ELECTRO-ENCEPHALOGRAPHIC STUDIES OF PSYCHOPATHIC PERSONALITIES *

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AN *abnormal personality* is one which deviates from its appropriate personality norm. *Psychopathic personalities* constitute a sub-group of *abnormal personalities*. Schneider (quoted by Kahn, 1931) has defined psychopathic personalities as *those abnormal personalities who suffer from their abnormality or from whose abnormality society suffers*. This definition points to a cleavage within the group which is apparent in many classifications, and which is the basis of the division into the bipolar types, inadequate and aggressive, adopted in this paper. A certain amplification is necessary. Psychopathic personalities do not include certifiable mental defectives, psychotics, neurotics, or those whose behaviour disorder is due to demonstrable physical disease.

Henderson (1939) classifies psychopaths into three broad groups, predominantly *aggressive*, *inadequate*, and *creative*. The aggressive group is subdivided into those who injure others, those who attempt self-injury, alcoholic and drug addicts, the epileptoid, and the sex variants. The inadequate group embraces a wide variety of types which have in common ineffectual behaviour. The creative group was formulated to bring together the brilliant but unstable eccentrics.

In this paper Henderson's classification is adopted with three modifications. The group of creative psychopaths is not used, as no clinical material of this kind has been investigated. The aggressives have not been subdivided into smaller groups. The sexual perverts have been divided between the aggressive and inadequate groups, but have also been brought together separately for comparison. This simplified method of classification is used, first because this investigation is largely concerned with the aggressive component of behaviour, second because of lack of time for making elaborate and detailed personality studies.

In the *Predominantly Aggressive* group have been included those psychopathic personalities with a history of either determined suicidal attempts, violence to others regardless of the consequences, repeated destruction of property, or combinations of such kinds of aggressive and impulsive behaviour. These are the patients who describe from early years uncontrollable outbursts of temper, which have almost invariably got them into trouble, either with their

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relatives or the police or other authority. At times they have insight and are able to discuss their abnormality with fair detachment. At other times they picture themselves as the products of hostile circumstances and the victims of a harsh fate; they are then surly, morose, resentful, contemptuous, and heavily sarcastic. Their hostility may be directed narrowly against a few persons, or against the world at large. Inner tension may be shown by tremor, tachycardia, excessive flushing, and occasionally by a peculiar blocking of self-expression.

These patients rarely apply for treatment voluntarily, but are usually sent to hospital for observation following several acts of violence. Frequent findings in their histories are morbid inheritance, disturbed surroundings in childhood (including bad relationships with parents and siblings), truancy from school, repeated changes of occupation, unsuccessful and often stormy marital careers (out of a group of 20 married aggressive psychopaths, marriage was a failure or markedly unsatisfactory in 13 instances), convictions in civil life for such offences as theft, housebreaking, assault, and drunkenness, and charges in the Services for absence without leave and insulting and violent behaviour.

Special mention should be made of the frequency of head injuries, usually incurred during brawling, boxing, or while resisting arrest. As far as possible, no case has been included in this group unless the history showed markedly aggressive behaviour before any head injury.

The *Predominately Inadequate* group is heterogeneous. It includes purely negative psychopathic personalities with no outstanding or distinguishing features except that they chronically fail in life from having too little energy and drive. This group also embraces diverse types such as the schizoid, hysterical, hypochondriacal, depressive and anxious psychopaths, and the pathological liars. These varieties cannot be illustrated in a short space; they rarely exist as separate entities, and most patients are a conglomerate mixture. Noticeably irritable psychopathic personalities, showing little or no overt aggression, have also been placed in this group. The criteria separating them from the predominantly aggressive psychopaths are: (1) The suicidal attempts they make are feeble and unlikely to be effective, e.g. swallowing a few aspirins. Usually suicidal threats only are made. (2) Violence against others is often contemplated, but is never practised. (3) Destructive acts are limited to throwing things about, petty incendiarism, etc. These patients know they are hot-tempered, but claim to be able to control themselves. Their life histories differ only in degree, but in marked degree, from those of the aggressive psychopaths.

There are no sharp lines between psychopathic personalities and the other mental disorders. Anxiety and hysterical symptoms are common among psychopaths, but a distinction is drawn between neurotics and psychopathic personalities, "in that the symptoms of the latter appear in behaviour, of the former more often in feelings and physical complaints" (Menninger, 1938). Psychopaths often complain also of depression, but this is usually shallow, rapidly variable, overshadowed by irritability, and not accompanied by retardation. Moreover, expression of guilt feelings tends to be replaced by expression of resentment, contempt, envy, and hate.

Clinical Material

The clinical material on which this investigation was based was drawn from four sources: a Military Mental Hospital, the Neurological Department of an Emergency Hospital, certain psychiatric out-patient departments, and in a few cases from out-patients sent directly for E.E.G. by Unit M.Os. It is selected material and does not represent a random sample of psychopathic personalities. It is largely made up of male personnel from the Services. The ages range from 15-51; 90 per cent. of the patients were between 20 and 30 years of age.

Histories have been obtained from the patients themselves, often supplemented by information from relatives, and in a small number from social workers' reports. Service cases are also accompanied to hospital by a report on behaviour from the Unit M.O. or C.O. As many of these patients are not always truthful, some of the histories we have obtained are not as reliable as we would have wished.

Table 1 shows the distribution of this material between the sub-groups. The "mixed" group of 24 patients includes those cases in which neurosis, psychosis, or epilepsy is superimposed on an abnormal personality; 16 of this group showed overt aggression. Only first-degree relatives (i.e. parents or siblings) have been included in the tabulated data showing abnormal family histories.

The control material of presumed-healthy persons was drawn from three sources: R.A.M.C. staff at a Military Mental Hospital, and staff and surgical patients of a general hospital. The clinical investigation of these controls was less thorough than that of the patients, but attention was paid to offences in civil life or in the Army, head injuries, fits and faints, irritability, impulsiveness, and aggressive behaviour.

TABLE 1

SUB-GROUP	NO.		TOTAL	MORBID FAMILY HISTORY	PATIENTS
Aggressive psycho- pathic persons..	77	<div>NO.</div> <div>Without recidivism 66</div> <div>With recidivism .. 10</div> <div>With perversion .. 1</div>	93	PER CENT. 44=47	Showing marked overt aggression.
" Mixed "	24	<div>With overt aggression 16</div> <div>Without overt aggres- sion 8</div>	58	22=38	Showing little or no overt aggression.
Inadequate psycho- pathic persons.	50	<div>With perversion .. 7</div> <div>With recidivism .. 5</div> <div>Without recidivism 38</div>	58	22=38	Showing little or no overt aggression.
TOTAL PATIENTS ..	..	 151	151	66=44	
CONTROLS ..	..		52		

Historical Introduction

Abnormalities in the electro-encephalogram can be divided into two main groups: (1) where the rhythms are too fast, and (2) when they are too slow. The normal range of dominant or alpha rhythm is from eight to thirteen cycles. There are wide individual variations in the voltage, frequency, and in the time during which the dominant rhythm is present. In some persons dominant rhythm makes up 95 per cent. of the record, in others only 5 per cent.; occasionally the dominant rhythm is of extremely low voltage, and very infrequently there is no dominant rhythm at all. Though in the present stage of knowledge all these variations must be regarded as within the normal range, it has been suggested that a relationship might exist between the dominance of alpha rhythm and personality traits. The results of such investigations have not been very convincing. Saul, Davis, and Davis (1937), using a Freudian interpretation of personality, found that persons with, to quote them, "a freely indulged in drive to activity, independent aggressive social leaders, doers in reality rather than intellectual sublimation, and personalities who dream of attacking and stealing the power, potency or ability of others" tend to have few alpha waves, i.e. a poor dominant rhythm. The opposite type, whom they describe as passive, dependent, and receptive, the men in their opinion having passive homosexual trends, have many alpha waves, i.e. a good dominant rhythm. Gottlob (1938), favouring a Jungian classification, found a relation between extraversion and a dominant alpha rhythm. He was unable, however, to correlate the introverted type with few alpha waves. Lemere (1936), on the other hand, has correlated the schizoid personality with poor alpha rhythm and the cycloid personality with a good one. Unfortunately, it does not appear possible to associate Saul's psychoanalytical personality classification with the psychiatric interpretations of Lemere, but the latter correspond well enough with those of Gottlob. It is interesting that Gottlob found an association between the cycloid personality and a good alpha rhythm, but no such association in the case of the schizoid personality. This is paralleled by other psychophysical studies, e.g. by the finding that there is an association between cycloid personality and pyknic physique, but only a doubtful one between schizoid personality and a leptosomatic physique.

Berger (1936), who believed that the electro-encephalogram in the schizophrenic and manic-depressive psychoses was normal, remarked on the poor alpha rhythm in the former, but considered this and the predominance of high-frequency potentials also present as evidence of emotional tension. Hoagland, Rubin, and Cameron (1937), using a quantitative assessment of abnormally slow waves (the Hoagland or delta index), found that this was higher in schizophrenics than in normal controls. MacMahon and Walter (1938) criticized this on the ground that eye-movement artefacts, which would increase the index, were very common in schizophrenics.

Imagery-type in schizophrenia was investigated by Rubin and Cohen (1939) who used another quantitative assessment—"the per cent time alpha." This is simply the number of dominant waves with a frequency over seven per second in five metres of record. They described a greater homogeneity among schizo-

phrenics than among normal controls, and in those with tactual temperature imagery a significantly lower "per cent time alpha." They suggested a correlation between this finding and Cohen's work (1938) on the change from auditory to tactual temperature imagery in schizophrenics and accounted for it by suggesting that it was part of the phenomenon of narcissistic regression or, as they put it, "a restriction of experiencing from the outside world . . . and the orientation of imagery becoming mainly concerned with the inside world, i.e. that of the body." This interesting psycho-biological approach cannot, unfortunately, be supported, and recently Walter (1942) has suggested that the flat, low-voltage rhythms seen in some schizophrenics may be related to changes in the electrical resistance of the meninges and scalp and be independent of the cortex itself.

It is agreed by most workers that from 5 to 10 per cent. of normal people have electro-encephalograms which fall outside the limits of an arbitrary norm. The view that cortical dysrhythmia (a term synonymous with abnormal E.E.G. for the purposes of this paper) is itself a constitutional defect has had support in the work of Lennox, Gibbs, and Gibbs (1940) on the relatives of epileptics. They found that 60 per cent. of the relatives had dysrhythmia and that of 35 per cent. of epileptic children, both parents were abnormal, both being normal for only 5 per cent. The writers suggest that dysrhythmia may be a dominant trait which is possessed by 12 per cent. of the population who are predisposed to epilepsy or to some allied disorder, either themselves or in their offspring. Episodic behaviour disorder associated with an increase of dysrhythmia in epileptics has been described by Putnam and Merritt (1941), but as far as we can ascertain from the literature, such behaviour *without epilepsy* but *with dysrhythmia* has not been described in adults. Jasper, Solomon, and Bradley (1938) were the first to report abnormal E.E.Gs. in behaviour problem children. These abnormalities are very similar to those found in the psychomotor equivalents of epilepsy, and the children, by their irritability, tempers, egocentricity, and hyperkinesis, are in some respects reminiscent of the epileptic personality. There appears, however, to be no clinical evidence that these children become epileptic. Lindsley and Cutts (1940) have shown that nearly 80 per cent. of behaviour problem children have abnormal E.E.Gs. and that the percentage abnormal in constitutionally inferior children is hardly less. (Under the term "constitutionally inferior" they place children with poor heredity whose problems were predominantly social, economic, or medical.)

Williams (1941a) has shown that 26 per cent. of 148 mixed psychoneurotic patients had abnormal E.E.Gs. Apart from this, epilepsy, and the behaviour problem children, the investigation of functional psychiatric conditions by the electro-encephalograph has proved disappointing. The workers who have described finer variations within the normal range are now exposed to the criticism that a considerable number of uncontrolled and probably uncontrollable chemical and psychological factors may be influencing their results. In addition to the electrical resistance of the supporting tissues, the pH, oxygen and CO₂ tensions, and the glucose concentration of the cerebral blood are among the known factors which must be considered. On the psychological side, the state

of attentiveness or relaxation, anxiety, and the special meaning which sensory stimuli may have for the patient must be considered when the dominance of alpha rhythm is assessed.

For these reasons, when investigating the electro-encephalograms of psychopathic personalities, we have recorded only abnormalities which lie outside the range of normal and have made no attempt to correlate personality with "per cent time alpha," frequency, voltage, or dominance of dominant rhythm, or the responsiveness of the latter to inhibitory stimuli.

Technique

The apparatus used was three ink-writers motivated by a standard three-channel Grass amplifying unit. The amplifiers were linear from 3 to 50 cycles. The high-frequency filters were kept at position "3," which is that used by other workers with this standard apparatus (Williams, 1941a). The patient sat at ease in a small earthed wire cage and was under continuous observation for eye, scalp, and other movements. The records were taken with the eyes shut, but it must be admitted that, although the environment remained fairly constant, not all the psychological factors tending to disturb relaxation could be controlled. For example, in some instances the patients were brought for the test under close arrest.

The electrodes were small, silver tubes, covered with saline pads, held to the head by means of an open-mesh rubber cap (Walter, 1937). Bipolar electrode placement was used in every case. The usual method was to place four electrodes on widely separated areas of the head, two on each hemisphere. Where more accurate localization of abnormality was attempted, the electrode placement advocated by Gibbs and Gibbs (1941) was used. The latter has, however, the disadvantage that it is impossible to say whether rhythms are bilaterally synchronous. By these methods, there were 20 to 25 minutes of actual recording, which also includes 3 minutes of voluntary hyperventilation. The record is observed for a further 3 minutes after the end of hyperventilation.

Criteria of Abnormality

For our purpose, the following abnormalities were accepted as criteria. They are certainly not the only ones detectable in the E.E.G. For instance, a variability in the frequency of dominant rhythm more than ± 1 cycle is almost certainly abnormal. No attempt to investigate the faster frequencies has been made, for the reason that no check could be kept on the chemical and psychological factors at the time of taking the records. Excessively slow waves were the only abnormalities accepted, except specific wave forms such as spike and wave complexes and the phenomenon which is associated with the aura of grand mal.

Resting Record

1. A dominant rhythm with a frequency of less than 8 per second.
2. Bursts of two or more waves having a frequency less than 7 per second and a voltage more than half that of the dominant rhythm.

3. Series of waves with a frequency of 14 or more rising in voltage to over half that of the dominant rhythm (the grand mal phenomenon).
4. Spike and wave complexes (the petit mal phenomenon).
5. Isolated random waves at 6 per second or less, with a voltage equal to or more than that of the dominant rhythm, provided such waves are repeated from the same cortical area.

Hyperventilation

Each patient was induced to hyperventilate for three minutes. This rather long period was used because many psychiatric patients will not co-operate with full ventilation. It is considered that the longer period may to a certain extent compensate for the deficient depth of breathing in the production of the temporary alkalosis. The significantly abnormal waves, apart from spike and wave complexes, are those with a frequency of 2-3 per second and a voltage over 100 microvolts, which persist after the hyperventilation has ceased. The typical abnormal response is one in which the rhythms, having started to return to normal, are suddenly interrupted by a paroxysmal burst of slow, high-voltage waves, usually from 8 to 15 seconds after the end of hyperventilation. In cases where slow, high-voltage waves persist continuously for more than 20 seconds after the hyperventilation, the response is also regarded as abnormal.

Where a decision as to normality, either in the resting record or on hyperventilation, could not be reached, the patient was re-examined after at least four hours starvation, as this tends to accentuate doubtful abnormalities.

Results

Of the total group of 151 patients, 73 or 48 per cent. had abnormal E.E.Gs. Of these, 20 or 13 per cent. were abnormal in the resting record *only*, and 22 or 15 per cent. after hyperventilation *only*. Thirty-one patients, or 20 per cent., showed abnormalities both at rest and after hyperventilation. In the control group of 52 individuals, 8 or 15 per cent. had abnormal E.E.Gs., and of these 6 were abnormal at rest *only* and 2 showed the twin abnormality: at rest and on hyperventilation. None of the controls showed the abnormal hyperventilation response alone. Fourteen of the patients and three of the controls had E.E.Gs., the normality of which remained in doubt. In these cases, the uncertainty was due almost entirely to irregularities in the resting record. Table 2 compares the total group of patients with the controls. The finding that 15 per cent. of the controls were abnormal is higher than that given by other workers. Lennox, Gibbs, and Gibbs (1940), whose criteria are similar, state that 10 per cent. of their controls were abnormal. Since this investigation was made, one of the abnormal cases has admitted to previous fits and another has admitted to having had a head injury. The selection of normal controls, by the elimination of those who have had head injuries and of those who at any time suffered from faints or fits, is obviously important. In the search for the normal control, however, factors other than head injury and fits must now be considered. The control material of Lennox, Gibbs, and Gibbs was mainly

composed of physicians, technicians, and students, which suggests some degree of selection. D. Williams (1941*a*) has recently shown that the percentage of abnormal E.E.Gs. in highly selected flying personnel who have completed their flying training is only 5 per cent., while in R.A.M.C. personnel it is 10 per cent.

TABLE 2

	POSITIVE				DOUBTFUL			
	PATIENTS (151)		CONTROLS (52)		PATIENTS (151)		CONTROLS (52)	
		PER CENT.		PER CENT.		PER CENT.		PER CENT.
E.E.G. positive rest only	20	13	6	11.5	13	—	2	—
E.E.G. positive hyperventilation only	22	14	0	—	1	—	1	—
E.E.G. positive rest + hyper- ventilation	31	21	2	3.5	0	—	0	—
TOTAL	73	48	8	15	14	9	3	5

An investigation of the personal and family histories of our control material has been made, as far as this was possible. According to the sources, the material can be divided into three groups: (1) R.A.M.C. personnel from a mental hospital, (2) lay and medical staff from an E.M.S. hospital, and (3) surgical patients. The R.A.M.C. personnel showed the greatest number of abnormal E.E.Gs. The histories of the four men with positive and of one man with a doubtful E.E.G. are informative. As already stated, one has admitted to having had fits; he is also regarded as moderately aggressive and irritable, and had suffered a head injury earlier in life. Of the four other abnormal controls, one was recently on a civil charge for threatening behaviour, another on a military charge for insolence, and another had twelve charges for inefficiency recorded on his military crime sheet. All four were regarded as showing varying degrees of aggressiveness, irritability, and impulsiveness. Only one control with an abnormal E.E.G. in this sub-group had normal personal and family histories. Among those members of the R.A.M.C. control group who had negative E.E.Gs., none had been on more than minor charges in the Army and none for insolence or violent behaviour. Among these there was, however, one man who was regarded as an aggressive psychopath and perhaps an epileptic. He had suffered three head injuries. Another normal control, regarded as slightly aggressive and irritable, had been on two charges for aggressive conduct when he was a boy, but his conduct since then had been good.

Similar information from the surgical group is, unfortunately, not available and, while the E.M.S. hospital staff group were not assessed as the result of personal interviews, the results from a written questionnaire have been obtained. The only person admitting quick temper had a doubtfully positive E.E.G.

Placing the three groups in order of abnormality, one finds R.A.M.C. personnel from the mental hospital highest, E.M.S. staff next, and surgical patients with the lowest degree of abnormality.

As already stated, for the purposes of classification the patients have been divided into 66 predominantly aggressive psychopaths, 38 predominantly inadequate psychopaths, 5 cases of delinquency without other psychopathic traits, 8 cases of sexual perversion, and a mixed group of 34 patients in whom aggressiveness, epilepsy, delinquency, perversion, schizophrenia, or cyclothymia occurred in various combinations. Table 3 gives the distribution of E.E.G. abnormality throughout the major groups. Out of 66 predominantly aggressive psychopaths, 43 or 65 per cent. were abnormal, and out of 38 predominantly inadequate psychopaths, 12 or 32 per cent. were abnormal. The five purely delinquent patients were normal, as were seven out of eight cases of sexual perversion. Analysis of the mixed group (Table 4) shows that only one of 11 cases of epilepsy with aggression had a definitely normal E.E.G. The three aggressive psychopaths who developed schizophrenic syndromes had normal E.E.Gs. Of the ten aggressive psychopaths who were also delinquent, five had abnormal E.E.Gs. It is apparent that there is a significant difference in the percentage of dysrhythmics between the inadequate and aggressive groups and the controls and also between the inadequate and aggressive groups themselves. The inadequate group has twice as many abnormal E.E.Gs. as the controls, and the aggressive group four times as many. It is necessary to examine (1) the types of E.E.G. abnormality within the two groups, and (2) the influence of any factors likely to have a bearing on the psychopathic state or on the E.E.G. Such factors are head injury, epilepsy, and the family history.

TABLE 3

	TOTAL	E.E.G.				TOTAL ABNORMAL	PERCENT.
		POSITIVE			DOUBT- FUL		
		REST ONLY	HYP. ONLY	REST + HYP.			
Aggression	66	10	14	19	4	43	65
Inadequacy	38	3	3	6	6	12	32
Delinquency	5	0	0	0	1	0	—
Sexual perversion	8	1	0	0	0	1	—
Mixed	34	6	5	6	4	17	50
Controls	52	6	0	2	3	8	15

Type of Abnormality

As Walter (1942) has pointed out, it is probable that the voltage of cortical rhythms when obtained from the scalp, being subject to variations of resistance

in the supporting tissues, is not necessarily significant of any vital activity of the cortex itself. It is fairly generally agreed, however, that the voltage of rhythms, relative to one another in the same record, has a significance. Thus in epileptics, bursts of slow waves with a voltage higher than that of the dominant rhythm are commonly seen and easily detected. In other epileptics, slow rhythms equal to, or less than, the dominant in voltage are seen and the E.E.G. is still unquestionably abnormal. The difficulty arises in deciding how great the voltage, relative to the dominant, an abnormally slow rhythm must have to be regarded as pathological. When examining a record one observes that there is a threshold voltage above which slow frequencies stand out as having an abnormal appearance. As already stated, the voltage which has been accepted in this investigation, and which we believe is accepted by most other workers in this country is that which is more than half the voltage of the dominant rhythm. While it must be admitted that this is an arbitrary standard, the percentage abnormality among the controls, though certainly higher than that given by other workers, compares not unfavourably.

TABLE 4

	TOTAL	E.E.G.				TOTAL ABNORMAL
		POSITIVE			DOUBTFUL	
		REST ONLY	HYP. ONLY	REST + HYP.		
Epilepsy + Aggression ..	11	2	2	5	1	9
Epilepsy + Perversion ..	1	1	0	0	0	1
Aggression + Delinquency ..	10	1	2	2	3	5
Aggression + Schizophrenia	3	0	0	0	0	0
Aggression + Trauma ..	2	1	0	0	0	1
Aggression + Cycloid ..	1	0	0	0	0	0
Inadequacy + Delinquency ..	6	1	0	1	0	2

The most characteristic abnormality of the resting record in this series was the presence of a 4-6 cycle rhythm, with a voltage slightly less than that of the dominant. The waves have a fairly smooth, regular form and are seen in bursts of three to six at a time. They are repeated at varying intervals throughout the record. In some cases, this abnormal rhythm has a voltage greater than that of the dominant and in many was equal to it. In 11 out of 51 abnormal resting records, three-cycle rhythms were seen and these, in the sense that they were more easily localizable, were comparable to Walter's delta foci in epileptics.

The importance of localization has been stressed by Walter and also by Jasper and Kerschman (1941) in their recent work on the classification of epilepsies. In 35 out of the 51 patients with abnormal resting records, it has been possible to form an opinion as to the probable site of origin of the abnormal potentials. In 25 cases, the rhythms were found in the post-central regions;

of greater interest perhaps is that in 26 the rhythms were bilaterally represented. These rhythms are not usually truly synchronous, but nearly so, and the possibility of "mirroring" by the opposite cortex of a discharge on one hemisphere cannot always be excluded. But as Jasper and Kerschman (1941) has pointed out, in such cases the false focus is usually of lower voltage and more irregular in form. This question in our series cannot at present be decided.

The question next arises as to whether there are any differences in the type of abnormality between the two main groups of patients. As Table 2 shows, while only 10 of the aggressive group had abnormal resting records *alone*, a total of 33 out of 66 had the abnormal response to hyperventilation, and 19 of these were also abnormal at rest. The comparable figures for the 38 patients of the inadequate group were 3 abnormal at rest *only*, 9 abnormal on hyperventilation, of whom 6 were also abnormal at rest. Taking now all the aggressive patients, irrespective of associated epilepsy, delinquency, or psychosis, and comparing these with all the inadequate patients, or more strictly speaking the non-aggressive, we find that of 58 dysrhythmic aggressives 14 or 24 per cent. were abnormal at rest *only*, and that of 16 dysrhythmic non-aggressives, 6 or 37 per cent. were abnormal at rest *only*. There is, therefore, the suggestion that the abnormal resting record, as a single factor, plays a greater part in the dysrhythmia of the non-aggressive group than it does in the aggressive group. As will be pointed out later, this is probably due to the greater incidence of past head injury in those inadequate patients who have positive E.E.Gs.

The abnormal response to hyperventilation has a very typical character and rarely gives rise to doubt when it is present. The 3-cycle smooth waves of high voltage appear either as a continuous series or in bursts of 3-6 at a time. Their persistence for more than 20 seconds after the cessation of hyperventilation or, as is more frequently the case, their re-occurrence after the record has started to return to normal constitutes the abnormality.

The induction of alkalosis by voluntary hyperventilation is now the classical method of producing the spike and wave complexes of petit mal. In only one instance has a series of these complexes occurred and this case was known to be epileptic. The production of a 3-cycle rhythm of high voltage has usually been regarded as the indication of an abnormally unstable cortex, and this finding has suggested a constitutional liability to the epileptic phenomenon. While it is certainly true that very many epileptics show this abnormality, Williams (1941) has demonstrated the abnormal response in a high percentage of chronic post-traumatic states. That conditions other than epilepsy can induce the abnormal response is further supported by an investigation of Hill and Sands, as yet unpublished, on the effects of induced convulsions on the hyperventilation response. The latter is definitely facilitated in some patients by a number of induced fits. It is therefore suggested that while abnormalities in the resting record may consist of a number of as yet unknown entities, the hyperventilation response is a non-specific effect, merely indicating an abnormally functioning cortex. This view is supported by the comparable percentage of hyperventilation abnormality within the total dysrhythmic groups. Thus, 77 per cent. of the total aggressive dysrhythmics, 75 per cent. of the total

inadequate dysrhythmics, and 65 per cent. of the dysrhythmic mixed cases showed the abnormality.

The examination of single traits, extracted from the total material, is of interest (Table 5); the finding that four times as many aggressive psychopaths have dysrhythmia as the controls is certainly significant. As the numbers in this further analysis are so small, no such significance can be claimed, but they further support the finding that aggressive psychopathy is associated with an abnormal E.E.G. They suggest that where epilepsy is also present the figure of 65 per cent. dysrhythmic is still higher. Where delinquency exists alone, 16 per cent. are abnormal—a figure comparable with the controls—but when aggressive delinquency is examined, half the patients have dysrhythmia. The lack of association between delinquency and dysrhythmia is further supported by the finding that its presence has no influence on the percentage dysrhythmic among inadequate psychopaths.

TABLE 5

	TOTAL	NUMBER DYSRHYTHMIC	PER CENT. ABNORMAL
AGGRESSION	93	58	62
With Epilepsy	11	9	81
Without Epilepsy	82	49	60
EPILEPSY	12	10	83
With Aggression	11	9	81
Without Aggression	1	1	—
DELINQUENCY	22	7	32
With Aggression	10	5	50
Without Aggression	12	2	16
INADEQUACY	44	14	32
With Delinquency	6	2	33
Without Delinquency	38	12	32
SEX PERVERSION	8	2	25

Within the aggressive group itself, a division between mildly aggressive, including those only aggressive to self, and severely aggressive, including those with homicidal attacks, has been made. Table 6 shows the results of such a

TABLE 6

	E.E.G. POSITIVE			TOTAL ABNORMAL	PER CENT. ABNORMAL
	REST ONLY	HYP. ONLY	REST + HYP.		
AGGRESSION (66):					
I Aggression + (49) ..	7	10	12	29	59
Aggression ++ (17) ..	3	3	6	12	70
AGGRESSION (93)*:					
II Aggression + (67) ..	11	11	18	40	59
Aggression ++ (26) ..	4	7	7	18	69

* Total group of aggressives, irrespective of epilepsy, delinquency, trauma, etc.

classification with relation to the incidence of abnormal E.E.Gs. It indicates a tendency for the more aggressive group to have a higher percentage of dysrhythmics. The second part of the Table, in which the results are given for all patients, irrespective of epilepsy, delinquency, trauma, etc., who have shown the aggressive personality disorder, indicates that this tendency is real and is associated with aggressiveness alone. The findings in this part of the Table are the same as when aggressiveness is examined alone.

The Influence of Head Injury

Williams (1941*b*) has shown that the E.E.G. may remain abnormal for many years after a head injury and has demonstrated a relationship between E.E.G. abnormalities and the severity of the injury, as judged by the length of post-traumatic amnesia. It has not been possible in this series to judge the severity of the injuries, as the majority have occurred many years previously, usually in childhood. Of the total group of 151 patients, 23 aggressive psychopaths and seven inadequate psychopaths had had head injuries. Ten of the aggressives and four of the inadequates had positive E.E.Gs. (Table 7).

TABLE 7

	TOTAL	E.E.G.		
		POSITIVE	NEGATIVE	DOUBTFUL
AGGRESSION:				
With head injury.. ..	23	10	11	2
Without head injury	63	43	15	5
INADEQUACY:				
With head injury.. ..	7	4	3	0
Without head injury	36	10	21	5

It can be seen from this Table that in the inadequate group, of the patients with probably normal E.E.Gs., 10 per cent. had head injury, while the patients with abnormal E.E.Gs., 28 per cent. had had head injury. In the aggressive group the picture is totally different. Of those patients with probably normal E.E.Gs., 39 per cent. had had head injury, while of those patients with abnormal E.E.Gs., only 19 per cent. had had head injury. The findings in the inadequate group are in accordance with one's experience that past head injury tends to produce an abnormal E.E.G. Among the aggressive group, however, one finds that head injury is less common among those with an abnormal E.E.G. than among those with a probably normal one. This suggests that the E.E.G. abnormality of aggressive persons is independent of previous head injury and that, though head injury can produce aggressiveness, and can produce dysrhythmia, these two results are probably not associated. It further suggests that dysrhythmia is commoner in the naturally aggressive psychopath than in the psychopath who is aggressive as a result of head injury.

The Influence of Epilepsy

The importance of estimating the degree to which epilepsy might increase the number of dysrhythmics among a group of aggressive psychopaths is, of course, great. Both from the clinical and from the electro-encephalographic points of view, there is plenty of evidence suggesting an association between certain forms of psychopathy and epilepsy. The episodic disturbance of behaviour, the explosive dangerousness of the aggressive psychopath who takes no thought for the consequences of his behaviour and the alleged amnesia, have led many psychiatrists to speak of an epileptoid personality. In our series, 11 patients, 8 aggressives, and 3 inadequates, had had fits in childhood which had ceased and from which they had not since suffered. The eight aggressive psychopaths had all abnormal E.E.Gs., as had two of the three inadequate cases. When fits had continued or when they were associated in time with behaviour disorder, as in 11 cases, 81 per cent. had abnormal E.E.Gs. As the figures are again small, it is impossible to claim significance, but the percentage is certainly higher than one would expect for epilepsy itself. An investigation previously made at this Unit, on about 50 psychotic epileptics, found that 69 per cent. had dysrhythmia. It is to be remembered that by far the greater number of aggressive psychopaths have never at any time had fits. Though our material includes, with large numbers of aggressive individuals only a small number of epileptics, which makes for uncertainty, yet it seems that when the two conditions occur together there is a tendency for the E.E.G. to be more frequently abnormal than when either occurs alone.

Family Histories

It has already been pointed out that Lennox, Gibbs, and Gibbs (1940) found a very high incidence of dysrhythmia among the relatives of epileptics and particularly among the parents. In this series we have classified only first-degree relatives, i.e. the parents and siblings, but it must be admitted that, as independent histories were frequently not available, the actual figures are probably not accurate. The interest and significance lie, however, in the differences within, as well as between, the two main groups. Thirty-eight per cent. of the patients of the inadequate group and 47 per cent. of the aggressive group had "positive" family histories in the widest sense in the first-degree relatives. The particular relationship which the abnormal E.E.G. has on the one hand with epilepsy and on the other with, as we have found, aggressive bad temper has led us to classify the family histories under the following headings: (1) general morbidity, which includes psychoses, psychopathic personalities, epilepsy, severe neuroses, and mental defect; (2) epileptoid states, which includes all cases of fits and bad temper; and (3) bad temper alone. Table 8 gives the percentages and the ratios between these percentages in the two groups.

TABLE 8

TYPE OF FAMILY HISTORY	AGGRESSIVES	INADEQUATES	RATIO
General morbidity	47 PER CENT.	38 PER CENT.	1.2
Epileptoid	29 "	15.5 "	1.9
Bad temper	14 "	5.2 "	2.7

In each category the aggressives show the higher incidence of abnormality. It will be seen that the ratio increases from 1·2 for general morbidity, to 1·9 for the epileptoid states generally, and to 2·7 when bad tempers alone are compared. Apart from the fact that the aggressives show a greater degree of abnormality throughout, the difference between this abnormality and that in the inadequate group becomes greatest when one narrows the investigation to the single trait—bad temper. The fact that the ratio is greatest for this trait and not for epileptoid conditions generally suggests that we are dealing with a factor which has a reality in its own right and is not merely a symptom of, say, the epileptic personality. Further, this factor is to be found among the relatives of the aggressive psychopaths nearly three times as frequently as among those of the inadequates. While none of the inadequate group admitted to suicide in the first-degree relatives, four cases were admitted by patients of the aggressive group, which suggests that aggressiveness is also to be found in the family histories of the latter. The father of another patient was confined in Broadmoor for homicide. Further evidence would probably be obtained if the investigation was extended outside the first-degree relatives. For example, one patient who was confined for homicidal attacks with alleged amnesia had a grandfather who was a murderer and later a suicide, and a paternal uncle who was also a suicide.

An examination of the E.E.Gs. of the patients whose relatives exhibit bad temper shows that while the three inadequates were negative, eight of the 13 aggressives were positive. Of the five negative cases, two were not “pure” aggressive psychopaths in the sense that one was thought to be developing a schizophrenic reaction and the other was a recidivist pilferer with aggressive crimes. Finally, there does not appear to be a greater incidence of dysrhythmia in either the aggressive or the inadequate patients whose family histories show epileptoid conditions.

Summary

Before discussing the possible explanation of the abnormal E.E.G. in psychopathic personalities, the findings may be summarized as follows. We are indebted to Dr. Eliot Slater for an examination of the results by statistical methods.

1. Forty-eight per cent. of 151 psychopathic personalities have abnormal E.E.Gs. Fifteen per cent. of 52 normal controls have abnormal E.E.Gs.
2. Sixty-five per cent. of 66 aggressive psychopaths have abnormal E.E.Gs. The more aggressive the patient the more likely is the E.E.G. to be positive. Thirty-two per cent. of 38 inadequate psychopaths have abnormal E.E.Gs.
3. Where epilepsy is associated with aggressive psychopathy, the percentage abnormal is probably much higher (82 per cent.).
4. Delinquency alone does not appear to be associated with an abnormal E.E.G.
5. Among inadequate psychopaths, head injury may account for a percentage of E.E.G. abnormality; there is no evidence that it is responsible to the same degree among aggressive psychopaths.

6. Examination of family histories shows that aggressive bad temper is found nearly three times as frequently among the first-degree relatives of aggressive psychopaths as among those of the inadequate group. Epilepsy is not found to the same extent. The presence of epileptoid conditions in the parents and siblings does not increase the chance of an abnormal E.E.G. in either group of patients.

Discussion

When it is remembered that no absolute knowledge as to the essential nature of cortical rhythms exists, it will be appreciated that attempts to evaluate the meaning of a generalized cortical disturbance, such as occurs, for example, in the abnormal hyperventilation response, must still be speculative. It is, we think, agreed that a localized discharge from a cortical area indicates impaired function of that area. With the exception of the hypnotic trance, there is no state of loss or true impairment of consciousness of clinically detectable degree, from any cause, that is not associated with changes in the E.E.G. There is some evidence that the spontaneous changes seen in the E.E.Gs. of epileptics are associated with changes in the *pH* of the fluid interchange through the cortical cell membrane. Nims, *et al.* (1940) have shown that the brains of petit mal epileptics have a deficient mechanism for dealing with the *pH* changes in the blood which result from the alkalosis of voluntary hyperventilation. It is typically in petit mal epileptics that the 3-cycle rhythms are produced on hyperventilation. It is therefore reasonable to ask whether the brains of aggressive psychopaths also show this defect of acid-base balance control. It is hoped, as a result of work now proceeding, to investigate this question.

Taking the E.E.G. findings alone, we must consider three factors known to influence cortical rhythms: (1) biochemical disturbances in the cerebral blood, (2) cerebral trauma either at birth or later, and (3) "constitutional defective" control of rhythms, such as Lennox, Gibbs, and Gibbs (1940) found proof of in epileptics.

Both hypoglycæmia and oxygen lack slow cortical rhythms, but only at the stage when consciousness is impaired. Most cases of toxic encephalitis in our experience have E.E.Gs. with a preponderance of fast frequencies. The problem of excluding cerebral trauma as the cause of E.E.G. abnormality in this series is very much more difficult. None of the abnormalities found could not have been produced by trauma. We are of the opinion, however, that the tendency for the greater number of resting records to show the bilaterally synchronous abnormality, the paroxysmal quality of the discharge, and the absence of the generalized irregularity seen so frequently in chronic post-traumatic cases is against it. Further the figures in Table 6 show that, in the aggressive psychopathic group known head injury was less common among those with abnormal E.E.Gs. than among those with normal ones. This finding is surprising in view of the common experience that head injury may produce both changes in behaviour towards aggressiveness and also changes in the E.E.G. In the inadequate group, however, trauma probably accounted for a number of the 32 per cent. dysrhythmic. It can be said, therefore, that in the total group,

1. Normal 9-10 cycle dominant rhythm to the left of the record, and a burst of 3-4 cycle rhythm to the right.
2. This record characterised by the absence of a dominant rhythm within the normal frequencies. Many abnormally fast and slow frequencies.

3. This record, taken by the multi-electrode placement technique, shows the localisation of a 4-cycle focus in the parietal region.

4. This shows the abnormal response to hyperventilation. Bursts of 3 per second rhythm of high voltage occur after the cessation of hyperventilation.
5. Shows the same record one and a half minutes later, when a further burst of abnormal rhythm appears.

and particularly in the aggressive cases, there is very little positive evidence that cerebral trauma is responsible for the E.E.G. changes.

Lastly, we have the rather vague concept of constitutional defect to examine. In view of Lennox, Gibbs, and Gibbs's work (1940), this must include epilepsy. It must again be emphasized that in the present state of knowledge the E.E.G. abnormalities in this series have no specific characters. They *could* be present following trauma, in patients with epilepsy, and possibly in the immature child's cortex. As the number of epileptics examined is so few, it cannot be said that the abnormal E.E.Gs. in these cases are definitely not associated with the epileptic tendency, but only a small number of the patients have actually had fits. The figures show that it is with aggressiveness that the E.E.G. shows the consistent abnormality. The more aggressive the patient, the more likely is the E.E.G. to be abnormal. In the relatives of aggressive persons, bad temper is found more frequently than epilepsy. It would be valuable to examine the E.E.Gs. of the relatives of aggressive persons. Apart from the psycho-analytical interpretation of inadequate psychopathy there is nothing to suggest that the latter contains an element of aggressive behaviour, nor with such cases would one associate the epileptic tendency, and yet this group had twice as many abnormal E.E.Gs. as the controls.

The idea of a cortical immaturity, with failure to reach adult control of rhythms, is in our opinion, worthy of consideration. The work of Jasper, Solomon, and Bradley (1938) emphasizes the association between bad-tempered, irritable children and abnormal E.E.Gs. Brill and Seidemann (1941), in a careful study of the E.E.Gs. of 100 normal children, show that the alpha frequency increases, and the incidence of slow activity diminishes with advancing age, the critical level for normality being reached at the age of nine and a half, though the frequency may go on increasing until 15. They also demonstrate a marked tendency for the abnormal hyperventilation response to appear in the E.E.Gs. of normal children, and state that this has no significance in childhood. In view of the similarity between the aggressive behaviour of psychopaths and the normal bad-temper response to frustration in young children on the one hand, and the similarity between the E.E.Gs. of aggressive psychopaths and those of young children on the other, the suggestion that the abnormality in the E.E.Gs. in these cases is produced by a failure of development in the central nervous system is very tempting. It fits in with our psychiatric, biological, and social conceptions of psychopathic personalities. Combining the data obtained in this investigation with those recently published by Williams (1941a), who used similar apparatus and criteria, we may construct the following table of ascending groups of abnormality.

TABLE 9

CATEGORY					ABNORMAL
Highly selected flying personnel (successfully completed training)	..	..	..	..	5 per cent. (Williams)
R.A.M.C. personnel	..	..	..	..	10 per cent. (Williams)
Mixed controls	..	..	..	..	15 per cent. (Hill & Watterson)
Mixed psychoneurotics	..	..	..	..	26 per cent. (Williams)
Inadequate psychopaths	..	..	..	..	32 per cent. (Hill & Watterson)
Aggressive psychopaths	..	..	..	..	65 per cent. (Hill & Watterson)

Examination of our own control group has led us to agree with Williams' statement that "the incidence of abnormality in a perfectly normal group of subjects may be halved by further selection upon criteria having no apparent relationship to electro-encephalographic selection." In our cases the criteria proved to be aggressiveness and irritability. On the evidence gathered by us from control material and patients, and on that obtained by other workers, one can have little doubt that an abnormal E.E.G. constitutes for its possessor a handicap in the business of biological adaptation, failure of which may show itself, as in our present series, in undesirable, asocial behaviour.

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REFERENCES

- Berger, H. (1936). *Arch. Psychiat. Nervenk.*, **104**, 678.
 Brill, N. Q., and Seidemann, H. (1941). *Amer. J. Psychiat.*, **98**, 250.
 Cohen, L. H. (1938). *J. ment. Sci.*, **84**, 284.
 Gibbs, F. A., and Gibbs, E. L. (1941). *Atlas of Electro-encephalography*. (Mass.)
 Golla, F., Graham, S., and Walter, W. G. (1937). *J. ment. Sci.*, **83**, 137.
 Gottlob, A. B. (1938a). *J. exp. Psychol.*, **22**, 67.
 Grass, A. M., Gibbs, F. A. (1938). *J. Neurophysiol.*, **1**, 521.
 Henderson, D. K. (1939). *Psychopathic States*. Chapman & Hall, London.
 Hoagland, H., Cameron, D. E., and Rubin, M. A. (1937). *Amer. J. Psychiat.*, **94**, 183.
 Jasper, H. H., and Kerschman, J. (1941). *Arch. Neurol. Paris*, **45**, 903.
 Jasper, H. H., Kerschman, J., and Elvidge, A. (1940). *Arch. Neurol. Psychiat.* (Chicago), **44**, 328.
 Jasper, H. H., Solomon, P., and Bradley, C. (1938). *Amer. J. Psychiat.*, **95**, 641.
 Kahn, E. (1931). *Psychopathic Personalities*. Yale University Press, New Haven.
 Lemere, F. (1936). *Brain*, **59**, 366.
 Lennox, W. G., Gibbs, E. L., and Gibbs, F. A. (1940). *Arch. Neurol. Psychiat.* (Chicago), **44**, 1,155.
 Lindsley, D. B., and Cutts, K. K. (1940). *Ibid.*, **44**, 1,199.
 Menninger, K. A. (1938). *Man Against Himself*. Harrap, London.
 MacMahon, J. F., and Walter, W. G. (1938). *J. ment. Sci.*, **84**, 781.
 Nims, L. F., Gibbs, E. L., Lennox, W. G., Gibbs, F. A., and Williams, D. (1940). *Arch. Neurol. Psychiat.* (Chicago), **43**, 262.
 Putnam, T. J., and Merritt, H. H. (1941). *Arch. Neurol. Psychiat.* (Chicago), **45**, 797.
 Rubin, M. A., and Cohen, L. H. (1939). *J. ment. Sci.*, **85**, 779.
 Saul, J. L., Davis, H., and Davis, P. A. (1937). *Traus. Amer. neurol. Ass.*, **63**, 167.
 — (1937). *Proc. Roy. Soc. Med.*, **30**, 33.
 Walter, W. G. (1942). *J. ment. Sci.*, **88**, 370, 110.
 Williams, D. (1941a). *J. Neurol. Psychiat.*, **4** (new series), 257.
 — (1941b). *J. Neurol. Psychiat.*, **4**, 131.