans Berger in unpublished observations he made in 1924 and 1925. His First Report (1929) illustrated 8 c/sec rhythmic activity in a 40-year old male (Fig. 1). In the majority of cases described in this publication, waves "of the first order", with durations of 90–100 sigma (milliseconds) were demonstrated. It was not until

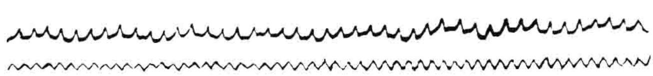

Fig. 1. First published photographic recording of alpha rhythm in man. EEG tracing (*top channel*) was obtained on 40-year-old subject who had a large skull defect extending from the forehead to the parietal region. Electrodes consisted of subcutaneous needles inserted 4.5 cm apart in the area of the bone defect. Amplification was provided by a double-coil galvanometer. Time marker (*bottom channel*) is waveform at 10 c/sec. (From Berger 1929, English translation by Gloor 1969)

his Second Report (1930) that this author, "for the sake of brevity", applied the designation "α-w" to these "waves of the first order". Berger's findings remained unconfirmed in the English speaking world until, in 1934, Adrian and Matthews succeeded in reproducing his results. They demonstrated a basic rhythm in the vicinity of 10 c/sec, which they chose to call "the Berger Rhythm". Berger himself (1935) declined this honor and proposed that his original term, "E.E.G.", be retained to designate this particular type of cerebral electrical activity. However, the identification of the electroencephalogram with a given type of rhythm was clearly undesirable especially in view of the demonstration by Berger himself of "waves of the second order" which he had labeled "β-w" or beta waves. The fact that Berger (1931) regarded slower potentials (*i.e.*, waves of durations ranging from 140 to 250 msec) as "longer" alpha waves may have contributed further to the confusion which occurred when "alpha waves", "Berger Rhythm" and "E.E.G." were regarded as equivalent.

A fundamental disagreement between Berger and Adrian and Matthews was apparent in these early publications. The latter authors (1934) expressed the belief that alpha waves originated in the occipital cortex whereas Berger felt that they arose from the entire cerebral cortex. In 1935, Berger also refuted the claim of the English investigators that blind persons displayed no alpha rhythm and very cogently pointed out that anxiety and heightened attention to non-visual stimuli attenuate this rhythm (see also Walter and Yeager 1956).

Adrian and Yamagiwa (1935) studied the topographic distribution of the alpha rhythm by means of closely spaced scalp electrodes and reiterated their belief that this rhythm originates in the occipital regions. Independent foci of alpha activity were demonstrated in the left and right cerebral hemispheres. Clearly, Berger's use of fronto-occipital derivations deceived him, for it is apparent that in these circumstances the frontal electrodes essentially served as reference and the occipital electrodes as active leads.

Berger (1933) commented extensively on the bilateral synchrony of alpha activity and its variability. His observations led him to believe that "...it is *one and the same process* which is recorded from both cerebral hemispheres... which occasionally, and only transiently, is masked or altered by local events". This concept was re-emphasized by Berger in his Fourteenth Report (1938a). Of special interest is the suggestion by the same author that the bilateral synchrony of this activity is mediated via the thalamus rather than the corpus callosum (Seventh Report 1933). Adrian and Matthews (1934) similarly believed that the alpha rhythm of the two cerebral hemispheres was approximately synchronous.

Later, Aird and Garoutte (1958) utilizing high-speed oscilloscopic recordings observed that 55% of all alpha waves were within 1 msec and 73% within 5 msec of perfect synchrony between the two hemispheres. When departures from perfect synchrony occurred, one side led or followed the other apparently at random (Fig. 2). These investigators placed the mechanism controlling such synchrony in the upper brain-stem or lower diencephalon and noted that agenesis of the corpus callosum did not affect the synchrony of alpha or other bilateral activities.

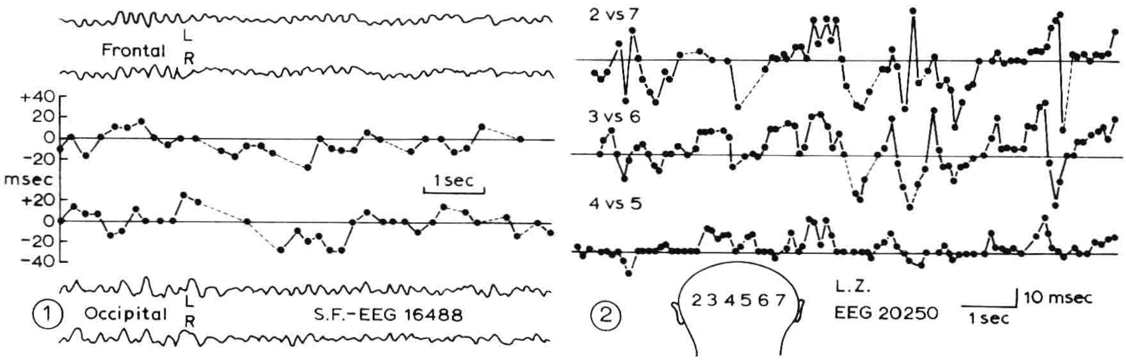

Fig. 2. Temporal relationships of EEG rhythms from homologous regions of the two hemispheres. *Section 1, top two tracings:* 6 c/sec rhythm from left and right frontal regions of one-year-old patient; *bottom two recordings:* rhythms from left and right occipital areas of same subject; top and bottom plots depict differences between times of occurrence of EEG waves over frontal and occipital areas, respectively, of the two sides; points plotted above and below zero line indicate earlier occurrence of waves on the right and left sides, respectively. *Section 2:* plots depicting differences between times of occurrence of 10 c/sec alpha rhythm over right and left occipital areas. Electrode locations are indicated by numbers. (From Aird and Garoutte 1958)

As described by Adrian and Matthews (1934), the alpha rhythm, in general, has an occipito-parietal distribution. Cobb (1963a) stated that differences in alpha activity between the two hemispheres include lower voltages and lesser amounts of this rhythm on the left than the right side. This author dismissed the possibility of a relationship between cerebral dominance and alpha amplitude asymmetry, at variance with an earlier report that reversal of this asymmetry correlates with reversal of handedness in identical twins (Raney 1939). Similarly, Lindsley (1940) did not find a relationship between unilateral alpha attenuation and hemispheric dominance, although he believed that good bilateral synchrony of this rhythm was related to a well developed degree of lateral hand preference. Cornil and Gastaut (1947) reported alpha asymmetry in 58% of normal subjects, with lower voltages on the presumably dominant hemisphere, a finding not supported by Glanville and Antonitis (1955). More recently, Provins and Cunliffe (1972) have utilized a 2-channel frequency analyzer to evaluate amounts of alpha and other EEG activities and attempted to relate these findings to those of tests of hand-preference. They reported that while the amount of alpha activity over the two hemispheres was reliably reproducible from one sample to another, the left-right differences were not.

One of the most interesting features of the alpha rhythm is its tendency to be reduced in voltage (*i.e.*, "attenuated") or apparently to disappear (*i.e.*, to be "blocked") when the subject attends to either internal or external stimuli (Fig. 3). This phenomenon was first reported by Berger (1929) in relation to "strenuous mental work". In his Second Report (1930) the same author showed an example of disruption of alpha activity incident to tactile stimulation, and discussed the occurrence of similar changes with other sensory stimuli and with focusing of attention.

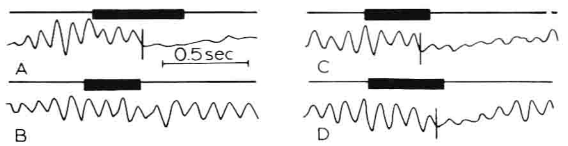

Fig. 3. Reactivity of alpha rhythm to visual stimulation terminated by motor responses of subject. In each section, solid block in top record depicts stimulus; bottom trace displays alpha rhythm and vertical mark indicates manual response. Samples demonstrate blocking (*A*), attenuation (*C* and *D*) and no observable changes (*B*) of alpha rhythm, respectively. (From Knott 1939. Copyright 1939 by the American Psychological Association and reproduced by permission)

3. Normative studies

While the alpha activity is the most prominent of all rhythms in the typical normal adult EEG, it is by no means continually present during the waking state in all persons. The normative studies of Gibbs *et al.* (1943a) showed that at least some alpha rhythm of 8–12 c/sec exists in 89% of normal waking adults, while 11% show little or no alpha activity. The amount of alpha rhythm varies considerably from one individual to the next. Some normal persons exhibit either no or little alpha activity, while others display an alpha rhythm almost 100% of the time (Davis and Davis 1936). These last investigators divided the population into quarters, depending on the amount of activity exhibited in the alpha band. Those who demonstrated an alpha rhythm more than 75% of the time were termed "alpha dominant" whereas those who displayed it less than 25% of the time were referred to as "rare alpha" subjects. They felt that the amount of alpha activity in an individual's EEG was a constitutional constant. Other investigators (Rubin 1938; Travis and Gottlober 1936, 1937a) elaborated further on the significance of these individual differences in alpha activity and stressed the constancy and individuality of this rhythm.

These early studies laid the foundations for the investigation of intra-individual and inter-individual variability. The former was central to the controversy between Adrian and Berger on the site of origin of the alpha rhythm, with its attendant discussion into the reasons why alpha activity might or might not be present in certain individuals. The latter naturally follows observations that some people have more abundant alpha rhythm or faster or slower alpha activity than others.

4. Inter-individual variability and long-term correlates

The problem of inter-individual variability of the alpha rhythm has received considerable attention since the earliest days of electroencephalography. Lemere (1936) was apparently the first to suggest that some relationship might exist between the electrical activity of the brain and "personality". He reported that persons with very persistent alpha rhythm tended to have cyclothymic personalities, whereas individuals with poor, sparse, or essentially absent alpha activity, tended to present schizothymic personalities. These rather coarse relationships received variable degrees of support. Gottlober (1938), on the basis of personality tests given to a group of presumably normal college studens, reported finding a relationship between percent time alpha activity and personality, as defined by an introversion–extroversion scale.

A very provocative report by Saul *et al.* (1937) associated high alpha indices (*i.e.*, percent time alpha) with a "passive dependent, receptive attitude towards other persons, provided this attitude is freely accepted and not thwarted or inhibited internally". Low alpha indices were believed to be "associated with a consistent, well-directed, freely indulged drive to activity". However, Lindsley (1938) found no significant correlation between the frequency and amount of alpha activity and "ascendence-submission" personality variables in a group of children.

Henry and Knott (1941) extended, through partial replication, the report by Gottlober (1938). Their study suggested that the relationships he had described might occur by chance alone. When Gottlober's results were combined with new data, yielding a total of 147 subjects, 58% of individuals showed high alpha indices. Of these, 62% were extroverts. Among the 42% of subjects who had low alpha indices, the proportion of extroverted individuals was 67%. The difference between 62 and 67% was not satistically significant. When the subjects were divided on the basis of their personality, 64% were extroverts. Of these 57% demonstrated high alpha indices. Thirty-six percent were introverts and 62% of these had high alpha indices. This difference, too, was not significant. These findings did not support the hypothesis of a close correlation between personality and alpha index in normal subjects.

Ulett *et al.* (1953c) utilized frequency analysis of the resting EEG to obtain quantitative data to be correlated with psychological characteristics. "Anxiety-proneness" was defined by tests and psychiatric ratings. Photic driving was also employed to detect inter-individual differences which might correlate with personality. These authors reported a significant relationship between anxiety-proneness and the amount of alpha activity in the resting EEG. Subjects with higher anxiety-proneness ratings had less developed alpha and more fast activity, whereas those who were less anxiety-prone tended to have more abundant alpha activity. Moreover, they noted a relationship between responses to photic driving and personality in that harmonic driving in the faster ranges was more prevalent among anxiety-prone individuals.

A further study of these relationships was made by Gastaut *et al.* (1959b), who reported a positive correlation between alpha frequency and high hypomania scores on the Minnesota Multiphasic Personality Inventory, and negative correlations between alpha amplitude and the same scores.

Savage (1964) investigated extroversion and "neuroticism" in a group of normal students and correlated scores derived from the Maudsley Personality Inventory with alpha activity. In this study, extroversion was found to be related to large amplitude alpha activity, whereas neuroticism was not so related. On the basis of the assumption that high voltage alpha waves might be related to inhibition, this author concluded that extroverts were characterized by a greater degree of cortical inhibition. At variance with his findings, Fenton and Scotton (1967) and

Young *et al.* (1971) found no correlation between personality as defined by the Maudsley Personality Inventory, and alpha index, alpha amplitude, and some characteristics of alpha blocking.

Mundy-Castle (1955) based his search for correlations between EEG and personality upon a temperament scale based on the individuals' characteristics with regard to "primary" as opposed to "secondary" functions. The primary mode of responding involves reaction to immediate experience, whereas the secondary mode refers to the effects of present experience modified by experiences in the past. This author reported that there were low but consistent correlations between alpha index and this broad typology. Individuals of the primary type (*i.e.*, those who are quick, impulsive and variable in their reactivity) were reported to have higher alpha frequencies than subjects of the secondary type (*i.e.*, those who are relatively cautious, steady and slow to react).

These inquiries into possible correlations between "personality" and "EEG" have assumed that each variable represents a "constitutional constant", present under all conditions. Broadhurst and Glass (1969) made measures of alpha rhythm during assigned mental work. These included percent time alpha, amplitude and frequency, and "rate of change of potential" (*i.e.*, the total length of EEG trace during a given time). In the course of arithmetic calculations they reported that introverts had higher alpha percent time and amplitude than extroverts (as determined by the Maudsley Personality Inventory). Smaller alpha amplitude and frequency were associated with neuroticism. Similarly, Becker-Carus (1971) evaluated extroversion, neurotic tendency, and "rigidity". "Vigilance" was maintained by multiple discrimination reaction time testing and task performance was assessed by serial subtraction. An increase in task difficulty was associated with augmented alpha frequency and decreased alpha index. Vigilance correlated positively with 8–9 c/sec activity ($r = +0.44$) and negatively with 12–13 c/sec activity ($r = -0.49$), alpha index in final resting state (after mental work) ($r = -0.62$), and 8–9 c/sec activity ($r = -0.76$). Rigidity (indicated by errors in task performance) correlated with high alpha frequencies, whereas no significant relationships were demonstrated for extroversion. Neurotic tendency yielded a positive correlation ($r = +0.41$) with alpha index during vigilance testing, and correlations of about +0.54 with 10–11 c/sec activity in the same circumstances. These results are reminiscent of the findings of Brazier *et al.* (1945), who reported that the resting EEGs of psychoneurotics had on the average a faster alpha frequency than those of normal adults.

Perhaps one may profitably return to the report by Gastaut *et al.* (1959b), for expressed in that communication is a significant kernel of statistical truth. Their investigation examined some 400 possible relationships between EEG and psychological variables. Out of this vast search the authors obtained only four X^2-derived "correlations" which were significant at the 0.01 level of confidence. It is of special interest that 4 out of 400 is precisely what one may expect at the 0.01 level on the basis of chance alone! Of course, the consideration that the present stalemate in the search for correlates between EEG and psychological measures may be compounded by chance factors does not deny the possibility that, should appropriate samples be selected, adequate measures devised, and suitable statistical design utilized, more satisfactory and defensible relationships could be uncovered.

Other approaches to inter-individual differences in alpha activity have sought correlations with intelligence. The earliest studies utilized only mentally defective subjects. Berger (1931) expressed "great disappointment" when he found no difference in the EEGs of imbeciles and normals. Later (1935) he reported possibly diminished voltage in 3 imbeciles, but in his final paper (1938a) he expressed disbelief in any claimed differences in EEG as a function of intelligence *per se*. Kreezer (1936) found that mental ages below 5 years correlated with alpha index in mongoloids. However, Shagass (1946) was unable to detect any significant relationships between alpha activity and intelligence of adults having IQs within the normal range. Earlier, Henry (1944) failed to demonstrate relationships between IQ and alpha frequency in a group of normal children. A similar lack of correlation existed between alpha frequency and skeletal maturity. This finding suggested that alpha frequency is a fairly unique and independent index of maturation.

Other approaches have yielded different claims. Mundy-Castle and Nelson (1960) reported a correlation of +0.34 between alpha frequency and IQ measured by the Wechsler Adult Intelligence Scale. They utilized an inbred, isolated group of subjects and postulated that IQ and alpha frequency both measured CNS excitability. However, Gastaut (1960) did not find encouraging correlations between any measures of alpha and intelligence test scores.

In contradistinction to the classification of alpha activity proposed by Davis and Davis (1936), which was based upon quantitative percent measures, another classification was introduced which utilized a typology of alpha based in part upon its abundance or scarcity and in part upon its reactivity. Golla *et al.* (1943) distinguished three types of individuals on the basis of their alpha activity: *P*, *M* and *R*. Subjects of type *P* (plus) displayed a persistent alpha rhythm which was resistant to attenuation by mental efforts: these persons were said to use predominantly auditory, tactile or kinesthetic rather than visual imagery. Individuals of type *M* (minus) showed little alpha activity and used essentially visual imagery. Persons of type *R* (responsive) exhibited an alpha rhythm readily attenuated by states of tension, and visual and other stimuli (see Fig. 4). In a more recent investigation, Short and Walter (1954) studied *M*, *P* and *R* subjects, and correlated EEG types with skills in learning finger mazes. They observed that type *M* and type *P* subjects showed shorter exploration times, whereas individuals of type *R* required longer exploration times and demonstrated incorrect responses related to the manifestation of alpha bursts in their EEG. These authors expressed the belief that subjects could be categorized on the basis of the degree of consistency of their mode of imagery. Those persons who were consistent tended to be the most successful. The study was replicated on a second group of individuals and the data obtained were found to be in accordance with the initial investigation. It should be emphasized that all these studies of the relationships of imagery to alpha activity rest upon the assumption that there are constant individual differences in