AGARDograph 110

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ADVISORY GROUP FOR AEROSPACE RESEARCH & DEVELOPMENT

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Electroencephalography in Aerospace Medicine

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ELECTROENCEPHALOGRAPHY IN AEROSPACE MEDICINE

P. M. van Wulfften Palthe

Advisory Group for Aeronautical Research and Development
Paris, France

1967

UNCLASSIFIED

AGARDograph 110

NORTH ATLANTIC TREATY ORGANIZATION

ADVISORY GROUP FOR AEROSPACE RESEARCH AND DEVELOPMENT

(ORGANISATION DU TRAITE DE L'ATLANTIQUE NORD)

ELECTROENCEPHALOGRAPHY IN AEROSPACE MEDICINE

Edited by

P.M. van Wulfften Palthe

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EDITOR'S FOREWORD

It was decided, after the meeting of the AGARD Aerospace Medical Panel held in Lisbon in September 1964, that an AGARDograph would be composed on the subject of Electroencephalography.

In a previous AGARDograph (No. 30, 1959) the collected papers of two symposia (Copenhagen 1956 and Paris 1957) were published; the subject matter was "Medical Aspects of Flight Safety (the Unexplained Aircraft Accident)". Four of the contributors were concerned, wholly or partly, with electroencephalography (Powell el al., Recond, Tompkins, and Luehrs). Comparing these earlier articles with those from Lisbon there appears to be hardly any overlapping and the variety of the contents of the present AGARDograph shows the increasing use and importance of EEG in Aerospace medicine.

This does not imply a steady growth along conventional lines but is due to a change in the direction of research by the workers in the field of electroencephalography. There has been a re-examination of the limits of normality of the EEG, of activation by drugs, of the significance of paroxysmal activity and of the value of the EEG in identifying organic conditions of the nervous system. All these points have been critically reappraised and in general it is emphasised that no decision can be reached upon an EEG tracing alone without the full medical history.

Chapter I (General) contains three contributions of general interest concerning interpretation of the EEG. The first two deal with aviation medicine and aircrew selection and the third deals with the use of the EEG in clinical medicine.

Chapter II is an extensive survey of EEG findings in aircrew and passengers. This is the most comprehensive work to date on this aspect of electroencephalography. It stresses the importance of a routine EEG at the start of a career in aviation and of serial EEGs in assessing the evaluation of individual cases of illness and accident. The abundance of cases examined makes it quite clear that the terms "abnormality" and "abnormal" must be done away with altogether and replaced by "unusual" or "peculiar" or "rare". There will remain the *pathological* EEG patterns, but even here one has to consider the age of the subject, the circumstances in which the tracing was taken, the persistence of the abnormality in the record and the presence or absence of artifacts. One is forced to the conclusion that, with the exception of spike activity and classical spike and wave patterns, all forms of bilaterally synchronous activity may be within normal limits. Focal asymmetry is much more likely to be diagnostic of local pathology.

Chapter III deals with the use of the EEG in selection; activation of the record by flicker and statistical evaluation of EEG characteristics are discussed as means of helping selection.

Because of the shortage of applicants selection is designed to exclude the manifestly unfit, instead of helping to select the best of the applicants.

Chapter IV deals with the relations between centrifugal acceleration and EEG changes. The last article is concerned with EEG changes associated with fluctuations in the level of consciousness.

Although the papers at the Lisbon meeting are not lacking in scientific value it will be seen that they are mainly concerned with practical problems in aviation medicine. This AGARDograph serves the modest purpose of giving information about some recent developments and of accepted limitations in the vast field of electroencephalography in relation to problems in aviation medicine.

P.M. van Wulfften Palthe
November 1965

AVANT-PROPOS

En 1956 (Oslo-Copenhagen) et à Paris en 1957 le Groupe Aéromédical a organisé deux symposia sur les aspects médicaux de la securité aérienne (accidents de vol inexpliqués). Dans l'AGARDographie No. 30, 1959) issu à cette occasion on rencontre quatre contributions (de Powell et coll., de Rémond, Tompkins et Luehrs) qui traitent de l'Electroencéphalographie.

Le présent AGARDographie est entièrement dédié au même sujet. Les contributions, exposées à la réunion AGARD de Lisbonne de 1964 donnent, sans beaucoup "d'overlapping", une idée du progrès en sept ans dans le domaine de l'EEG. Cette évolution ne suit pas en cours rectiligne des simples augmentations en connaissance. Plutôt on peut la considérer comme une mise au point de la valeur et des limitations de cette discipline récente qui au début était menacée d'une mythologie indéniable. Plusieurs auteurs quittent la voie conventionelle et constatent qu'une décalage d'idées s'est montrée en dispositions et dans les conceptions et les interprétations de ceux qui s'occupent de l'EEG en médecine aéronautique.

Des méthodes d'activation par des produits convulsivants sont considérées comme inutiles sinon inadmissibles; le terme "anormal" est reconnu comme équivoque avec un accent diffamatoire, la statistique se montre parfois comme guidée d'une idée préconcue. On commence une appréciation de l'EEG en soulignant - par habitude du premier jour - sa valeur primordiale pour la découverte d'une epilepsie idiopathique, pour l'oublier en route parce qu'on sait trop bien, qu'il n'en est rien et que les mérites de l'EEG résident plutôt dans d'autres domaines neurophysiologiques et pathologiques.

Toutes ces controverses sont analysées avec une critique constructive. On remplace des conceptions obsolètes par des notions nouvelles et avec des expériences approfondies mais en même temps en insiste - avec des rares exceptions - de ne pas se fier exclusivement à l'EEG et d'exiger pour une conclusion d'inaptitude une corrobation médicale ou neuropsychiatrique.

Le chapitre I (Généralités) constitue l'essentiel de l'appréciation et de la critique constructive mentionnée ci-dessus. Les premières contributions traitent du rôle de l'EEG en Médecine Aéronautique (ci-inclus la sélection du Personnel Navigant). La dernière rapporte l'expérience actuelle en médecine clinique où les experts aéromédicaux quand ils ne disposent pas d'un propre laboratoire EEG sont forcés de se former une opinion sur les rapports et sont confrontés avec des documents d'éminents spécialistes de l'electroencéphalographie qui sont moins au courant de l'aviation et ne se rendent pas toujours compte des conséquences, que leur terminologie, déjà discutable pour des malades, ne s'adapte pas forcément au groupe d'individus en bonne santé (apparente) qui vivent dans une ambiance très spéciale.

Le chapitre II donne une synthèse des données rassemblées en examens et en surveillance médicale d'un très grand nombre de toutes catégories de fonctionnaires de l'aviation. Ce travail d'une dizaine d'années sur une population tant civile que militaire en France complète les investigations de ce sens en d'autres pays sur une échelle plus modeste en proportion de leur nombre de sujets.

L'importance d'un EEG de routine pour chacun qui entre une carrière en aviation, comme un document de référence en face des "particularités" constitutionelles, des états morbides ou des accidents et incidents de vol en cours de la carrière, est mise en évidence ainsi que la valeur des Electroencéphalogrammes quand il faut se faire une idée de l'évolution (progressive ou régressive) dans un cas individuel.

Quand on remplace l'usage du mot "anormal" par une terminologie plus nuancée il est tout de même évident qu'il existe des tracés franchement *pathologiques*. Néanmoins, avant de poser un tel diagnostic il faut considérer l'âge du sujet, les circonstances dans lesquelles l'EEG fut pris, la constance et la reproductivité du tracé et sans doute aussi le hasard insidieux des artefacts.

Quand on rencontre des tracés avec déviations bilatéralement synchrones il ne s'agit que très rarement de Pathologie obligatoire (exception faite pour des bouffées in-interrompues de pointes ou de pointesondes). Des asymétries focales sont plus révélantes ayant une valeur localisantes.

Ce sont les leçons qu'on peut tirer du chapitre II.

Des considérations spéciales de sélection sont traitées dans le chapitre III. Les tracés sont étudiés sous l'influence de stimulation lumineuse intermittente (Flicker). Dans la deuxième contribution on trouve une indication statistique d'une différence qui paraît exister entre Pilotes et Mécaniciens de Bord en matière électroencephalo-graphique. Ici comme ailleurs la sélection, en raison d'une insufficience en nombre des candidats retient un aspect plus ou moins négatif; on peut pas choisir les meilleurs mais il faut se contenter de cribler les aspirants manifestement inaptes.

Chapitre IV: a la fin deux problèmes sont abordés expérimentalement, l'un sur l'influence des accélérations à la centrifugeuse, l'autre sur les effects de la solitude, tous deux en rapport avec des changements électroencéphalographiques.

En somme la présente AGARDographie consiste en rapports raisonnés issu de la Réunion de Lisbonne (1964) supplementés par quelques contributions en relation avec l'électroencéphalographie. Elle ne manque pas de valeur scientifique mais les exposés trouvent le point central dans leur application pratique.

Le propos modeste de cette AGARDographie n'est d'autre que de fournir des informations utiles au sujet de quelques développements récents et non moins d'insister sur le danger d'une confidence sans limites dans le vaste terrain de l'Electro-encéphalographie en évolution.

P.M. van Wulfften Palthe
Novembre 1965

PART I

GENERALITIES

RESUME

L'auteur estime que l'utilisation rationnelle de l'électroencéphalographie en médecine aéronautique consiste à effectuer des électro-encéphalogrammes systématiques sur tous les candidats aviateurs à leur arrivée dans les Forces Aériennes et à répéter ceux-ci toutes les fois que se manifestent des symptômes révélateurs de troubles des fonctions cérébrales.

Les électro-encéphalogrammes systématiques ont un triple objectif:

1. Empêcher les sujets présentant des signes épileptiques évidents d'entreprendre un stage d'entraînement à la navigation aérienne.
2. Souligner toute anomalie, même mineure, révélée par le tracé électro-encéphalographique et traduisant un trouble cérébral, grâce aux comparaisons avec l'électro-encéphalogramme de référence effectué à l'arrivée du candidat à l'armée.
3. 15% des individus normaux présentent des anomalies dans leurs tracés électro-encéphalographiques. Si ces anomalies sont découvertes pour la première fois à la suite d'une affection cérébrale, on peut les attribuer à ces troubles récents. l'aviateur sera alors radié temporairement du personnel navigant jusqu'à ce que des électro-encéphalogrammes successifs montrent que l'anomalie est de nature non évolutive. En relevé électro-encéphalographique effectué au moment où le sujet commence à voler permettrait d'éviter cette erreur.

L'électro-encéphalogramme est utilisé en médecine aéronautique comme dans tout examen clinique classique, et peut constituer un instrument de valeur inestimable pour diagnostiquer une affection cérébrale; cependant, son rôle primordial, en médecine aéronautique, est de mettre en lumière les troubles de la conscience. L'auteur illustrera, par des diapositives, les divers types de troubles de conscience que l'on rencontre en médecine aéronautique.

THE USE OF THE ELECTROENCEPHALOGRAM (EEG)
IN AVIATION MEDICINE

by

Group Captain P.J.O'Connor

Central Medical Establishment
Royal Air Force

SUMMARY

I believe the correct way to use the EEG in Aviation Medicine is to make a routine recording on all aviation candidates when they join the Service and to repeat the record whenever there are symptoms which suggest disturbance of brain function.

The value of the routine tracing is three-fold:

1. It prevents men with grossly epileptic records from starting aircrew training.
2. If a minor abnormality develops in the EEG as a result of brain disorder, it is high-lighted by comparing it with the normal EEG which was made on joining.
3. 15% of normal people have abnormalities in their EEG's. If this abnormality is discovered for the first time after a brain disorder, it may be thought to be due to the recent brain disturbances. The aviator will be grounded until serial records show that the EEG abnormality is non-progressive. A tracing made when the man started flying would avoid this error.

In Aviation Medicine, the EEG is used as in ordinary clinical work and can be an invaluable tool in diagnosis of brain disease, but its paramount use in Aviation Medicine is in elucidating disturbances of consciousness. Illustrations show the various types of disturbances of consciousness which are met with in Aviation Medicine.

THE USE OF THE ELECTROENCEPHALOGRAM (EEG) IN AVIATION MEDICINE

Group Captain P.J.O'Connor

The EEG is used in Aviation Medicine in the same way and for the same reasons as in clinical practice. It is an investigation which gives information about disturbances of brain structure and function. As a diagnostic tool it has two advantages: it is free from risk to life and it does not hurt the patient. The main indication for using the EEG in Aviation Medicine is in the diagnosis of disturbance of consciousness, whereas in clinical medicine the search for brain disease is equally important.

I believe the best way to use the EEG in Aviation Medicine is to do a routine tracing on all aircrew cadets as part of the medical examination on enlistment and a further record whenever symptoms arise which point to disturbance of the brain.

The routine EEG helps in three ways:-

1. It stops men with grossly epileptic tracings from starting flying training.
2. It heightens the accuracy of EEG diagnosis and
3. It tells which of the EEG abnormalities, found after a brain disturbance, were present before the illness.

I will give examples of the three ways in which this routine EEG helps. The first EEG history is of a pupil who had passed his aircrew Medical Examination and Selection Test and had joined the Initial Flying Training School. The tracings show that his brain was extremely sensitive to flicker; in successive examinations photo stimulation produced grand mal fits. Although this man had never had a fit before in his life, the response to photic stimulation recalled to him how he had occasionally felt on cross-country races through woods in sunlight; on one occasion when he was driving his car along a tree-lined road he had to stop because of a similar feeling. But for the routine EEG this man would have started flying, although his chances of having a fit were excessive. He was grounded.

The second way a routine tracing on enlistment helps is by highlighting minor abnormalities which develop in the EEG during illness. A Navigator (G.K.M.) developed what he called a stammer in times of emotional stress. When lecturing he would suddenly feel odd and repeat a word as in stammering - e.g. he would say "stop, stop, stop, stop" - then his speech would become normal and he was able to continue his lecture. When this symptom was not cured by speech therapy and hypnosis, an EEG was done; this showed a slow wave abnormality in the left temporal region (Fig.1). Much greater weight was given to this abnormality because his EEG was normal when he started training (Fig.2). Treatment with anticonvulsants abolished the attacks and afforded further indication that they were due to epilepsy.

Figure 3 shows an unimpressive abnormality from the EEG of a pilot (J.T.) whose only symptom was a quite sudden mild dysphasia. A previous normal record highlights this abnormality. He had a small left temporal lobe abscess which was successfully treated by surgery.

A third way a routine tracing helps is by identifying EEG abnormalities, found during an illness, which were present beforehand and are not related to the current brain disturbance. Figure 4 shows a paroxysmal disturbance, found after a head injury to this area, arising focally in the right post-central region. I would normally have stopped this man flying for 3-6 months and repeated the EEG to see if the abnormality cleared or at least was non-progressive. Because I had a pre-injury record showing the same abnormality (Fig. 5), I could discount the significance of this EEG and avoid wasting six months of this highly paid pilot's productive flying.

The cost of a routine EEG for aircrew is calculated as follows. A whole-time EEG Consultant can read 2,500 tracings in a year if these are for the most part normal tracings. He is paid £3,500 annually, so that each report costs (£3,500)/2,500, which is £1.8s.0d. A Technician in the R.A.F. does 1,300 EEGs in a working year. His salary is £1,000 so that the cost of each EEG in Technician's time is (£1,000)/1,300 or 17s.0d. Typist's time for typing the report is 3s.0d. EEG paper costs 1s.6d. An EEG machine costs £2,000 and its life is about ten years: in this time it will make 13,000 recordings, each of which cost (£2,000)/13,000 or 3s.6d. Thus the total cost of each EEG is £2.13s.0d., i.e. almost £3. The cost of training a pilot is £100,000 so that £3 is a small price to pay for insuring against some loss of aircrew time due to sickness.

The paramount value of the EEG in Aviation Medicine is in the diagnosis of disturbance of consciousness. Pilots are still employed in aeroplanes instead of "black boxes" because the alert human brain can interpret a wider range of signals than any computer of similar size and weight. For this reason aviators who are subject to disturbances of consciousness are unfit for all aircrew duties.

The common causes of disturbances of consciousness in aircrew, in my experience, are as follows:

1. Syncope.
2. Epilepsy.
3. Excess gravitational force (G).
4. Lack of oxygen.
5. Carbon monoxide poisoning.
6. Hypoglycaemia.
7. Decompression sickness.
8. Sudden cerebral catastrophes (subarachnoid haemorrhage, stroke, severe vertigo and concussion).
9. Psychological disorders (fear states, severe pain as in barotrauma and bends, excessive air-sickness and hyperventilation).

Syncope can usually be diagnosed by the onset, in a setting conducive to hypotension, of an aura of faintness lasting half a minute or longer, with pallor and sweating. In contrast, epilepsy may occur in any setting: the aura, if there is one, is usually reckoned in seconds only and the onset of unconsciousness is sudden: pallor is rare in epilepsy and cyanosis common: observed tonic and clonic phases, incontinence and post-ictal confusion followed by headache, all typify the epileptic attack. In classical cases distinction between syncope and epilepsy is easy but atypical episodes are very difficult to diagnose and it is here that a clearly epileptic EEG is of great help. In at least half of all cases of epilepsy, paroxysmal activity will be found in the resting EEG or after activation by hyperventilation: more sophisticated investigations, e.g. sleep records, sphenoidal tracing and photic stimulation will show paroxysmal activity in at least 90% of epileptics.

The diagnosis of epilepsy is a very serious one in Aviation Medicine, as it makes an aviator permanently unfit for all aircrew duty. The diagnosis is a clinical one, which can only be made after weighing all the evidence available. Apart from the EEG all the evidence available to the clinician about the episode of unconsciousness is hearsay from the patient and observers. The interictal paroxysmal EEG is the only objective sign of epilepsy when the patient comes for examination. But just as glycosuria can be due to causes other than diabetes, so a paroxysmal EEG can occur in men who have never had a fit and it must always be interpreted along with the clinical history. It is in the atypical case that the epileptic EEG is such a help, as shown by the following case.

P.G.C. was an experienced senior pilot. He had overslept and jumped out of bed, when he eventually awakened, because he was late for duty. Within seconds of assuming the erect position he fell, struck his head and was observed to convulse. Because he was a tall, thin, asthenic man, and because he had just assumed the upright position while his skin vessels were still dilated due to sleep, the setting suggested syncope and I made a diagnosis of a simple faint causing a fit. Figure 6 shows that his EEG is mildly epileptic. This prompted further questioning which elicited a history of previously noted phenomena and the man was grounded. Six months later he had a frankly epileptic grand mal fit.

Unconsciousness due to excess G is usually diagnosed by the setting in which the attack occurs. Tolerance of G may vary from time to time with the state of physical and psychological health, but is usually constant for each man. An EEG done while the man is in the centrifuge shows objectively at which force of gravity he loses consciousness: a non-epileptic EEG in normal G conditions lends weight to the diagnosis.

Oxygen lack and carbon monoxide excess are routinely considered in all cases of unconsciousness in the air. The diagnosis is usually reached by finding a technical fault in the oxygen supply or in the aircraft or by a raised carboxyhaemoglobin level. Carbon monoxide poisoning may cause convulsions and a normal EEG after recovery helps to show the fit was due to a non-recurring cause, i.e. CO intoxication.

Hypoglycaemia occurs while the man is fasting: the onset is gradual with sweating and faintness: blood sugar is less than 50 mgm% during an attack: giving sugar corrects the symptoms. The EEG becomes diffusely abnormal during attacks and this is also corrected by raising the blood sugar level.

Decompression sickness should be considered when a disturbance of consciousness occurs at heights in excess of 25,000 feet. Pains in joints or the abdomen may usher in the attack and there may be transient neurological symptoms such as teichopsia (battlement or zig-zag scotoma), paraesthesiae and numbness or weakness of one or more limbs. The EEG done soon after an attack may show transient focal disturbances which clear within days or weeks.

Sudden cerebral catastrophes may occur in aircrew. Diagnosis follows the usual lines of neurological practice. The EEG helps by pointing to the site of the damage and may shed some light on its nature.

Psychological disorders will, in general, be diagnosed by the history, the symptoms of neurotic illness (insomnia, irritability, headache, etc.), the absence of signs of organic disease, and this will be confirmed by finding a normal EEG. Hyperventilation often accompanies acute anxiety and adds the symptoms of hypocapnia to those of fear. Routine hyperventilation as part of the EEG examination will often reproduce the symptoms of hypocapnia which the patient will then recognise. A case in point is Flying Officer P.A., a Navigator who was found slumped over his navigation table in the air. During routine overbreathing as part of his subsequent EEG examination he said the feeling induced was what he had had in the air. Adequate psychopathology was present to cause anxiety on that trip. With psychotherapy he has continued flying and remained symptom free for the past three years.

Hysterical fugues should be associated with a normal EEG. When the EEG is abnormal it prompts one to search for an organic cause for the fugue. Master Signaller H.H. arrived in his home town to tell his wife that he had failed his Flying Control Course and might have to leave the Service. When he got off the train he claimed he could not remember his own house or where he lived, and was found wandering. The EEG (Fig.7) showed a right temporal slow wave and slowing of the alpha rhythm in this region. He had a corpus callosum glioma presenting on the right, which caused him to fail his course and to have difficulty in finding his way by memory. In this way his condition resembled an hysterical fugue.

Severe headaches may be associated with some impairment of consciousness and here the EEG may be of great help. Sqn. Ldr. W.J.P. developed a gross accentuation of migraine during a period of overwork as a Flight Commander. He said, that at the height of his headaches he was not as alert as normal. EEG (Fig.8) shows a left frontal slow wave abnormality, which was due to a very large frontal glioma.

To conclude, in neurological and psychiatric practice in the Royal Air Force, I find the EEG of crucial help in the diagnosis of disturbances of consciousness and, less frequently, of other disturbances of brain function and structure. In the R.A.F. we have used the routine EEG at the start of aircrew training for three years. It has so far paid its way by excluding one man who was extremely sensitive to stimulation by flicker, before he commenced flying training, by enabling four pilots to get back to duty after a head injury six months earlier than would otherwise have been the case, and by helping in the diagnosis of disturbances of consciousness in aircraft.

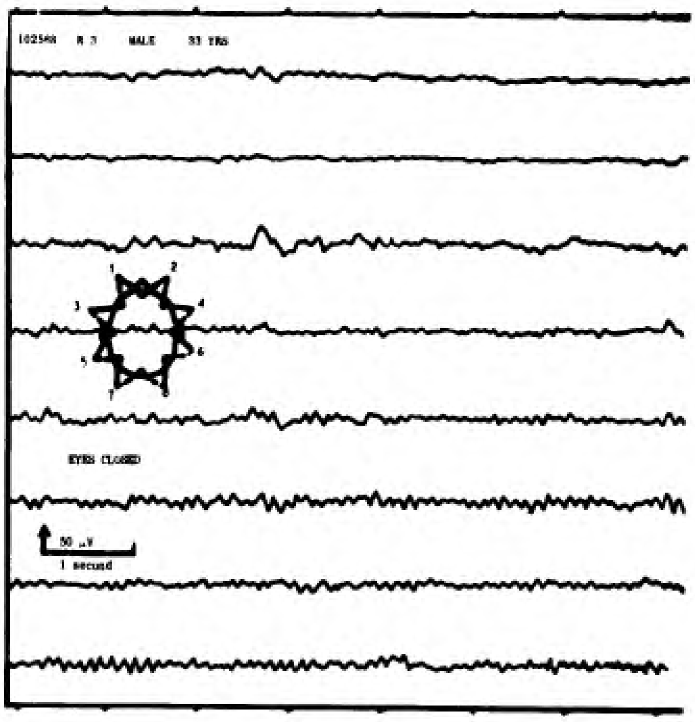

Fig. 1 G.K.M. - Left temporal lobe slow wave in channels 1, 3 and 5

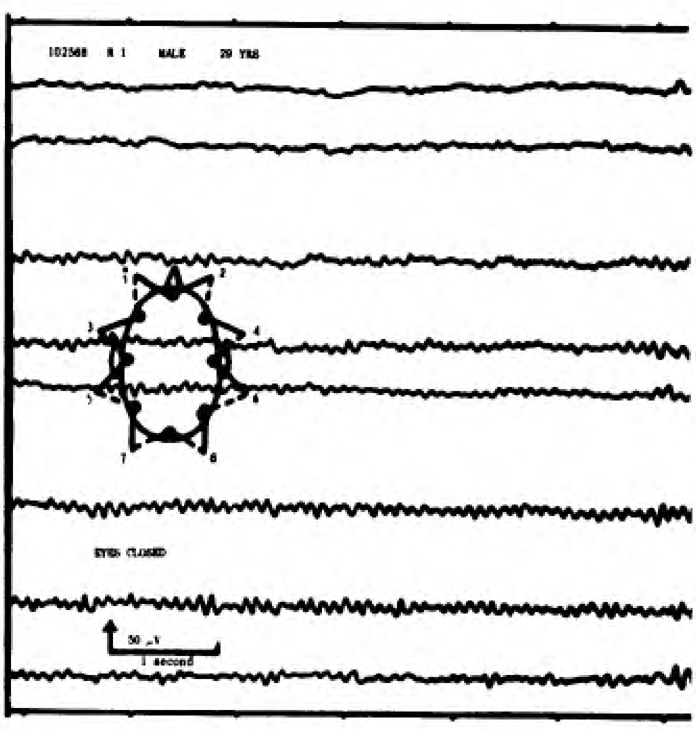

Fig. 2 G.K.M. - Normal routine EEG on enlistment

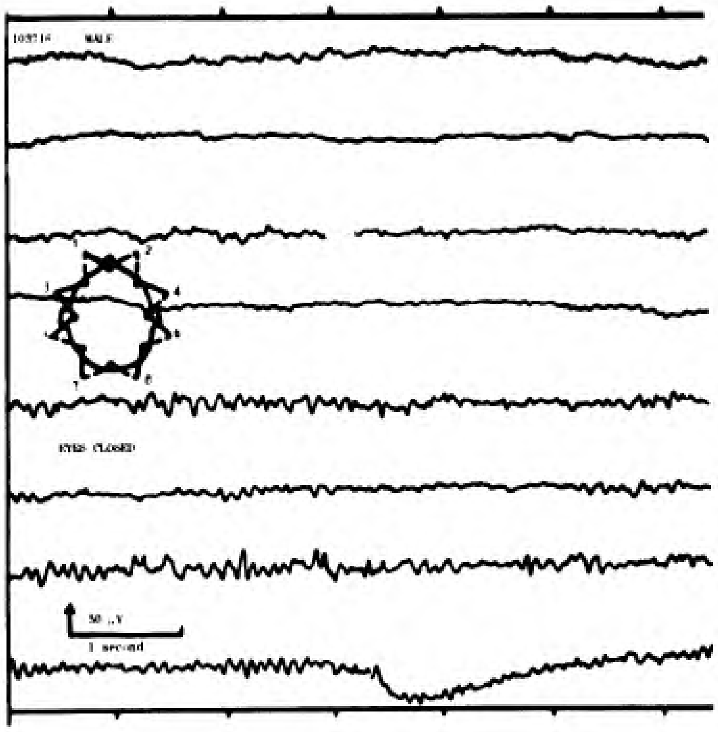

Fig.3 J.T. - Left temporal lobe abscess. (Slow wave in channels 5 and 7.)

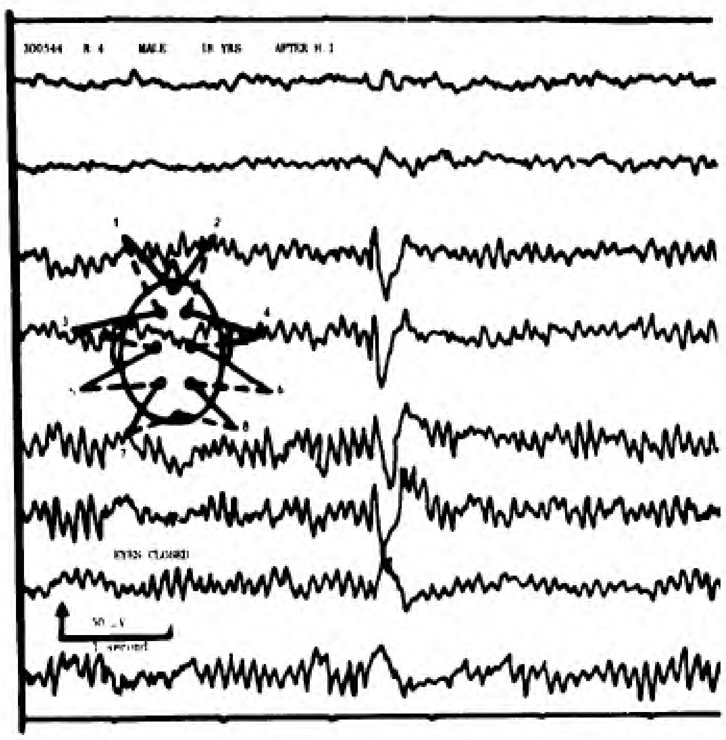

Fig.4 I.M H. - Focal disturbance right post-central region after a head injury

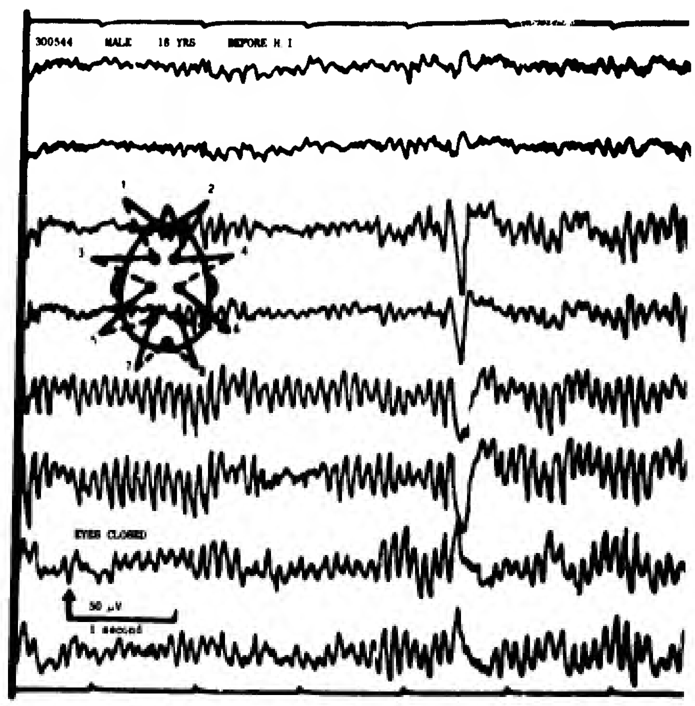

Fig.5 I.M.H. - Routine EEG on enlistment, showing the same abnormality as in Figure 4, paroxysmal disturbance arising between channels 6 and 8

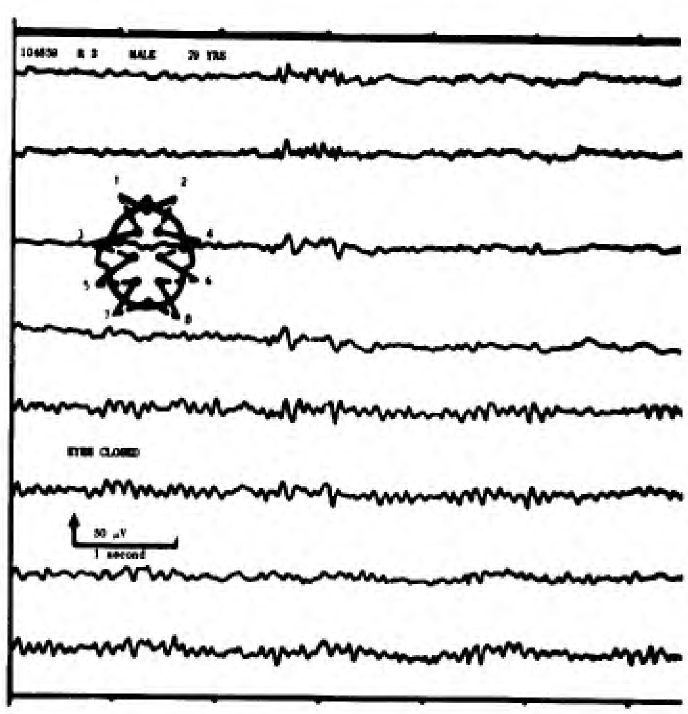

Fig.6 P.G.C. - Shows how the EEG can help in the differential diagnosis between syncope and epilepsy: note paroxysmal tendency

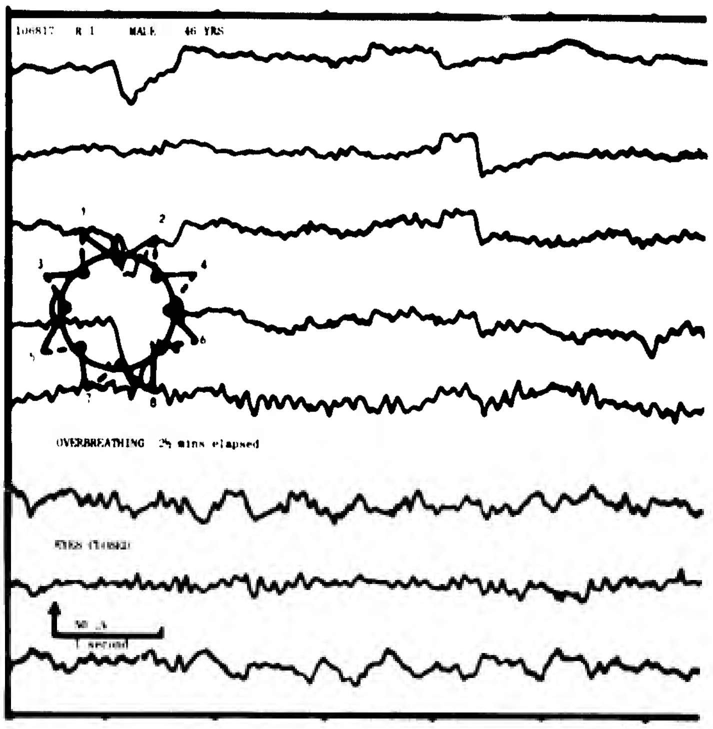

Fig.7 H.H. - Right post temporal slow wave due to a glioma

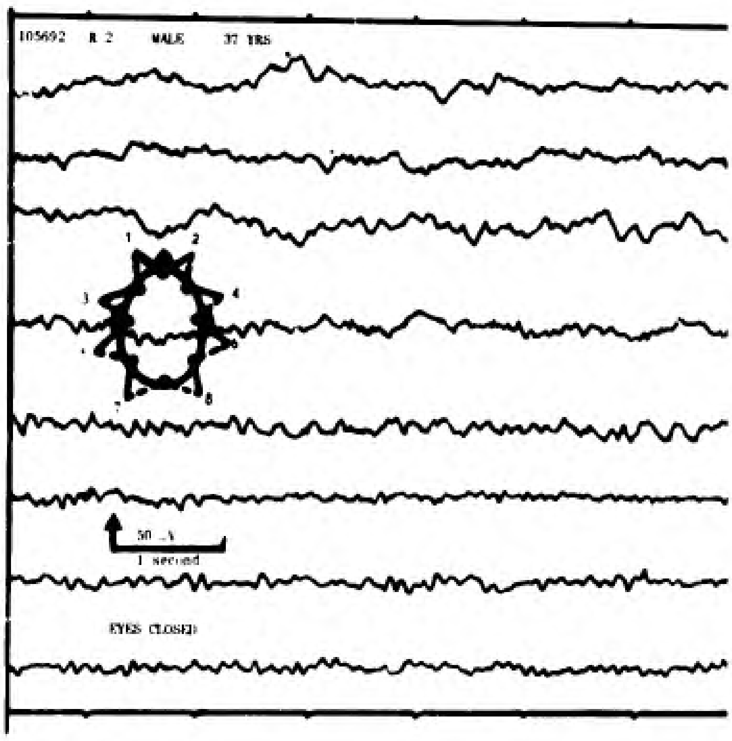

Fig.8 W.J.P. - Left frontal slow wave due to a glioma

THE USE AND ABUSE OF THE EEG IN AIRCREW SELECTION

by

John W. Scott, M.D.

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Toronto, Canada

SUMMARY

One of the objectives of the medical examination in selecting aircrew, is to recognize and reject those candidates who are liable to suffer brief periods of unconsciousness. In 1939, the electroencephalograph provided a means of detecting epilepsy, brain damage and other pathological conditions. With the establishment of the Commonwealth Air Training Scheme in Canada early in that war, the EEG was used as a screening test. The definition of normal was sufficiently narrow that an unduly large proportion of the candidates was rejected. As a result, the use of the EEG as a screening test fell into disrepute.

During the last twenty years, there has been a great increase in the experience of electroencephalographers and a much broader range of pattern is now accepted as normal. In addition, the changes that occur in a single individual with maturation are recognized. About ten years ago, the Royal Canadian Air Force instituted a long term study of the EEG and aircrew. All men accepted for training as pilots have an EEG recorded; if this shows abnormalities, the candidate is referred to a neurological consultant for assessment, who uses the EEG in its proper perspective as part of his examination. This is a long term study and attempts are being made to correlate irregularities in the EEG pattern, with subsequent success in their training program and career in the Air Force.

A second aspect in the use of EEG is to monitor cerebral insufficiency produced by various physiological stresses. This is proven a useful laboratory tool in determining the limits of stress that can be accepted in the space programs, and the cumulative effect of various stresses such as fatigue, high acceleration, hypoglyceamia, etc.

Finally, the EEG plays its usual clinical role in the assessment of pilots being returned to duty following illnesses and injuries involving the nervous system.

SOMMAIRE

L'un des objectifs des examens médicaux, dans la sélection du personnel navigant, est le dépistage et le rejet des candidats susceptibles de présenter de courtes phases d'inconscience. En 1939, l'électro-encéphalographie permit de déceler l'épilepsie, les lésions cérébrales et autres états pathologiques. Lorsque fut créé, au cours de la dernière guerre, le Programme de Formation Aérienne du Commonwealth, on eut recours à l'électro-encéphalogramme en tant que test de sélection. La définition des normes était si étroite qu'une proportion exagérée de candidats se trouvait rejetée et que le discrédit frappa bientôt l'usage de l'électro-encéphalogramme dans ce domaine.

Ayant acquis une expérience considérable au cours des vingt dernières années, les spécialistes de l'électro-encéphalographie rangent maintenant dans la catégorie "normale" une gamme beaucoup plus étendue de tracés. En outre, ils reconnaissent les modifications qui surviennent, avec l'âge, chez l'individu pris isolément. Il y a environ dix ans, l'Armée de l'Air Royale du Canada entreprit une étude à long terme de l'électro-encéphalogramme chez le personnel navigant. On procède à un électro-encéphalogramme de tous les sujets admis au stage de formation au pilotage; si cet électro-encéphalogramme présente des anomalies, on envoie le candidat à un neurologue pour établissement d'un diagnostic; au cours de son examen, le neurologue utilise l'électro-encéphalogramme dans une juste perspective. Il s'agit là d'une étude à long terme, et l'on s'efforce de déterminer la corrélation entre les irrégularités du tracé électro-encéphalographique et le comportement ultérieur du candidat au cours de son stage de formation et de sa carrière dans l'Armée de l'Air.

On a recours, d'autre part, à l'électro-encéphalographie pour définir les insuffisances cérébrales causées par divers stress physiologiques. L'électro-encéphalogramme s'est en effet révélé un instrument utile dans la détermination des limites acceptables de stress pour les programmes spatiaux, et de l'effet cumulatif de divers stress tels que la fatigue, les fortes accélérations, l'hypoglycémie, etc.

Enfin, l'électro-encéphalogramme est utilisé, dans son rôle clinique habituel, pour déterminer si un pilote, à la suite d'une affection ou de blessures ayant atteint son système nerveux, est apte à reprendre son service.

THE USE AND ABUSE OF THE EEG IN AIRCREW SELECTION

John W. Scott, M.D.

It is now 35 years since Hans Berger published the first reports of Electroencephalography[1]. He was a psychiatrist and he hoped to use the EEG as a means of classifying psychiatric disorders. At first Berger's work was distrusted since it could not be repeated with animals. However, in 1934 Adrian and Matthews[2] conclusively demonstrated that the "Berger rhythm" arose from the cerebral cortex near the occipital pole. Not only did they confirm Berger's observations but proceeded to describe in detail the characteristics, the blocking and photic driving of the alpha rhythm, and included a human electrocorticogram as supporting evidence. Its clinical value was soon appreciated and, following the publication of the papers by Gibbs, Davis and Lennox[3] on the EEG in epilepsy and by Grey Walter[4] on tumor localization it was used extensively.

The first wave of enthusiasm created the impression that the diagnostic problems and classification of the epilepsies had been solved. All that was needed to give a definitive answer was to examine the EEG; the history and physical findings were unimportant. Before long confusing cases were reported and conveniently forgotten, but at the outbreak of hostilities in 1939 the EEG appeared to offer the most reliable method of identifying epileptics, potential epileptics and other cerebral malfunctions that could endanger an aircraft. The success in the organic field led observers to believe that the psychiatric field could also be conquered and that an EEG could identify the accident-prone individual and the emotionally unsuitable aircrew candidate. This belief was supported by Berger's original work among psychiatric patients. Consequently, in the early years of the war several studies in Canada, Great Britain, and the United States were undertaken to establish EEG criteria for accepting or rejecting candidates.

At first, since there was no reliable data, it was assumed that even minor irregularity in the EEG pattern should be considered abnormal and would exclude the candidate. At this time the Empire Air Training Program was established in Canada, and pilots from all parts of the British Commonwealth received their initial flying training in Canada from the Royal Canadian Air Force. All new entry aircrew had an EEG recorded and only very minor variations from the normal were accepted. As a result a large proportion of the candidates were rejected. This caused considerable furore throughout the Commonwealth, for it was known that the incidence of epilepsy in the population is about 0.5% while the so called "abnormal" patterns were found in almost 20% of recruits. With the rejection of one in five of otherwise suitable candidates the value of the EEG as a screening procedure was questioned and the EEG thrown into disrepute.

At the same time programs were instituted in Canada, Great Britain and the United States, to extend Berger's original work in correlating EEG patterns with clinical psychological and psychiatric disorders and to correlate the patterns with the pilot's success and achievements. Although each group worked independently, there was close liaison and cross-checking of results. The names of almost all the pioneers of electroencephalography appear on the reports - Adrian[5], Brazier[6], both Davises[7], Forbes[7], both Gibbs[8], Goodwin[9], Schwab[6], Thorner[8], Williams[10], etc., yet the results were disappointing, for the patterns seen are not specific and do not correlate with the undesirable personality traits. As a result, by the end of 1942 the use of the EEG as a selection procedure was discontinued.

Meanwhile there was a growing body of clinical experience with the EEG. When used in its proper context as part of the Neurological Examination, it was found to be of value in determining the aetiology of unexplained periods of unconsciousness. The identification and localization of organic lesions such as tumours, scars and abcesses, proved rewarding and accurate and the EEG became established as a reliable diagnostic tool, although the interpretation remained entirely empirical. In spite of the vast number of records from psychiatric patients, the EEG has not proved to be a useful diagnostic or prognostic procedure for assessing emotional disturbances of mentally ill patients. In spite of this, the routine EEG examinations of patients in mental hospitals is valuable, for it identifies those patients who have organic cerebral lesions.

As the art matured, electroencephalographers began to recognise the value and the limitations of their technique. The changes of the patterns that result from the maturation of the individual were studied, classified and comprehended, while the variations between normal individuals, as well as the variation of the pattern seen in the same person from month to month, were recognised. The abnormal patterns produced by neoplasm, trauma and infection were also identified and confirmed by pathological studies. The further classification of the epilepsies was undertaken and it was recognised that some paroxysmal patterns occur in persons who never have seizures.

The electroencephalogram is a graph plotting voltage changes, as observed at the scalp surface as ordinate with time as the abscissa. This is analysed visually, looking for the regularity, frequency and voltage of the waves, the symmetry of the record and the presence and area of origin of wave forms or frequencies that are considered abnormal. The recognition of abnormal patterns depends upon the accumulated experience of electroencephalographers in correlating EEG patterns with the clinical and pathological findings. There are differences in the pattern observed from the various parts of the head; from a single area the pattern is not repetitive but is constantly changing. In making a record all areas of the scalp must be adequately explored. A total recording time of at least 20 minutes is desirable and simple activation procedures such as three minutes of hyperventilation and photic stimulation with a stroboscope should be included. At present very little of the total information in the tracing is utilised but, in spite of the special analytical techniques that have been devised such as frequency analysis, auto and cross correlograms, toposcopes, etc., visual analysis continues to be the most useful routine method. Computer analysis should be possible, but so far it has proved cheaper and more convenient to train an electroencephalographer than to design and program a computer. I think that even the most cynical critic will admit that the electroencephalogram is invariably correct; however I must admit the electroencephalographer frequently fails to interpret the tracing correctly. To which it should be added that an EEG cannot be adequately interpreted "in vacuo" but must be seen in its proper perspective in the whole clinical setting. For this reason a discussion by the clinician and the electroencephalographer of each individual case is most valuable.

In spite of their failure in the past most electroencephalographers believe that the EEG will ultimately be of some value in selecting aircrew, and in most NATO countries there are research programs in progress and routine EEG's are part of the selection routine for new aircrew.

In Canada an EEG is part of the joining routine for all new entry aircrew[11]. The records are classified into six pattern types, (I) is normal in the strictest sense, (II) shows occasional random irregularities and (III) shows a minor instability to hyperventilation that is abolished by glucose. These three categories would be called Normal in routine civilian clinical work. Category (IV) shows minor diffuse irregularity with hyperventilation not abolished by glucose and (V) has paroxysmal patterns. These two would be borderline in clinical parlance. Category (VI) includes all abnormalities, focal or paroxysmal or merely a diffuse dysrhythmia. It is not a linear scale, nor is pattern (V) any more abnormal than pattern type (IV). Any recruit with an abnormal EEG that is pattern type (VI) must be assessed by a neurological consultant who will consider not only the EEG but also the relevant history and physical findings in determining his fitness to fly. In addition to providing an initial screening, these records will be used in an attempt to correlate EEG pattern types with the successful careers in the Air Force.

It is hoped that such an EEG screening routine excludes those men who are liable to have unconscious episodes while flying. These episodes may be either syncopal or epileptic in nature, but either can cause a fatal accident. For discussion purposes an epileptic attack can be considered as originating within the brain itself, and consists of abnormal activity of the neurones. A syncopal attack is the cessation of cerebral activity produced by cerebral anoxia, caused either by circulatory collapse or from inadequate supply of respiratory oxygen. The separation of syncope and epilepsy may be little more than an academic exercise, for each produces a period of reduced consciousness which is the dangerous feature. Some individuals during a syncopal attack have convulsive jerks, so that it may be difficult to distinguish the two groups.

The geneticists believe that epilepsy is produced by the interaction of factors from several genes. There is a continuous series of individuals ranging from the severe epileptic, having several seizures a day, to the completely normal individual who never has a seizure throughout his whole life regardless of the provocation. Consequently the distinction between normal and epileptic is arbitrary but if the stress and strains of everyday life produces seizures he is considered to be epileptic. The cause of the seizures it not known and there may be several contributing factors. Hyperventilation and photic stimulation are used routinely in recording EEG's. Hypoglycaemia, fatigue and disturbances of water balance lead to the occurrence of fits. There is an interaction of these various factors, and mild cerebral anoxia may trigger a seizure in the presence of other factors[12]. The figures show EEG's obtained from an experienced fighter pilot of the R.C.A.F. and recorded while in the gondola of the human centrifuge. Figure 1 shows the resting record taken in the fasting state with the blood sugar in the low normal range, Figure 2 shows the EEG during an exposure to 3.4G for 5 seconds, Figure 3 shows the effect of 3 minutes of hyperventilation and Figure 4 shows the pattern observed one hour later with the pilot subjected to 3.4G during the third minute of hyperventilation. At this time the pilot lost consciousness and had some convulsive jerks. The effect of any two of low normal blood sugar, hyperventilation, and excess G forces in the human centrifuge can be tolerated by experienced pilots, but all three together will cause loss of consciousness and sometimes convulsive jerks. If the man were given food producing a higher blood glucose level, he would be less liable to have a seizure. This observation justifies flight line and in-flight feeding of aircrews.

We found that a second three-minute period of hyperventilation[13], if repeated within half an hour of the first, was more liable to produce abnormal patterns. It is so effective that I now use a second hyperventilation routinely as part of the EEG examination in my civilian work. It does have important considerations for flying personnel for if hyperventilation occurs the man is particularly vulnerable if he should have a second period of hyperventilation during the subsequent half hour.

The EEG has established itself as an experimental tool in assessing the physiological state of the brain during stress. Sem-Jacobsen[14] has used it in studying the combined effect of fatigue and high G forces in the Norwegian Air Force and the EEG is one of the routine studies used in the US space program.

To summarise the EEG has proven a useful clinical tool which has a place in the detection of epilepsy and organic cerebral lesions in new entry aircrew. It does not help in identifying personality and emotional traits that produce good pilots, but it is a valuable tool for monitoring cerebral function during physiological stresses.

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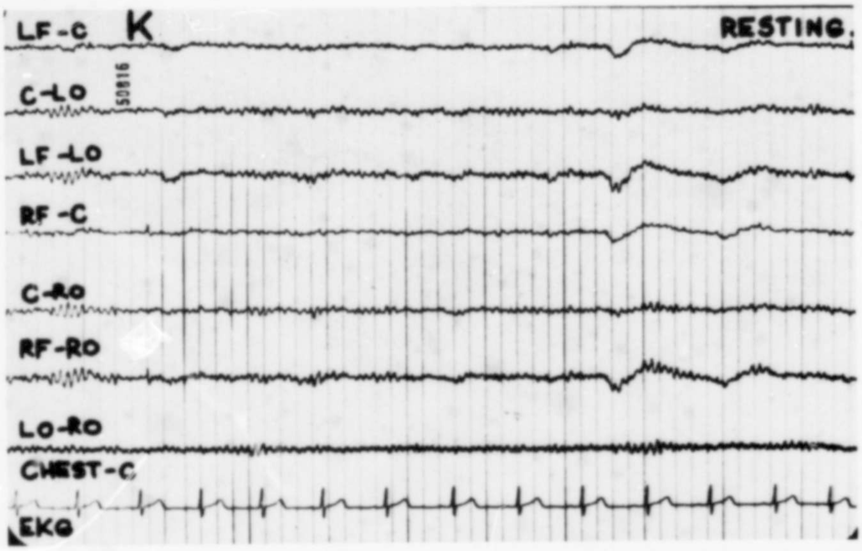

Fig. 1 Resting EEG of a fasting fighter pilot

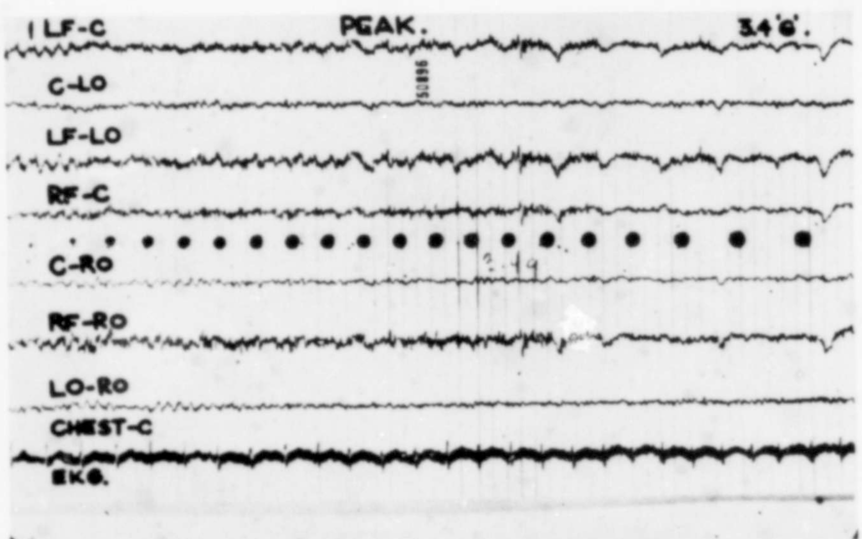

Fig. 2 EEG of the same pilot during exposure to 3.4G in the human centrifuge

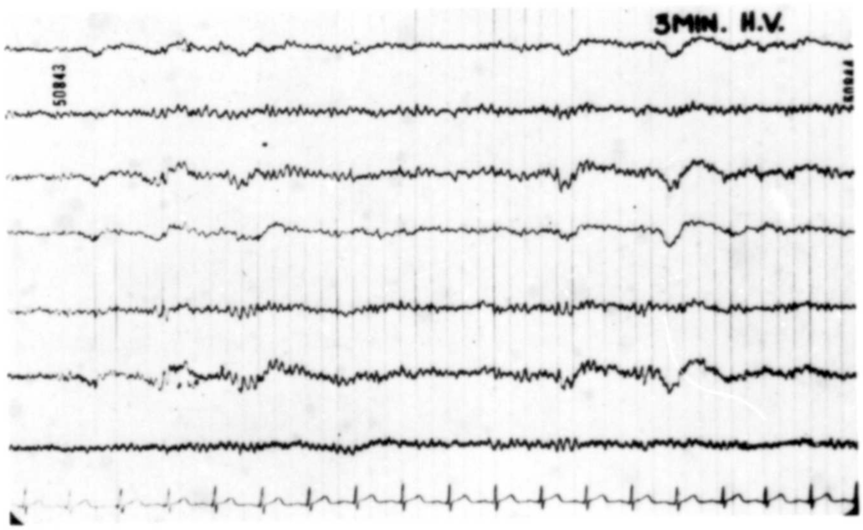

Fig. 3 EEG showing the effect of 3 minutes of hyperventilation in the same pilot

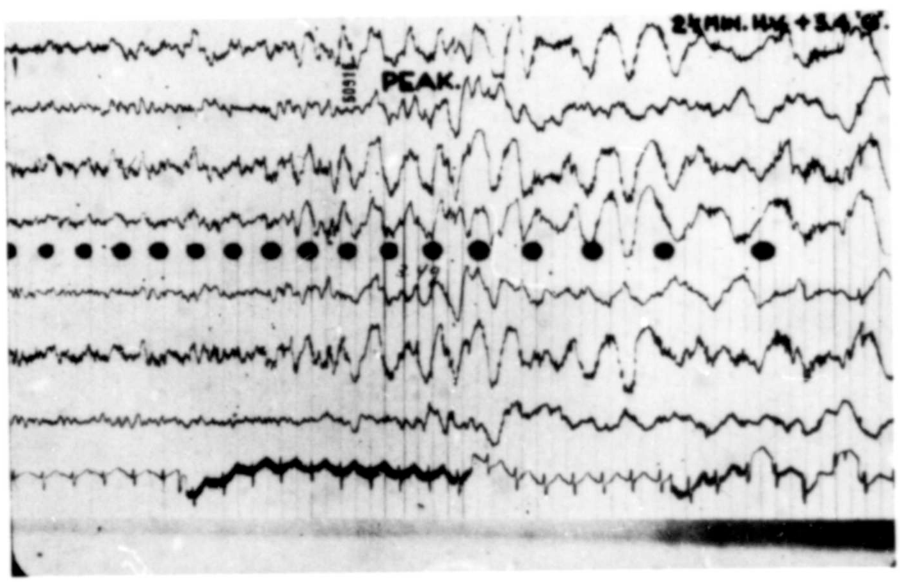

Fig. 4 EEG of the same fasting pilot one hour later showing the disorganisation produced by 3.4G during the third minute of hyperventilation

THE USE AND ABUSE OF ELECTROENCEPHALOGRAPHY IN CLINICAL MEDICINE

by

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SUMMARY

There is a serious need to find a middle course between blind acceptance of the EEG as a routine investigation, and the attitude summarised by dismissing an EEG department as "another waste-paper store". Change will be difficult while every doctor expects his epileptic patients' problems to be solved by the EEG, and every patient demands it. Under such demands few electroencephalographers can claim never to have written such futilities as "the record is compatible with epilepsy", well knowing that this applies to every record ever taken. The established clinical uses are in the fields of neurosurgery, neurology, and internal medicine, with comparatively little relevance to psychiatry. It must be accepted that the direct clinical applications, while definite enough, are far more restricted than was at first hoped; at the same time, the technique is still a valuable experimental method.

Departments should not be run exclusively by over-worked neurologists with no time for experimental techniques, by psychiatrists with insufficient neurological experience, or by physiologists with no clinical experience at all. The close collaboration between physiologist and clinician is the ideal, and this would greatly add to the efficiency, purpose, and meaning of EEG departments. Shortage of suitably trained staff would inevitably lead to a reduction in the number of such departments - an event that might be supported with equanimity.

SOMMAIRE

Il y a un besoin sérieux de prendre un parti moyen entre une acceptation intégrale de la valeur de l'EEG comme moyen d'investigation courant et le rejet total de l'EEG comme: "un entrepôt de vieux papiers". Ces points de vue opposés seront difficiles à s'harmoniser tant que la plupart des médecins croient que l'EEG puisse résoudre tous les problèmes de l'épilepsie et tous les malades le demandent. Dans ces circonstances il est rare de trouver parmi les Electo-encéphalographistes ceux qui n'ont jamais écrit une absurdité telle que: "Cette EEG est compatible avec l'Epilepsie", sachant bien qu'on peut dire cela de tous les tracés sans aucune exception. Les usages cliniques établis sont dans les domaines de la neurologie, la neurochirurgie et la médecine interne, mais relativement rare au sujet de la psychiatrie. Il faut admettre que les applications directes au terrain clinique, quoique assez nettes, sont beaucoup plus limitées qu'on avait espéré; néanmoins la technique EEG comme méthode expérimentale retient toute sa valeur.

Le service de l'EEG ne doit être contrôle ni par un neurologue surmené à qui manque le temps pour des recherches expérimentales, ni par un psychiatre sans assez d'expérience en neurologie, ni par un physiologue ignorant la pratique médicale. L'idéal, c'est la colloboration intime entre physiologues et cliniciens ce qui augmenterait considérablement le bon fonctionnement et la signification des laboratoires EEG. Insuffisance de personnel instruit reduira forcément le nombre de ces services; peut-être on pourrait bien supporter cet évènement avec sérénité!

THE USE AND ABUSE OF ELECTROENCEPHALOGRAPHY IN CLINICAL MEDICINE*

W. B. Matthews

".... the empirical approach to the subject has failed" – J.D.N.Hill†

"migraine?" – recent request for EEG

These two quotations summarize the extraordinary contrast between expert opinion and common clinical practice in this country. When it first became known that the electrical activity of the brain could be recorded from the scalp, it was naturally hoped that information comparable to that provided by the electrocardiogram might be obtained – that is to say information on the functioning of the brain of both theoretical and of immediate practical value. Before these assumptions could be verified "departments" of electroencephalography (EEG), usually precariously staffed, spread thick and fast throughout the country; and increasing thousands of recordings were made every year. Apart from wasting time, space, and money, deluding the medical profession and the general populace, and debasing scientific methods of thought, no great harm resulted from this premature expansion because the investigation was at least painless and safe. This was too good to last. If the electrical activity that struggles through the coverings of the brain to the surface does not provide the information required it must be made to do so; it must be "activated". If the surface of the scalp is an insufficient area for investigation, the area must be extended by electrodes implanted strategically and painfully beneath the temporal lobes. "Activation" involves the injection of convulsant drugs or, much more dangerously, thiopentone. These measures may indeed sometimes provide information necessary for the welfare of the patient or the advancement of knowledge. But it is the increasing use of a general anaesthetic, with a specific and by no means negligible depressant action on respiration, as a routine measure, when no such information can be hoped for that has prompted me to write this article.

SCOPE OF THE EEG

The EEG may be used as an experimental method or as an aid to clinical medicine. It is common knowledge that in this country it is mainly used by those with no training in neurophysiology and often insufficient experience of clinical neurology. There are fortunate exceptions, but the general result is that little experimental work is done and a great volume of often ludicrously inapposite reports are written, painfully

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† Hill, J.D.N., *Proc. Soc. Med.*, 1957-50.899.

misleading to those who believe them, and discrediting the technique in the eyes of many to whom it might be useful. I shall say nothing about the experimental approach except that to continue the empirical method by estimating the proportion of "abnormal" records in patients with some specific disease, can now seldom be accepted as a useful investigation. There is much to be learnt from the study of evoked potentials, conditioned responses, and depth electrodes, but such methods are beyond the scope and interest of most departments.

As a clinical tool the EEG suffers from certain inescapable disadvantages. In contrast to an investigation of known clinical value, such as the serum-calcium, there is no accepted normal range. The grossest "abnormalities" may sometimes be found in the records of those entirely free from any neuropsychiatric disorder. With one possible exception, there are not abnormalities specific for any one disease or disturbance of function which are comparable with, for example, the electrocardiogram in heart-block. It is at once obvious that the EEG, if it is to have a place at all, must be used quite differently from the familiar methods of clinical pathology. Unfortunately, so apparently complex is the technique, so imposing are the yards of paper covered with signals from the very seat of reason itself, and so profound is the mystique that surrounds their production, that the uninstructed clinician has come to demand not less but more precise information than can be obtained from a simple blood-count. I propose to describe the questions commonly asked of the EEG and the extent to which they can be answered.

1. Is the Patient an Epileptic?

Although there is no *a priori* reason why the EEG, in those subject to recurring fits, should show any disturbance except during a fit, it was at first hoped that this question might be reliably answered. Diagnostic difficulties had assumed particular importance in the period immediately preceding the universal availability of the EEG because "blackouts" had been used as a favourite means of evading the more arduous forms of military service. In a proportion of epileptics, particularly children, the inter-seizure record will contain abnormalities: spike-and-wave complexes, spikes, and other paroxysmal disturbances. These are not specific for epilepsy, although they are vastly more common in those who have had fits than in those who have not. The discovery of a temporal-spike focus in an adult with attacks of possible clouding of consciousness, or of spike-and-wave discharges in a child with possible petit mal, will, at least, greatly influence the diagnosis. I have found, however, that in the great majority of patients referred there is not the slightest doubt of the diagnosis of epilepsy, and this can in no way be affected by the result of the EEG. There seems to be some reluctance to accept that the patient who has had recurrent epileptic fits for no obvious reason has some form of epilepsy, and that the clinical history is a far more assured guide than the EEG. If the diagnosis is in doubt, the EEG will rarely contain any striking abnormality. Such abnormalities may be produced by the injection of convulsant drugs, but these drugs also act as convulsants in those who have never had a fit.

2. Why has the Patient had Epileptic Fits?

This is, of course, a question of great theoretical and practical importance, embracing many considerations beyond the scope of the EEG. In the present restricted context, the immediate practical help we might demand of the EEG is the demonstration that the fits are caused by a focal lesion potentially, at any rate, amenable to surgery or, which is almost as useful, the positive statement that no such cause is present. In certain circumstances these answers can be obtained. Thus a delta focus may be a valuable indication of a cerebral tumour, and the discovery of 3 per second spike-and-wave activity is good evidence of idiopathic epilepsy. The practical value of such findings is, however, less than might be supposed.

Epilepsy in children may be caused by brain damage or it may be idiopathic, but only very rarely is it due to a tumour of the hemisphere. I can only recall a single child in whom the EEG demonstrate a tumour as the cause of epilepsy, in the absence of clinical features which clearly demanded investigation. The demonstration of idiopathic epilepsy may, however, be useful in abating surgical enthusiasm.

One of the classical problems of clinical medicine is that of the patient who presents with fits for the first time in adult life. It is known that a cerebral tumour will be present in a small proportion only of such patients, but the recognition of this group presents formidable difficulties. The EEG will sometimes provide valuable information; and, in particular, it may be the only localising evidence of a frontal tumour. This alone is a sufficient reason for a routine EEG in all such patients. In the great majority, however, if there are no localising clinical features, there will be no definite abnormality in the EEG, even in those in whom a tumour subsequently declares itself. By the time the clinical evidence is sufficient to warrant carotid angiography the EEG is usually also clearly abnormal. The discovery of a delta focus, or its development in serial records in a patient who continues to have symptoms, is the most important contribution of the EEG to the practical management of the problem of epilepsy presenting in adult life. The investigation of lesser abnormalities, not substantiated by clinical evidence, is unrewarding, and a normal record is quite valueless.

3. What Type of Fit is the Patient Having?

Here the practical value lies in the distinction between petit mal and temporal-lobe fits. Even if full clinical details are available, this distinction is not always easy and the decision will influence treatment. The demonstration of a spike focus will suggest that remedies specific for petit mal are unlikely to be efficacious, while their use may be indicated if symmetrical spike-and-wave discharges are found.

4. Is the Patient's Epilepsy Improving?

It is apparently widely believed that it can be determined from the EEG whether it is safe to stop treatment or for the patient to drive a car. This is not so. Epilepsy comprises having fits and not abnormal brain-waves. If there have been no fits for several years, it is reasonable to conclude that some improvement has occurred.

5. Is the Patient suitable for Temporal Lobectomy?

The EEG has much to contribute here, but the techniques now employed in centres where the operation is done are much more elaborate than those of an ordinary department. The consistent finding, in routine recordings, of a unilateral temporal-spike focus, in a patient with intractable epilepsy, is at least a useful starting-point. No purpose is served by attempting to find such a focus by activation or sphenoidal electrodes if the patient is not clinically suitable for operation.

6. Is there an Intracranial Space-occupying Lesion?

This question is often asked about patients with symptoms other than epilepsy - e.g., headache, dementia, or focal signs such as hemiplegia. The EEG nearly always contains gross but non-specific localised abnormalities in the presence of a cerebral abscess or of a subdural haematoma. An entirely normal record would be strong evidence against either condition. In all other circumstances a normal record excludes nothing. Slight asymmetries may sometimes be highly significant, but to determine which are important and which are apparently meaningless is usually impossible from the appearance of the record alone. If they are consistent with the clinical features their relevance is more assured, but these minor abnormalities are always slender and unreliable evidence. The delta focus is a much stronger indication of localised disease, but every electroencephalographer will have had the embarrassing experience of finding such a focus on the wrong side, in a patient with a supratentorial tumour.

The EEG never directly indicates a pathological process. A delta focus may be caused by a tumour or abscess, an infarct or haemorrhage, a plaque of disseminated sclerosis, or many other lesions. A change in the pattern may be of considerable diagnostic value. The clinical distinction between cerebral infarction and tumour is not always easy. The disappearance, in serial records, of a well-developed delta focus is strong evidence in favour of infarction.

While the EEG may provide useful and occasionally vital information, the great advances in neuroradiology have rendered unnecessary the earlier attempts at extreme accuracy of electrical localisation. This is fortunate because the results were often misleading. The abnormal waves are not produced by the tumour but by damaged brain in the vicinity. As the brain appears to function by conveying electrical impulses from one point to another, it is not surprising that abnormal activity can sometimes be recorded from areas which are relatively remote from their site of origin.

7. Is the Patient Insane?

The EEG cannot answer this question. Advanced dementia from any cause is often accompanied by EEG changes, but these are not specific and they are certainly not required to establish the diagnosis of dementia. The psychoses do not specifically distort the EEG. Since Hill and Watterson* reported that a higher proportion of patients with psychopathic personality had temporal theta foci than could be found in the normal population, such patients are often referred for EEG. If this was to confirm or extend the original interesting observation it would be admirable; but this is not so. The reasoning has somehow become inverted, and it is now often believed that the discovery of such foci in some way strengthens the diagnosis. A little thought will show that the personality will remain either psychopathic or normal whatever the result of the EEG, and that temporal theta foci are compatible with either.

These are the commonest questions asked of the electroencephalographer, but they by no means exhaust the use or usefulness of the technique. The EEG can contribute to the assessment of recovery from head injury, the control of cerebral symptoms from hepatic failure, the control of hypothermia, the detection of intra-cerebral haematomata in subarachnoid haemorrhage, and of recurrence of excised cerebral tumours. In nearly all instances serial records are essential and no dangerous or unpleasant methods of activation are required.

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* Hill, D., Watterson, D. *J. Neurol. Psychiat.* Vol.5, p 47, 1942.

PART II

ELECTROENCEPHALOGRAPHY OF LARGE POPULATIONS OF FUNCTIONARIES AND ASPIRANTS IN CIVIL AND MILITARY ORGANISATIONS

MEANING AND VALUE OF ELECTROENCEPHALOGRAPHY IN AERONAUTICAL MEDICINE

by

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SUMMARY

The authors describe the outstanding results of ten years' experience covering 8,000 electroencephalographic recordings made on subjects belonging to the Air France Cabin Staff. The criteria of the conventional EEG tracings were analysed by the use of a longitudinal classification distinguishing the "evolutive tracings" and the "stationary tracings". In about a hundred monographic studies spread over a period of several years, evolutive correlations appear between the psycho-affective and psychophysiological factors, and the electrical disturbances. Major EEG anomalies (generalised paroxysms, left temporal foci, photo-sensitivity) are transitorily observed in the course of anxiety neurosis, neurotic depressions and psychosomatic syndromes. The extent of disorders in the hypnotic function is shown in the genesis of the occasional disturbances in EEG tracings with normal subjects.

Certain electrical patterns observed on recruitment tracings, seem to have an anticipatory value, a predictive significance necessitating an exploration of the personality by a psychiatric examination.

The importance of the EEG with subjects presenting antecedents of cranial traumatisms without clinical after-effects, is also stressed.

SOMMAIRE

Les auteurs rapportent les résultats saillants d'une expérience de dix ans portant sur 8000 enregistrements électroencéphalographiques pratiqués chez des sujets du Personnel Navigant Commercial de la Compagnie Air France. Les critères de l'EEG conventionnelle ne sont pas transposables tels quels en médecine aéronautique. L'analyse des tracés EEG a été pratiquée en utilisant une classification longitudinale distinguant des "tracés evolutifs" et des "tracés stationnaires". Dans une centaine d'études monographiques étagées sur plusieurs années, des corrélations évolutives apparaissent entre les facteurs psycho-affectifs et psychophysiologiques et les perturbations électriques. Des anomalies EEG majeures (paroxysmes généralisés, foyers temporaux gauches, photo-sensibilités) s'observent transitoirement au cours des névroses d'angoisse, des dépressions névrotiques et des syndrômes psychosomatiques. L'importance des troubles de la fonction hypnique est mise en évidence dans la genèse des perturbations accasionnelles des tracés EEG chez les sujets normaux.

Certaines figures électriques observées sur les tracés d'embauche semblent avoir une valeur de prévision, une signification prédictive, nécessitant une exploration de la personnalité par un examen psychiatrique.

L'importance de l'EEG chez les sujets présentant des antécédents de traumatismes crâniens sans séquelles cliniques est également soulignée.

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MEANING AND VALUE OF ELECTROENCEPHALOGRAPHY IN AERONAUTICAL MEDICINE*

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1. INTRODUCTION

The purpose of this article is to restate and clarify all the data and information provided us by the use of EEG in the sphere of aeronautics. In the course of the last fifteen years, EEG has made considerable progress and its practical applications have gradually been extended to numerous branches of medicine. The value of EEG has been confirmed by the variety and importance of the data, which it can provide, concerning the organic and functional state of the brain. It was therefore logical to introduce this technique into aeronautics for the selection and medical supervision of commercial aviation flight personnel. This is what the Air France Medical Service has been doing since 1954. This article describes the general outline of the salient results of experience, dating back ten years and covering more than 8,000 recordings.

The aim of EEG in respect of aeronautics is twofold:

To detect epilepsy and the after-effects of organic cerebral diseases which are likely to produce paroxystic dissolutions of consciousness.

To anticipate possible incidents or decompensations in apparently normal subjects, i.e. those who are well adapted and who show no general major neuropsychiatric or pathological symptoms or antecedents.

Ten years ago the detection of epilepsy and the after-effects of traumatic cerebral damages were the main preoccupation of A.Robert and M.B.Dell, who promoted the introduction of the systematic EEG for Air France flight personnel. As we pointed out in several earlier articles, the advantages offered by electroencephalographic data have been gradually extended to the study of psychological and psychiatric factors. It was the study of the significance of infraclinical anomalies which led us to carry out research on the evolutive correlations between EEG data and psychological data.

At the outset there were, in fact, complex problems connected with the interpretation of the EEG tracings of flight personnel and these remained practically insoluble for several years. As we shall see, these have now been overcome for the most part.

The main problem raised by the use of EEG in aeronautics is linked to the frequency of infraclinical anomalies observed in apparently normal subjects.

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The numerical analysis of the 8,000 records in our files reveals a considerable proportion of disturbed electric tracings, being about 35 for every 100 if we adopt the criteria of conventional EEG provided by epileptology and neurology. 35% of our subjects produced electric patterns, on at least one recording, which are conventionally symptomatic of epilepsy or organic lesions of the nervous system (generalized paroxysms, foci, pathological reactions to the stroboscope). These patterns usually appear in the course of activation tests: hyperpnea, photic stimulation, hypoxia. They are observed in subjects with no neurological or comitial antecedents.

This striking and, in many ways, illogical inconformity raised several questions:

1. Is EEG, which has given proof of its value in neurology, an absurd technique when used with normal subjects?
2. Must the limits of normality such as is understood by most electroencephalographists throughout the world be extended?
3. Do the so-called pathological patterns, observed with apparently normal subjects, have any special psychological significance, or do they, on the contrary, constitute biological epiphenomena which we must disregard or forgo interpreting?
4. Finally, can we satisfy ourselves with a purely negative definition of normality? Are the absence of neurological or comitial antecedents and a negative medical examination, sufficient to define a normal man?

2. METHODS

In order to reply to these questions we focused our efforts on two essential points:

the limits of normality,

the significance of EEG and the analysis of its value as an index of lesional or comitial organicity.

As a result of a retroactive study of the files, the analysis of individual observations and periodic electric tracings spread out over several years, we introduced new parameters into the discussion. Besides neurological factors, interpretation of the EEG must be taken into account:

the psychological structure of the subject, features of his personality and biography,

general physiological and pathological factors of extra-neurological origin but with possible repercussions on the nervous system and psychic life.

The results and hypotheses of the work we are now presenting were obtained by using a method different to the conventional electro-clinical confrontation used in pathology. We carried out longitudinal studies of individual observations focused on research for evolutive correlations.

We made longitudinal monographs spread out over several years by studying, simultaneously, the morphologic and dynamic evolution of EEG tracings and the concomitant psychological and psychopathological factors.

Emphasis was placed on the study of personality and psychological and psychopathological factors. An attempt was made to detect neurotic traits, antecedents of periods of depression and psychosomatic disorders through a clinical talk.

Finally, we prepared a Longitudinal Classification of EEG Tracings based on the different types of evolution observed, which we substituted for the conventional morphological classification describing conventional patterns considered as normal or pathological in themselves. We distinguished between two types of tracings:

Evolutive tracings, which change at a given moment in a certain psychological or pathological context.

Stationary tracings, which follow an identical pattern in the course of recordings repeated over several years.

The work we have already published led us to a conclusion which might form the basis of this article: the criteria of conventional EEG cannot be transposed as such to aviation medicine and, more generally, to the study of a population of normal subjects. Examined in an evolutive perspective, the infraclinical disturbances observed in young subjects with no neurological or comitial antecedents are related to the psychological, psychophysiological and psychiatric factors in the majority of cases[10,11,12,13,16].

3. RESULTS

Several new notions appear in the analysis of these electroclinical monographs spread out over several years and treated in connection with an evolutive classification of electric tracings.

3.1 The Major, Transistory, Reversible Disturbances

These are most often contemporaneous with an episode of depression or neurosis (90% of our observations). They are observed in neurotic depressions, anxiety neuroses with phobic elements and neuroses with psychosomatic disorders.

In one hundred longitudinal studies, the following observations were made from the point of view of EEG pathology:

72 left temporal foci (theta-delta, sharp-waves),

20 generalised or localised paroxysms during photic stimulation,

8 generalised paroxysms during hyperpnea.

These subjects are members of the Cabin Staff (stewardesses and stewards). They have no neurological or comitial antecedents. In all the cases evolution occurred following a stereotyped pattern, the maximum EEG disturbances coinciding with the clinical syndrome condition period. The EEG disturbance is reversible, the tracing assuming its primary aspect at the time of cure. These stereotyped evolutions produce true "Electroclinical Decompensation Syndromes" during which the maximum psychic and bioelectric disturbances occur simultaneously. We have about one hundred observations of this type and report briefly on a few of them overleaf.

Observation I (Fig. 1)

Subject: Miss S., Stewardess.

1955: at the age of 22, a focus of theta activity on the left temporal lobe (tracing at time of recruitment). No neurological or comitial antecedents. Normal psycho-affective equilibrium.

1956: episode of depression of the neurotic type: anxiety, tedium, difficulties with sleeping and nightmares; psychosomatic digestive disorders. Psychogenetic release factors.

Constitution on the EEG of a focus of left temporal sharp-waves; bitemporal paroxysms during hyperpnea.

The subject receives no drugs when the EEG tests are being carried out.

1959: depressed is cured, the EEG tracing assumes its former aspect.

1960: the EEG tracing remains stationary, while the subject is in good health and has been back at work for more than a year.

Observation II (Fig. 11)

Subject: Miss R., Stewardess.

1956: normal tracing during photic stimulation.

1959: state of depression. Difficulties with sleeping, anxiety raptus, neuropathic attacks without loss of consciousness.

Pathological responses to photic stimulation. Slow waves on occipital regions. Abnormal driving responses on the anterior cerebral regions.

1960: clinical cure; the EEG tracing becomes normal.

Observation III

Subject: Mr L., Steward.

Generalised paroxystic anomalies during hyperpnea occurring in the course of an anxiety depression with difficulties in sleeping and digestive troubles of the psychosomatic type. Resorption of anomalies after cure.

Observation IV

Subject: Miss H., Stewardess.

1955: focus of theta activities and sharp-waves at the time of recruitment. No neurological or comitial antecedents.

1956: sharper left temporal localisation. Sharp-waves focus with generalised paroxysms during hyperpnea. From the clinical point of view: anxiety depression, weeping fits, insomnia, nightmares. Family and sentimental troubles. The subject must cease working for several months.

1957: the fit of depression is cured. The EEG tracing assumes its former aspect.

1960: second fit of depression: second decompensation of the EEG tracing. Generalised paroxysms occurring during hyperpnea.

1961: the second fit of depression is cured. The EEG tracing assumes its primary aspect (left temporal focus).

In this observation made over a period of more than eight years, two decompensations of the EEG tracing were recorded, both contemporaneous with a fit of depression.

The common feature of all these observations, which exceed a hundred in number, in our material is the stereotyped character of the electroclinical observations. In all cases, psychic and bioelectric disturbances occur simultaneously. The EEG tracings assume their primary aspects at the time of cure, sometimes with a certain delay as electric disturbances may last several weeks after the clinical cure

More than 60% of these observations were made with subjects whose tra... time of recruitment showed atypic infraclinical patterns (temporal foci, p... sensitivity with bioccipital expression) whereas the candidates' psycho-aff...ive equilibrium was normal. This fact confers a predictive value, a predictive significance to certain electrical patterns.

3.2 Occasional, Transistory Disturbances

Such disturbances, of variable importance, may be observed in a single recording in different contexts.

These are theta overloads, temporal foci, or diffused paroxystic anomalies. In the psychophysiological context one finds highly varied factors as possible etiological elements:

loss of sleep or troubles with the hypnotic function linked with time alterations,

monthly periods in the case of hostesses,

absorption of psychotropic medicines (transquillisers, hypnotics, neuroleptics, amphetamins),

pathological factors (infections, fever, algic conditions),

states of physical exhaustion with difficulties in sleeping.

Of all these elements, it is the awakeness-sleep cycle alterations, which seem to play the most important part. Loss of sleep may provoke left temporal foci, very likely "functional" (Fig. 3) and also generalised sharp-wave or slow wave paroxysms. The recent work carried out by Rodin, Luby and Gottlieb[20] showed results similar to ours. They demonstrated that experimental deprivation of sleep may produce paroxysms of the comitial type in normal subjects. The disturbances they observed appeared 48 hours after lack of sleep, with certain subjects. The individuals showing these disturbances are considered as being predisposed. With them a lowering of the threshold of activation to megimide is observed.

Among stewardesses, slow wave bisynchronous paroxysms and transistory temporal foci are not exceptional during menses.

3.3 The Non-Evolutive, Disturbed EEG Tracings

These raise complex problems which have not been solved, and are still being studied in our laboratories.

They may be observed among subjects presenting character neurosis or psychopathic traits which appear in the analysis of their biographies or of their behaviour in private life. These subjects are sometimes perfectly adapted to their professional activities (stewardesses, stewards). In other cases, they concern subjects normal from both the neurological and psychiatric points of view. Temporal foci, right and then left, and generalised paroxysms are recorded alternately (Fig.4). These patterns appear most often during hyperpnea.

Besides these main aspects, several remarks may also be made with respect to our evolutive classification of the EEG tracings of Cabin Staff.

With your subjects, about 20 years of age, cerebral electro-genesis cannot have reached its final organisation as yet. Strong paroxystic reactions are not exceptional during hyperpnea. These patterns, which had initially been considered as pathological, often disappear at about the age of 25 (see Figure 6). This is progressive normalisation linked to the maturation factor.

The electric aspects of depressions and neuroses noted in psychiatric treatment are somewhat different to those observed among flight personnel. In a recent study published by C.Blanc and G.C.Lairy[6] on a group of hospitalised patients, the EEG anomalies are less spectacular and mainly concern the space organisation of alpha frequencies. These differences are no doubt explained by many factors (older subjects with serious depressions requiring hospitalising, the use of large doses of tofranil, niamide and nozinan).

On the other hand, in the neurotic states recorded in private practice on subjects treated but not hospitalised, the EEG aspects are of the same type as flight personnel cases[2].

We shall briefly report on a few observations for the sake of example.

Observation A (Fig.7)

Subject: M.D., 25 years old.

Anxiety neurosis with psychosomatic digestive disorders. Difficulties with sleeping and nightmares for several months. Anxiety reptus 48 hours before the EEG examination. Agoraphobia. Situational context: failure in recent examination. Family troubles. Neurological examination: negative. No comitial or neurological antecedents. The EEG tracing reveals sharp-waves and potentials of irritativeness together with slow waves on the left temporal lobe.

A few months later, the tracing became normal again after cure with immipramine and levomepromazine.

The neurological patterns observed in the course of neurotic states are morphologically identical to the patterns recorded in organic or comitial pathology (see Figure 8).

Table I, which is devoted to the semeiological analysis of fifty observations of neurotic states recorded in private practice, among subjects who did not belong to aeronautical personnel, stresses several important factors common to all subjects:

permanent difficulties with sleeping: insomnia and nightmares,

intense anxiety and emotional states,

neurotic structure of depression; importance of psychogenetic and conflictive factors,

permanent psychosomatic disorders (digestive, cardiac disorders and headaches).

Table II outlines various evolutive aspects of the EEG tracings of the Flight Personnel and their clinical correlations.

4. DISCUSSION

4.1 Theoretical and Practical Problems

The electropsychological, even electropsychiatric, correlations we have established, make it necessary to reconsider a certain number of conventional concepts and to restate certain of the conventional EEG criteria set up on subjects connected with neurology.

1. The notion of infraclinical, electric epilepsy, defined on the basis of exclusively electroencephalographic criteria appears as a *misconception* in our material. This concept, based on the theoretically specific significance of certain cerebral potentials (spikes, spikes and waves) does not stand up to a critical analysis of the facts. None of our many subjects with disturbed EEG tracings showed comitial accidents in the course of constant evolutions for a period of about ten years.

The concept of electric epilepsy must be limited practically exclusively to observations in which a current or previous neurological context exists (cerebral organic damages at a young age and particularly antecedents or after-effects of cranial traumatisms).

2. When an EEG tracing shows isolated electric disturbances with a negative neurological examination and with no convulsive or organic antecedents, the significance of the EEG must be discussed on the basis of references or parameters, till now ignored by the neurological EEG which had concerned itself practically exclusively with lesional or epileptic organic factors. Our studies have led us to search for these references:

on the one part, in the study on the structure of personality and

on the other part, in the analysis of extra-neurological factors with direct or indirect repercussions on the *functioning* of the nervous system or behaviour and adaptation of the individual (general physiological factors, factors linked to professional activity).

A psychological talk, even a brief one, and a balance sheet of the practical conditions of the examination (psychological, situational) are necessary for interpreting EEG data.

EEG must not be considered as a technique or a machine intended to decide between normality-pathology alternative by yes or no. The existence of electrical peculiarities in a subject should give rise to a thorough psychological study which makes it possible to set in perspective EEG data in the total psycho-biological context of the individual. When the EEG shows disturbances in a normal subject from the neurological point of view, this does not necessarily constitute an "index of lesional or comitial organicity" but, in many cases, a "neurotic index" which must be directed to exploring the personality.

3. Until now these facts have had a dual practical outcome:

a liberalisation and relaxation of EEG selection criteria,

a parallel increase in supervision leading to decisions of "controlled aptitudes", i.e. with supervision of EEG tracings every six months or every year when the atypical electric aspects constitute an absolutely isolated element in the medical file.

This attitude constitutes a point of balance between the extremes, in our opinion erroneous positions, which led some, in the past, to attach a rigid value to EEG data (the disturbances all being attributed to *infraclinical* epilepsy) and others to disclaim all value for electroencephalography.

Our personal position is founded on two theses:

the EEG disturbances in a normal neurological context are practically never comitial or organic.

They are unquestionably observed in many cases with subjects presenting neuroses or neurotic or depressive predispositions. They are therefore of significance. Subjects presenting, for example, left temporal foci, even if they prove to be perfectly normal from the psychological point of view at the time of the examination, are those who have anxiety neuroses, depressions or psychosomatic disorders with greater frequency. These subjects may be apt but they must be examined periodically.

The importance of the human factor, stressed by all authors who have considered the psychological aspects of the aeronautical vocation, compels us to be vigilantly liberal. The peculiarity of individual cases considered with comprehension must in no case lead us to disregard the safety requirements which constitute one of the objects of a Medical Department. It is in fact capital to anticipate possible incidents. The infraclinical disturbances must be subjected to periodic checks.

4. These slight alterations and rectifications, which we propose introducing into the conventional EEG criteria, will have to be completed in a few years by statistic studies impossible to carry out at present.

The EEG neurological data remain valid and continue to be applied to all cases in which there exists an antecedent or a neurological context to be elucidated. Thus with the Technical Flight Crew and the Cabin staff electroencephalography is very useful in cranial traumatisms, which are becoming increasingly frequent. The association of a skull fracture, a fit of unconsciousness or a coma with persistent electrical anomalies will be eliminatory. On the other hand, several normal EEGs with a subject who had suffered a trauma, make it possible to eliminate an organic after-effect and may produce an aptitude.

When the EEG is negative, it is also very useful in many cases of lipothymy, pseudo-vertigo, or poorly characterised indispositions, which occur during states of anxiety or neurosis. Several negative tracings eliminate the hypothesis of comitial equivalents.

5. Finally, let us make all efforts to partly re-establish a balance of concepts, which we upset for a while, to the effect that tracings corresponding to the conventional definition of normality remain, despite everything, the ones most frequently observed and that they represent more than 60% of our files (Fig.5).

4.2 Physiopathological Problems

Theoretically, the observations we have just made raise complex physio-pathological problems, which we have not yet been able to solve. By confronting bioelectric data, neurophysiological knowledge and psychiatric conceptions on neuroses, it will be possible to lay down a certain number of hypotheses.

1. The temporal foci raise the question of the part played by the reticular and rhinencephalic subcortical structures, in the genesis of certain electrical patterns, observed in the course of depressions and neuroses. We shall not consider the many studies which have, over the last fifteen years, emphasised the part played by subcortical structures in certain psychic processes (consciousness, emotion, instinctive life, memory ...). The action of these formations on cerebral electrogenesis appears to be unquestionable, as proved by the studies carried out on temporal epilepsies, but the part they play in psychic life, whether normal or pathological, raise far more delicate problems. As was shown by one of us, many arguments can be formulated about the localising subcortical psychisms[1,3,4,5]. Various theories put forth by W. Penfield and H. Jasper (centerencephalic system), P. MacLean ("Visceral brain") and L. Kubie, do not appear to be of any use in clinical psychology and psychopathology. The study of the centerencephalic system and the rhinencephalon must be based on the cerebral organisation and their function is to be examined in the context of the psycho-biological organisation of the subject and its relational forms of adaptation to reality. That is why, although temporo-rhinencephalic neurophysiological activities are reflected in temporal foci, we do not feel that we must, for all that, adopt the "rhinencephalic conception" on neurosis and depression.

More than 80% of the temporal foci which we have observed are left foci. The reason for such preferential topography is still unknown. In particular, there does *not* exist any correlation between left localisation and hemispherical predominance. They may be observed with left- as well as right-handed subjects.

The problems raised by temporal localisation are not the same when the foci are stable and when they are intermittent.

Stable foci which remain stationary and non-evolutive in the course of examinations repeated over several months or years, are most often observed among subjects whose personality presents neurotic traits.

These foci seem to reveal a certain type of psycho-biological organisation in the individual, most often contemporaneous with an episode of depression or neurosis, or disorders in behaviour. Temporarily we shall term them as "structural foci", which means that the foci show a certain psychobiological structure of which they constitute the bioelectric correlation.

In such cases, the notion of "neurotic immaturity" can hardly provide anything but a verbal explanation. It is only useful so far as segmental electroencephalography is concerned, but it cannot be accepted when the psychobiological problems raised by neuroses are considered as a whole.

As a matter of fact, despite present progress and the theoretically ever-increasing number of psychiatric conceptions, can anyone say whether neurosis must be defined as a fixation connected with immaturity, or as a regression with deficit, or even as a specific form of psychobiological organisation of the subject?

In this perspective, it appears that the conception of neuronic immaturity seems out-worn and inadequate. It implies purely verbal options on the causality of the neurophysiological disturbances of which we record the EEG correlations.

Intermittent foci could be considered as "functional foci". They are left temporal foci observed among subjects showing intense thymic and emotional disorders, with difficulty in sleeping, for instance, anxiety neurosis during depressive decompensation.

Their lability and total reversibility constitute so many arguments in favour of functional hypothesis. But in such cases, we are not yet able to say whether the foci have a causal value in the genesis of clinical disorders or, on the other hand, they represent the secondary effect of certain symptoms (emotional disorders, difficulty in sleeping and nightmares). We think that certain post-traumatic left temporal foci may show not local lesion or shock but, on the contrary, a "functional" consequence of prolonged lack of sleep, as they disappear when sleep becomes normal again after non-barbituric, pharmacological cure (levomepromazine).

All the problems remain dependent on a great number of factors. For the time being, we think that we must not supply temporal foci with a definition based on physiopathology. Only one datum appears to be firmly established: in cases of depressive or neurotic state they have no comitial or lesional significance.

2. The paroxystic activities recorded during hyperpnea or photic stimulation raise the problem of the lowering of the epileptogenous threshold. Formerly, the question was examined by the means of the photocardiazolic test. The method consists of an injection of a 5% solution of cardiazol at the rate of 1/cc every thirty seconds. It was used in particular by A. Robert and M. B. Dell, together with the SLI, only for candidates showing major disturbances. Usually the threshold of convulsion lies around 7 mg/kg. Candidates with a threshold below 4 mg/kg are considered by the authors as being inapt.

During the last few years, the question of the value of the photocardiazolic test, now no longer in use, has been raised again. As a matter of fact, the lowering of the cardiazolic threshold does not seem to have the same specific significance it had formerly. As E. Rodin, in particular, proved in 1958, there exist significant correlations between the degree of tolerance to cardiazol and certain psychological factors, namely neurotic predispositions*, anxiety and psychiatric antecedents. Epilepsy is not the only affection presenting a lowering of the threshold of activation to cardiazol.

Besides, it is not exceptional to observe differences between the EEG data of standard tracings and the results of cardiazolic activation. A disturbed EEG tracing may coincide with a paradoxal raising of the cardiazolic threshold. A lowered threshold of convulsion may also be observed among subjects with normal standard tracings. The same is true for other products which have been proposed more recently, in particular megimide. In most cases, psychological control and psychiatric examination make it possible to avoid activation tests which have the disadvantage of being extremely painful and causing anxiety among candidates on whom they are carried out.

A certain number of paroxystic anomalies, namely photosensitivity with bioccipital expression (slow-waves and waves recorded under the stroboscope when the eyes are closed) seem to have no comitial significance. We observed them among subjects presenting psychological traits of the hysterical type. Lately H. Gastaud and M. Dongier made similar observations. Any candidate showing electric tracings of this type must undergo psychiatric examination.

* and climatic influences - Editor's note

Such are the broad outlines of the results obtained from our experience with the EEG in aviation medicine. We are of the opinion that the interpretation of electrical data will have to be directed more and more to the psychological and psychophysiological sides of the individual considered as a psychophysical whole within his professional and personal context.

All the documents presented in this report concern stewardesses or stewards who agreed to have their EEG checked periodically. This subject population forms a group with particular psychological and electrical characteristics, rather different from those observed in subjects belonging to other groups, which for this reason cannot be transposed as such to the pilot population without any alterations or rectifications.

We shall shortly be publishing evolutive studies devoted to EEG evolution in terms of psycho-physiological factors on a group of pilots. For reasons beyond our control, these studies were made a later date and cannot as yet be seen in proper perspective to provide demonstrative value. They raise problems of the same type but, no doubt because of the severe clinical selection standards, the percentage of EEG disturbances is much less than in the group of stewardesses and stewards.

The problem of the utility of electroencephalography in respect of aeronautic and cosmonautic selection, does not exist at present. In our opinion this examination is of capital importance. It provides essential data which may be classified in the following order:

Cranial traumatisms, becoming increasingly frequent, most often caused by automobile accidents.

Psychoaffective disorders (neuroses, depressions, psychosomatic syndromes).

Detection of epilepsy. Epilepsy is exceptional in aviation circles but its elimination must be a fundamental preoccupation because of the catastrophic results it may produce.

With its possibilities for exploring sleep and its disorders, sensory deprivation, cerebral hypoxia, etc ..., we feel that electroencephalography should extend its sphere of application even more to aerospace medicine. Integrated within the complete psychobiological study of the subjects examined, electroencephalography should be able to provide essential particulars in the selection of pilots for supersonic aircraft and cosmonauts.

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TABLE I

Left temporal foci in neuroses and depressions without neurological or comitial context.

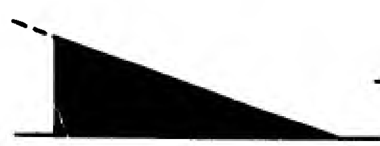
PERUSAL OF FIFTY OBSERVATIONS:

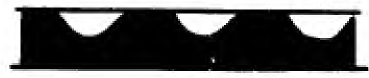
Anxiety neuroses	15
Phobic neuroses	20
Character neuroses (disequilibrium, psychopathic personalities)	10
Miscellaneous	5
(melancholy depressions 2	
neurotic hypochondry 1	
traumatism neuroses 2)	

PSYCHOPATHOLOGICAL CONTEXT	ANXIETY NEUROSES	PHOBIC NEUROSES	CHARACTER NEUROSES
Former neurotic structure personality	+ +	+ +	+ +
Anxiety	+ + +	+ + +	+ + +
Difficulties with sleeping			
Insomnia	+ + +	+ + +	+ + +
Nightmares	+	+ + + + +	+
Psychosomatic disorders	+	+	+
Depressive element	+ +	+ +	+ +
- neurotic type	+	+	+
- melancholy type	0	0	0
Conflictive context and psychogenetic factors	+	+	+
Fits of neuropathy of the convulsive type	0	0	0
Neurological or convulsive antecedents	Infantile febrile convulsions 3, Enuresis 4, former somnambulism 3		
Neurological examination	normal	normal	normal

TABLE II

Longitudinal Classification of EEG Patterns

EVOLUTIVE TRACINGS		CLINICAL EVOLUTIVE CORRELATIONS
1 - Major transistory and reversible EEG disturbances	 →	NEUROTIC DEPRESSIONS ANXIETY NEUROSIS PSYCHO-SOMATIC DISORDERS
2 - Occasional disturbances	 →	SLEEP DEPRIVATION MONTHLY PERIOD PSYCHOTROPIC DRUGS FATIGUE, PATHOLOGICAL FACTORS
3 - Regressive disturbances	 →	MATURATION CRANIAL TRAUMA ANTECEDENTS
4 - Increasing disturbances	 →	PSYCHO-AFFECTIVE FACTORS CRANIAL TRAUMA ANTECEDENTS

STATIONARY TRACINGS		
1 - Normal stationary tracings		
2 - Disturbed stationary tracings	 →	PSYCHOPATHIC PERSONALITIES NORMAL SUBJECTS X....

ABBREVIATIONS (ENGLISH-FRENCH) FOR FIGURES 1, 2, 3, 4 and 6

RF – RC	FD. RD....	Frontale droite, rolandique droite
RC – RP	RD. PD....	Rolandique droite, pariétale droite
RP – RO	PD. OD....	Pariétale droite, occipitale droite
RAT – RPT	TAD. TPD...	Temporale antérieure droite, temporale postérieure droite
FM – PCM	FM. PCM...	Frontale médiane, pré-centrale médiane
PCM – V	PCM. V.....	Pré-centrale médiane, vertex
VOM	VOM........	Vertex, occipitale médiane
LF – LC	FG. RG....	Frontale gauche, rolandique gauche
LC – LP	RG. PG....	Rolandique gauche, pariétale gauche
LP – LO	PG. OG....	Pariétale gauche, occipitale gauche
LAT – LPT	TAG. TPG...	Temporale antérieure gauche, temporale postérieure gauche
PCM – RAT	PCM. TAD...	Pré-centrale médiane, temporale antérieure droite
RAT – LAT	TAD. TAG...	Temporale antérieure droite et temporale antérieure gauche
LAT – PCM	TAG. PCM...	Temporale antérieure gauche, pré-centrale médiane
V – RMT	VTMD.......	Vertex, temporale médiane droite
RMT – LMT	TMD. TMG...	Temporale moyenne droite, temporale moyenne gauche
LMT – V	TMG. V.....	Temporale moyenne gauche, vertex
PM – RPT	PM. TPD...	Pariétale médiane, temporale postérieure droite
RPT – LP	TPD. PG....	Temporale postérieure droite, pariétale gauche
LPT – PM	TPG. PM....	Temporale postérieure gauche, pariétale médiane
OM – RO	OM. OD....	Occipitale médiane et occipitale droite
RO – LO	OD. OG....	Occipitale droite et occipitale gauche
LO – MO	OG. OM....	Occipitale gauche et occipitale médiane

ABBREVIATIONS (ENGLISH-FRENCH) AND TEXT IN FIGURES 7 and 8

RAT – V	TAD. V.....	Temporale antérieure droite, vertex
LAT – RAT	TAG. TAD...	Temporale antérieure gauche, et temporale antérieure droite
RAT – V	TAD. V.....	Temporale antérieure droite, vertex
RMT – V	TMD. V....	Temporale moyenne droite, vertex
RMT – LMT	TMD. TMG...	Temporale moyenne droite, temporale moyenne gauche
LMT – V	TMG. V.....	Temporale moyenne gauche, vertex
LPT – PM	TPG. PM....	Temporale postérieure gauche, et pariétale médiane
RPT – TM	TPD. PM....	Temporale postérieure droite, temporale médiane

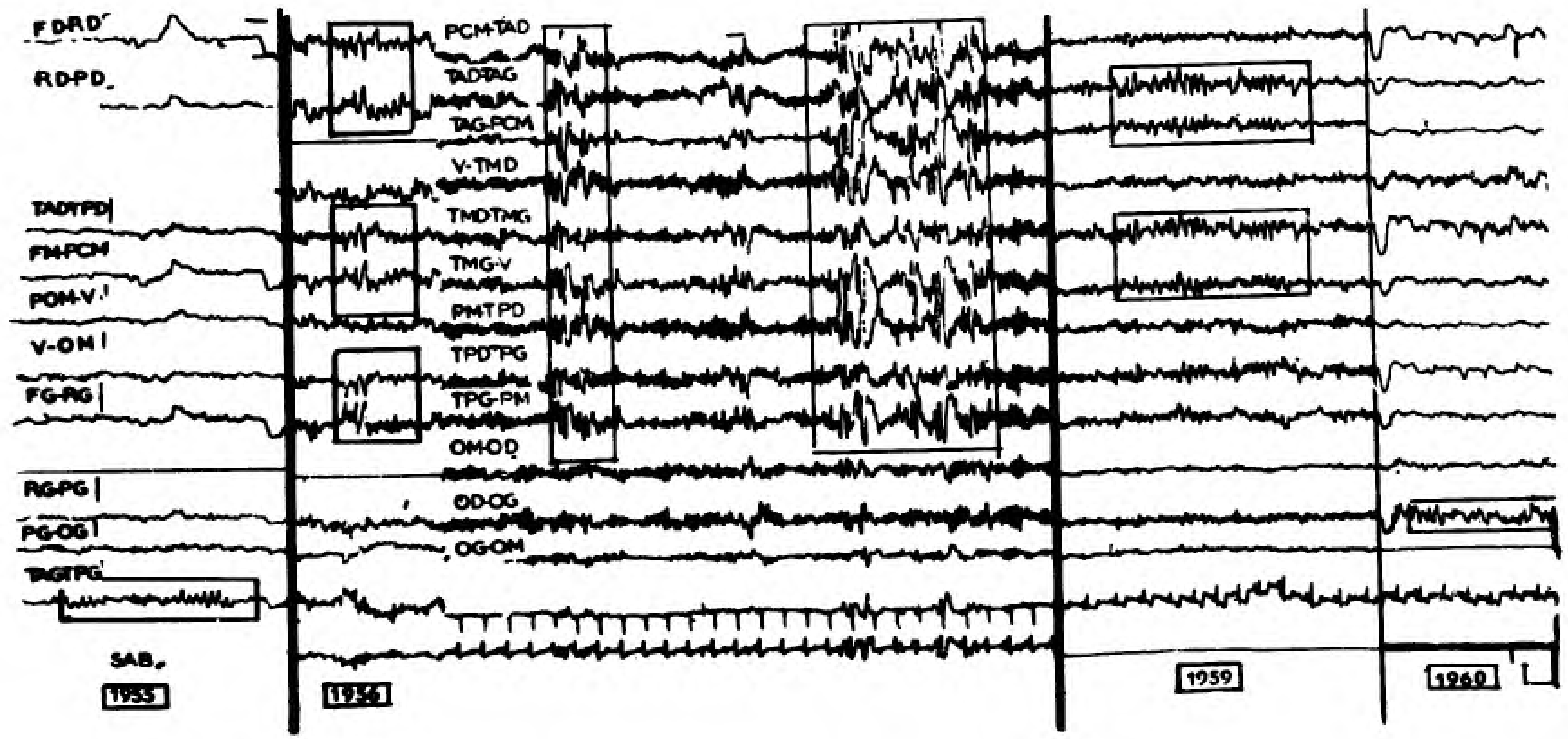


Fig. 1 Observation I. Miss S., Stewardess.
In 1956. Episode of depression of the neurotic type. Constitution on the EEG of a left temporal focus, and of bitemporal paroxysms

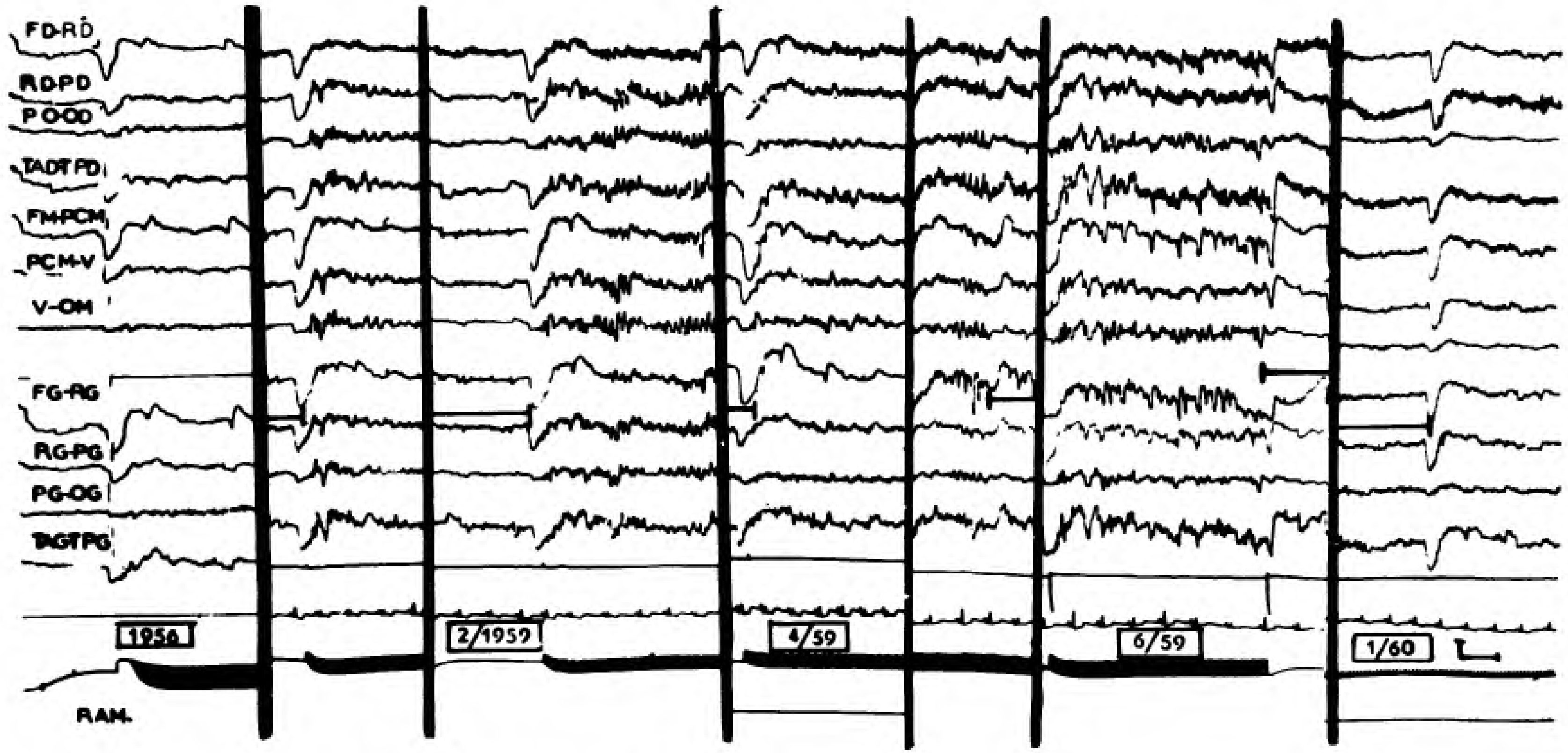


Fig. 2 Observation II. Miss R., Stewardess.
1959. Pathological responses to photic stimulation during a state of depression with neuropathic attacks

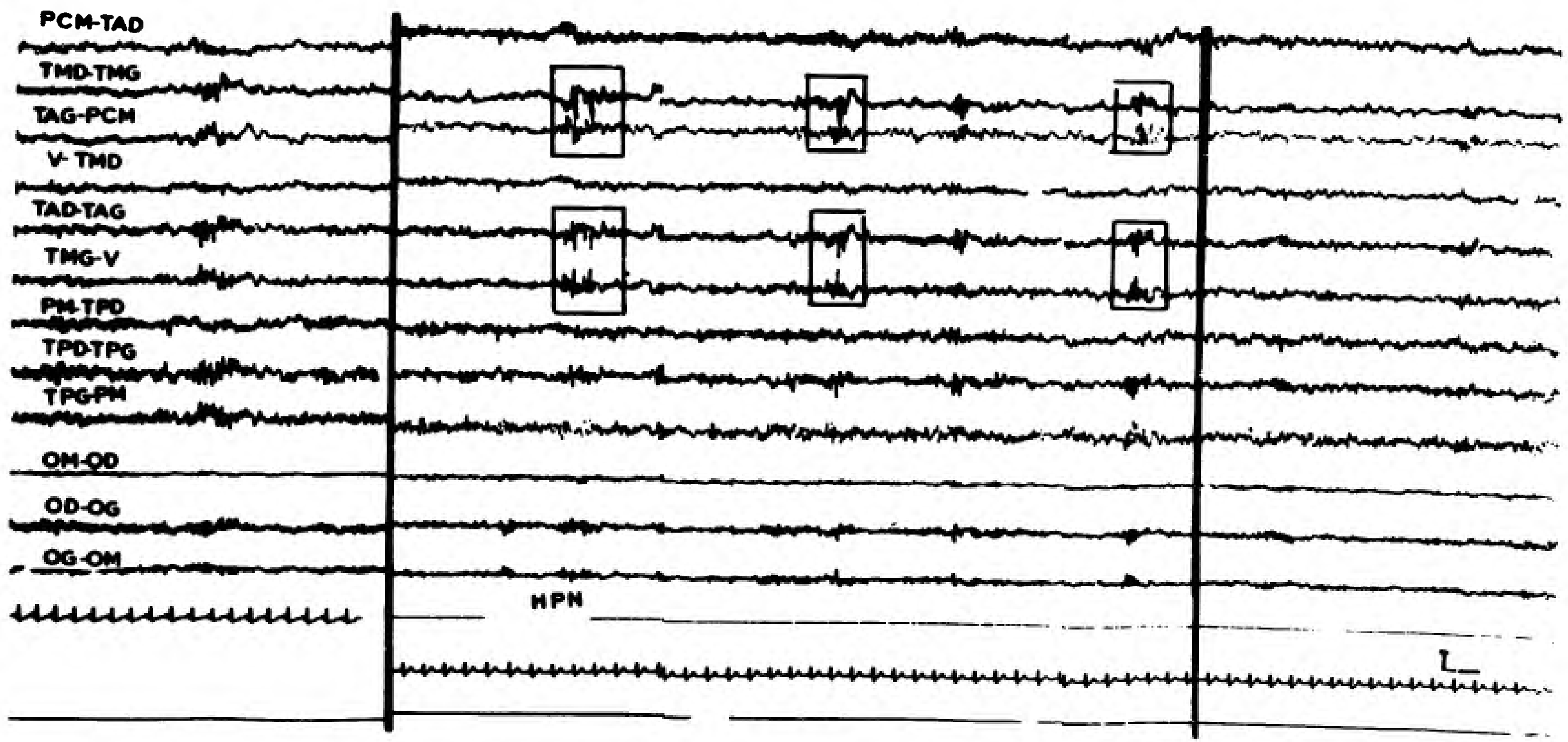


Fig. 3 Occasional transistory disturbances. Left temporal focus (spikes and theta rhythms) observed during hyperpnea (HPN in second column) after a two days sleep deprivation

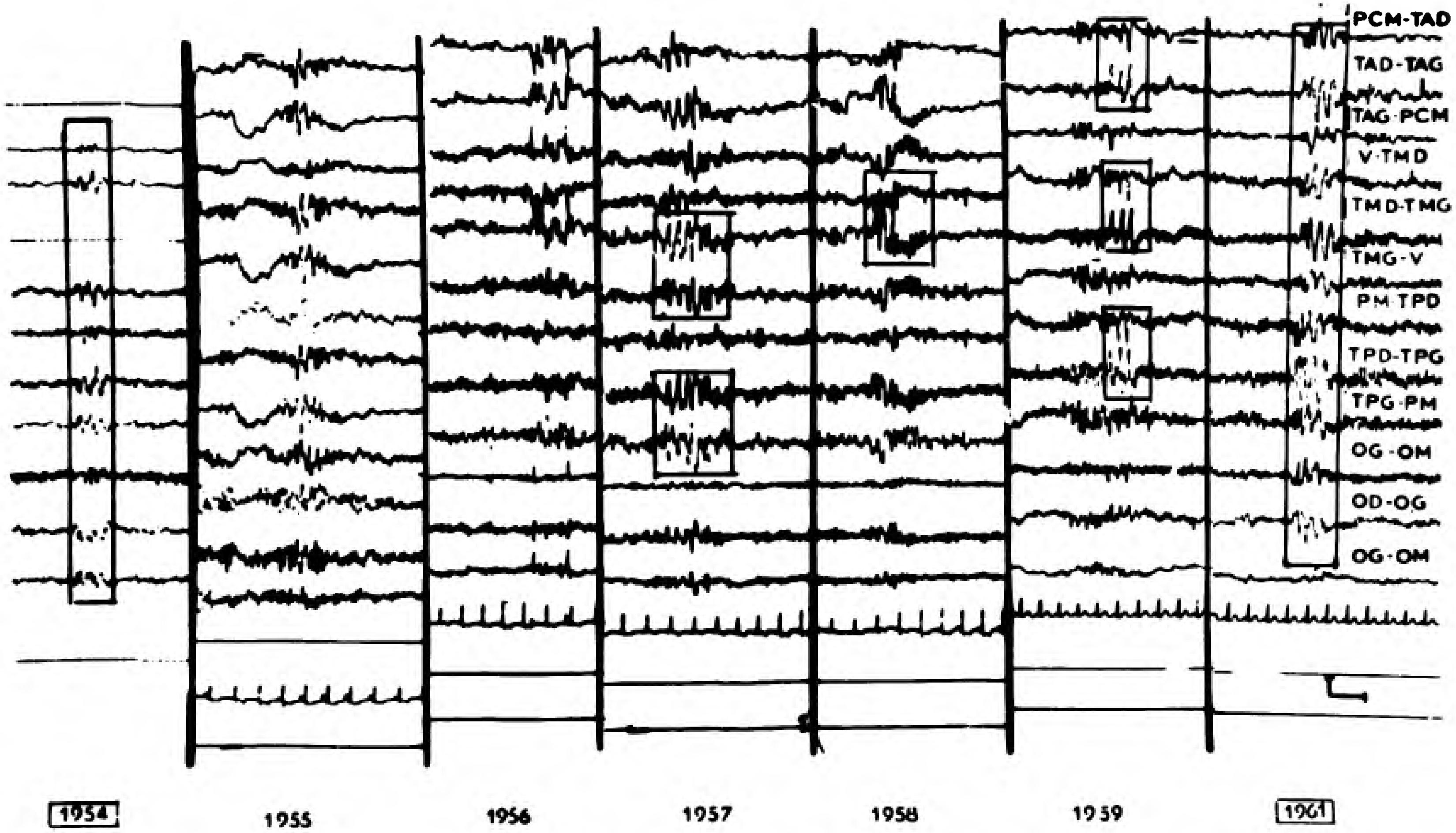


Fig. 4 Non-evolutive disturbed EEG tracing. Stewardess presenting a character neurosis. No neurological or comitial antecedents. Perfect professional adaptation

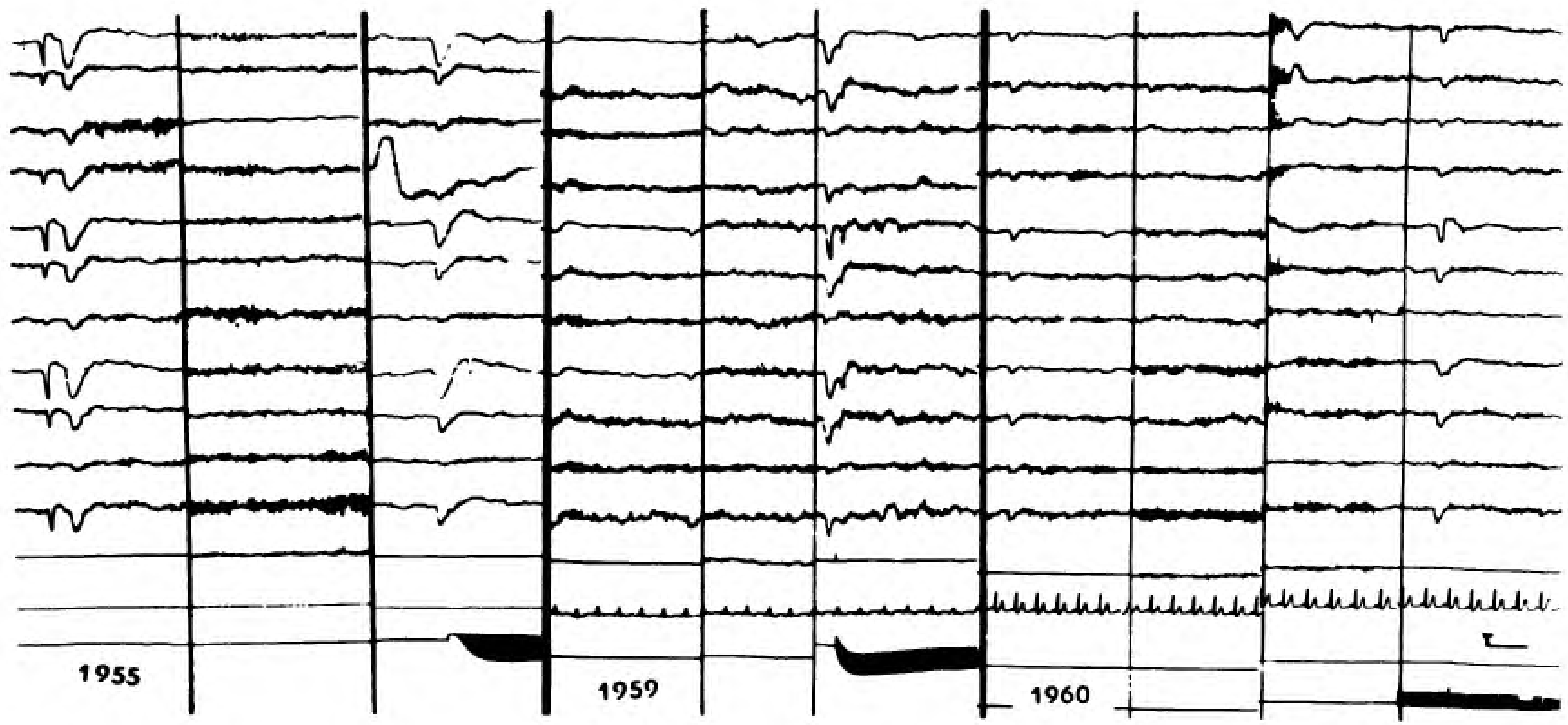


Fig. 5 Normal stationary tracing

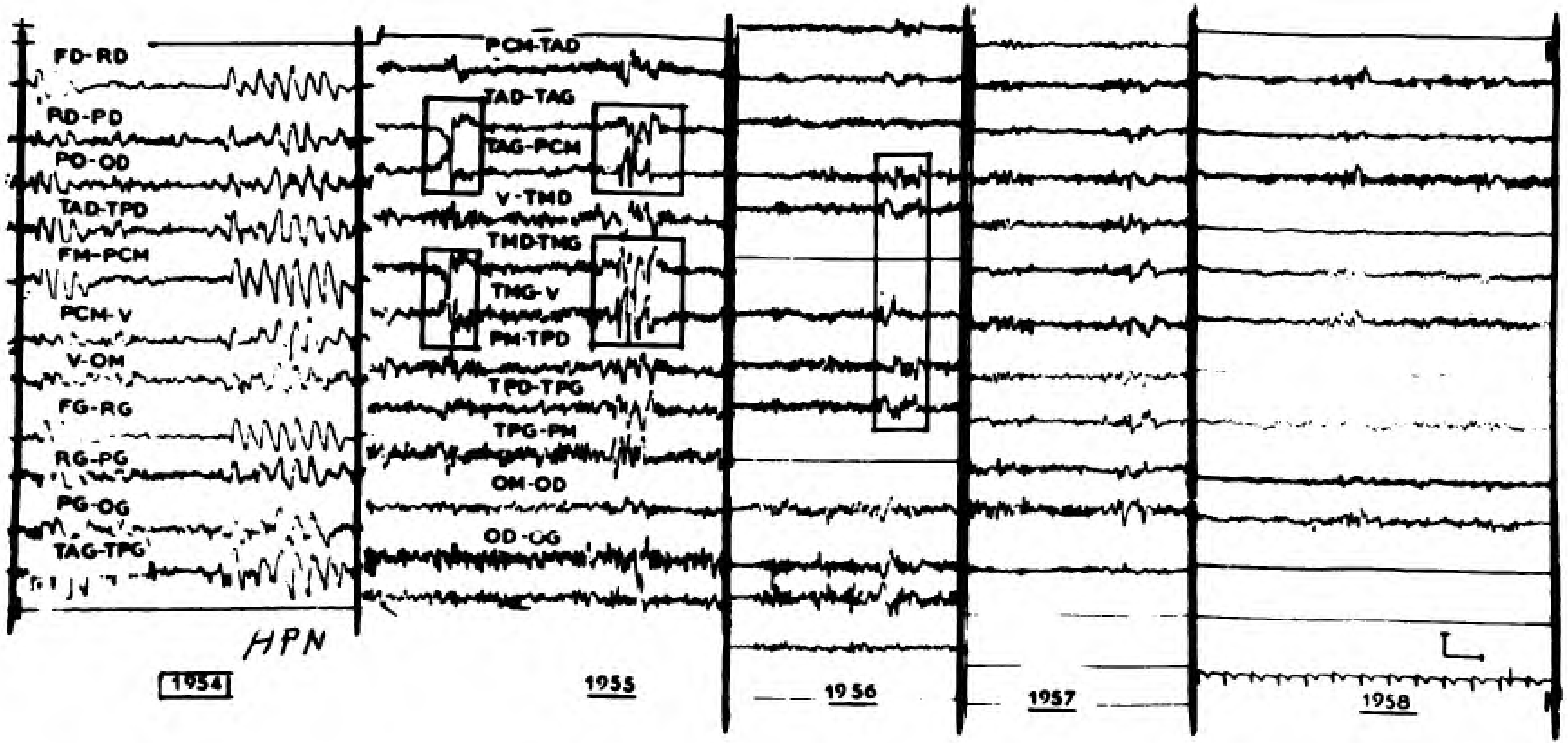


Fig.6 Regressive EEG disturbances. Miss P., Stewardess.
1954 at 21 years old: generalised paroxysms during hyperpnea (HPN)
1955 left temporal focus
1958 subnormal tracing
No neurological or comitial antecedents. Normal psycho-affective equilibrium

Fig.7 M.D. Anxiety neurosis with psychosomatic disorders. Sharp-waves focus on the left temporal lobe

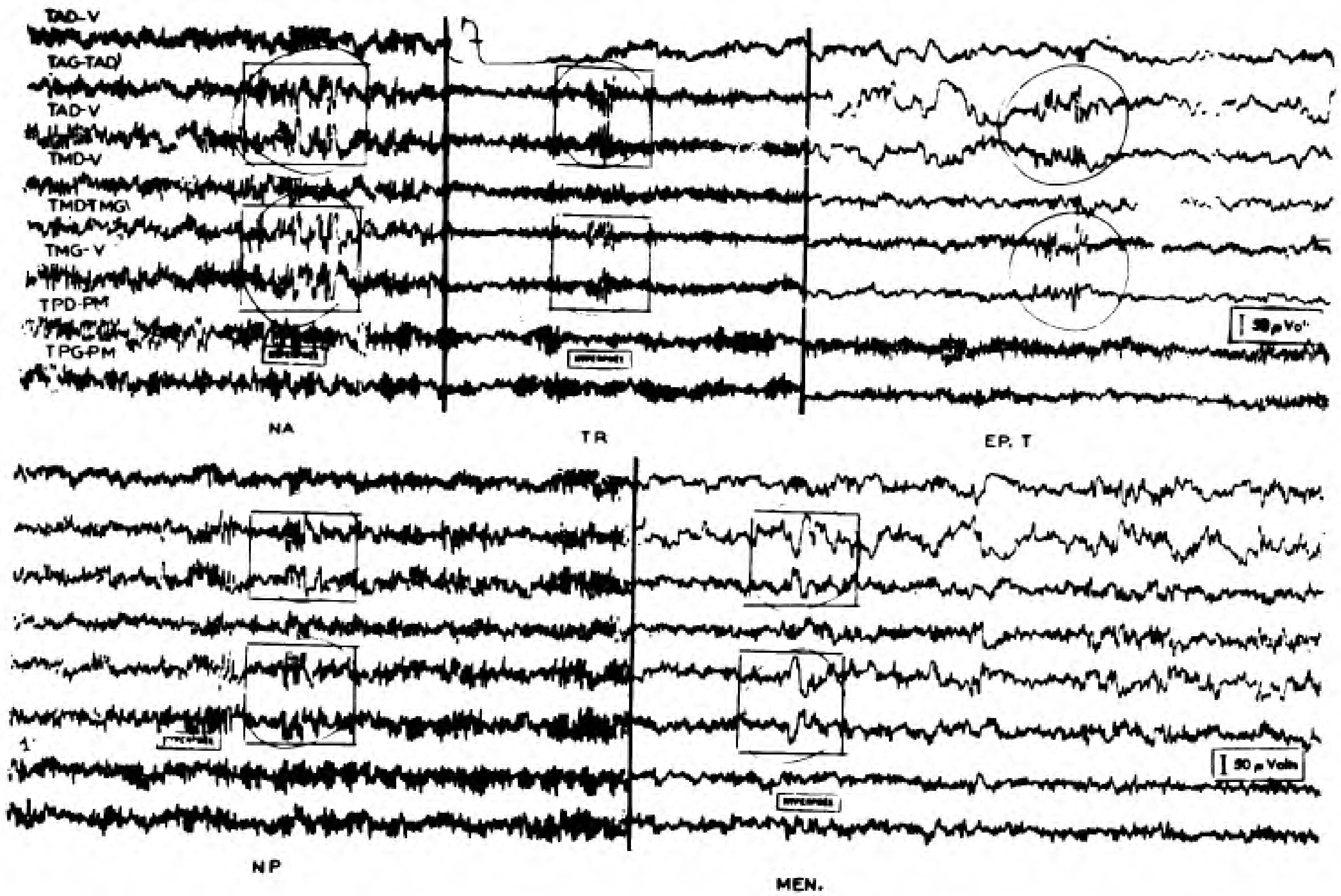


Fig.8 Left temporal foci in different neurological and psychiatrical syndromes

NA	Anxiety neurosis
TR	Cranial traumatism
EP.T	Temporal lobe epilepsy with dreamy states fits
NP	Phobic neurosis
MEN.	Meningioma

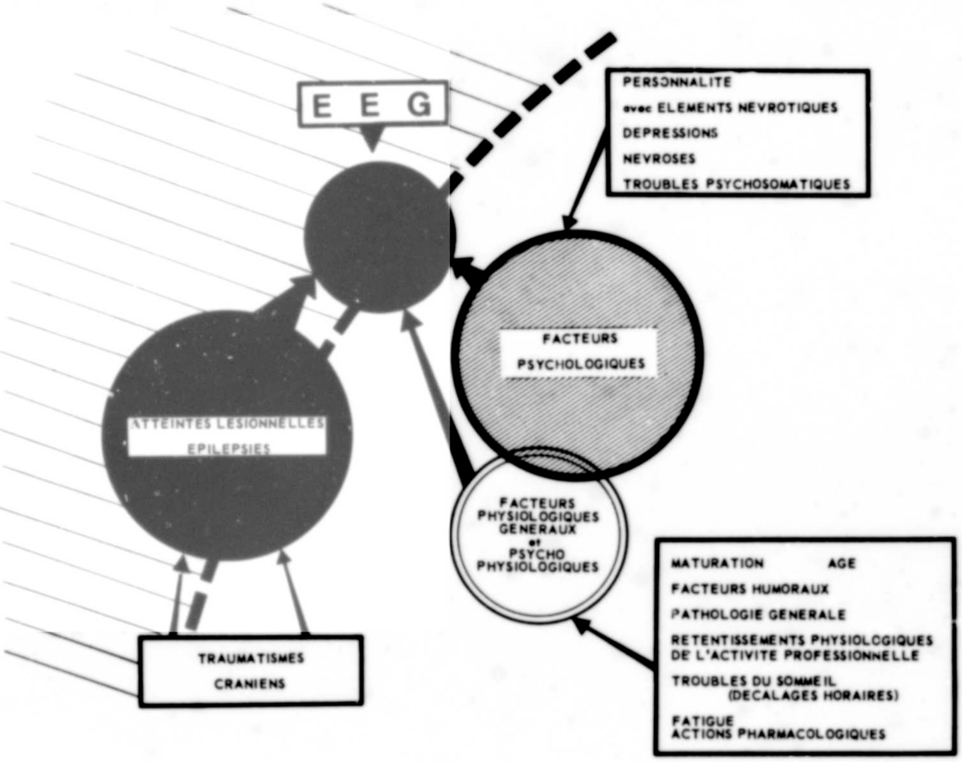


Fig.9 This diagram represents the three parameters which are necessary to hold the significance of EEG data in aeronautics:

Neurological factors and epilepsy
Psychological factors
Psychophysiological factors

The field of aeronautical EEG is on the right-hand area of this diagram. Conventional neurological EEG is on the left

PRINCIPLES AND METHODS OF APPLICATION OF ELECTROENCEPHALOGRAPHY IN AVIATION MEDICINE

by

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Central Medical Department of the
Compagnie Nationale Air France

SUMMARY

Aviation EEG undoubtedly constitutes one of the most delicate branches of clinical electroencephalography. 10,000 EEG recordings, arranged in evolutive studies, were made in Air France laboratories these last ten years (8,000 tracings in the cabin-staff group, 950 in the pilot group, 1050 in the ground-staff group). The subclinical EEG disturbances frequently observed in this population (35% in the cabin-staff group, 20% in the pilot group) appear to be correlated with psychological, psychiatric or psychophysiological factors in a great number of our longitudinal observations. They do not seem to be linked to potential epilepsies, as had been initially supposed. In the aeronautical medium, electroencephalography must be considered as a satellite technique of psychological and neuropsychiatric selection.

SOMMAIRE

L'EEG aéronautique constitue certainement l'une des branches les plus difficiles de l'électroencéphalographie clinique. 10.000 enregistrements EEG groupés en étude évolutive ont été pratiqués dans les laboratoires d'Air France depuis 10 ans (8.000 tracés chez le personnel navigant commercial, 950 chez les pilotes, 1.050 chez le personnel au sol).
Les perturbations EEG infra-cliniques fréquemment observées dans cette population (35% des cas chez le personnel navigant commercial, 20% des cas chez les pilotes), sont en corrélation avec des facteurs psychologiques, psychiatriques ou psychophysiologiques dans un grand nombre de nos études longitudinales. Elles ne semblent pas être en rapport avec des épilepsies potentielles comme on l'avait supposé initialement. En milieu aéronautique l'électroencéphalographie doit être considérée comme une technique satellite des méthodes de sélections psychologiques et neuro-psychiatriques.

PRINCIPLES AND METHODS OF APPLICATION OF ELECTROENCEPHALOGRAPHY IN AVIATION MEDICINE*

C. Blanc, E. Lafontaine and R. Laplane

1. INTRODUCTION

During the last twenty years, EEG has found an important place in neurology, psychiatry and in different branches of medicine, because of the interest and diversity of information it provides as to the organic and functional state of the brain. This is practically the only technique which allows a non-aggressive exploration of the living brain. Its interpretation criteria are well systematised. They make it possible to establish or, on the contrary, to eliminate different diagnoses. EEG is certainly one of the first examinations each of us would like to undergo in the event of an unaccounted or doubtful loss of consciousness, for instance.

In aviation medicine, the use of electroencephalography as a selection and control technique has proved to be much more complex to handle. At the outset, we lacked references on the EEG of normal subjects. EEG had set up its first criteria on the basis of pathology.

The electric information obtained with the apparently normal subjects is far from being univocal. Aviation EEG undoubtedly constitutes one of the most difficult and most delicate branches of clinical electroencephalography. A year ago, in Los Angeles, we presented a general outline of our theoretical and practical concepts as to the significance of EEG (see the preceding paper). In the present paper we shall try to elucidate a few general principles and practical conclusions.

Our material consists of 10,000 EEG recordings arranged in longitudinal studies spread out over periods of four to ten years. It includes three groups:

Cabin-staff	8,000 EEG recordings
Pilots	950
Non-flying staff	1,050

We shall now consider the population of the 950 pilots.

2. METHODS, FACTS AND INTERPRETATIONS

The initial objects of EEG when this examination was introduced at Air France, ten years ago, were simple and precise. It was aimed at

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detecting ignored, disguised or potential epilepsy,

evaluating the organic state of the encephalon and, in particular, revealing any after effects of brain lesions (traumatic, vascular or other).

In a word, the fundamental aim of EEG was to reveal diseases likely to bring about paroxystic alterations of consciousness. In actual fact, these objectives were less easy to achieve than might have been supposed at the outset. On the other hand, the interest of the information provided by EEG appeared in other directions.

At first, EEG in aviation came up against a major difficulty: the great number of apparently isolated disturbances observed in young subjects with no neurological or comitial antecedents and a somatic evaluation which proved normal. The proportion of disturbed EEG tracings varies with the population considered (stewardesses, stewards/pilots) and with the examination techniques used.

In the applicant pilots' group, the proportion of infraclinical disturbances is smaller than in the Cabin-staff group, but remains quite considerable. About 20% of the atypic or borderline electrical patterns are noted. Major anomalies represent no more than 2 - 3% of the subjects examined (2.5% according to Soussem and the military experts who pre-select candidates). But there remains about 18% of the atypic or doubtful patterns which would be considered significant in a neurological context (generalised paroxysms of sharp-waves during hyperventilation, left temporal foci, bioccipital spikes or sharp-waves during the stroboscope test, theta-delta overloads).

The different aspects of the EEG infraclinical patterns are shown on Figure 1. Precise figures for each type of electrical pattern cannot be provided. As we have established in our longitudinal classification of EEG tracings[1,2,3] these patterns may be evolutive and convertible. For instance, theta rhythms may be transformed into spikes or spikes and waves and the alternation of temporal foci and generalised paroxysms may be noted.

It is by dealing with 250 evolutive EEG surveys, that we studied the significance of the EEG infraclinical patterns. For practical reasons, which may be easily understood, the population which served us as a reference was that of stewardesses and stewards. With this population we were, in fact, able to take risks which would have been unthinkable with applicant pilots. In a word, we accepted a certain number of subjects with absolutely isolated EEG disturbances as, in the event of loss of consciousness in the case of a stewardess, no professional risks are involved, in terms of air safety.

In the case of applicant pilots the main elements of the problem are the following.

We are convinced that, in the case of the cabin-staff, these EEG disturbances practically never indicated infraclinical epilepsies. Despite everything, the hypothesis of potential epilepsy cannot be set aside entirely. The surveys carried out on the general population show that belated epilepsies are not exceptional. In 25% of the cases, the attacks may begin after the age of twenty (and three-fourths of them appear between 20 and 40 years, Lennox, Raynor et al.[1,4,5].

During the last few years, several observations have been made of comitial attacks during flight. These were cases of old epilepsies which were disguised or ignored (Stevens, Seipel, Wentz[3,2]).

With regard to EEG data, the electric patterns which we record are non-specific phenomena which do not, of themselves, provide a solution to etiological problems. Absolutely identical disturbances may sometimes be the result of an epilepsy, and sometimes of a neurosis. It is by dealing with the neuropsychiatric context and the biography that the significance of EEG data may be specified but these examinations must be carried out with maximum care in the case of applicant pilots.

3. DISCUSSION AND PRACTICAL CONCLUSIONS

We shall list, in a few points, the positions we have adopted and which we now propose as a basis for discussion.

An EEG reference tracing made at the time of selection tests, is a basic element of the medical file, for pilots as well as for stewards and stewardesses. It represents an irreplaceable basis of reference and discussion in the event of a pathological episode occurring with a subject already in active employment:

cranial traumatisms which become increasingly frequent,

neurotic disorders which raise the problem of paroxystic alterations of consciousness (lipothymy, pseudo-vertigo and fainting fits).

Thus, *in the absence of a primary tracing* at the time of recruitment, cranial traumatisms with EEG disturbances, in the case of pilots, give rise to insoluble problems.

A decision of inaptitude must never be made on the basis of an isolated EEG recording. It is essential to repeat examinations in all cases which raise problems.

EEG data must never be used singly. It must be discussed and restated in the context of the medical evaluation and the neuropsychiatric examination. EEG must be considered as a satellite branch of neuropsychiatry. In almost every case, the decision as to aptitude or inaptitude must be taken from longitudinal and vertical electro-clinical correlations.

We have considerably enlarged and liberalised the EEG criteria for selection, such as were worked out ten years ago, on the basis of the neurological EEG criteria. In addition, there is increased control. Now we assess *controlled conditional aptitudes*, with periodic checks, every six months or every year, of the EEG tracing and the psychological condition of the subject.

Figure 2 shows the elements which influence the decisions concerning the aptitude of applicants with infraclinical EEG disturbances. We take into consideration:

the character of the anomalies (borderline or major EEG disturbances),

the neurological antecedents (cranial traumatisms, doubtful attacks),

the psychiatric antecedents which have necessitated hospitalisation,

the data of the psychological examination carried out by a neuropsychiatrist.

In the case of Applicant Pilots, EEG anomalies are eliminatory when they are associated with neurological or psychiatric antecedents or with characterised states of neurosis. When borderline anomalies are absolutely isolated, they result in conditional aptitudes with periodic EEG and clinical checks. Only major anomalies, even when absolutely isolated, are eliminatory (3 per second spike and wave, spike foci). These are exceptional cases, about 1% of the applicants.

This severe attitude is founded on two thesis: compliance with safety requirements and the inadequacy of our knowledge as to the possible significance of absolutely isolated major anomalies. We do not know if the EEG patterns are indicative of potential epilepsies, states of neurotic immaturation or potential psychiatric disorders. When the safety of hundreds of human lives is involved, we cannot allow ourselves to speculate as to pathogenic theories or hypotheses. Our decision does not affect the destiny of a single person, as in the relationship between a doctor and his patient. It concerns the safety of a collectivity. We must reason not as specialists preoccupied by scientific problems, but as statesmen, if we may say so. We must, at the same time, comply with principles, judge the extent of our responsibilities and remain realistic. That is why our decisions are always collegial. They are adopted by the medical board. We must sometimes abandon our specialist status, to act merely as men of sound common sense. . .

The use of EEG in aviation medicine has made it possible to broaden the scope of this technique and to introduce gradations in certain criteria of neurological EEG. Although the spotting of epilepsies and organic lesions of the brain still constitutes the basic concern of all aviation EEG specialists, the importance of the electro-psychophysiological correlations, which have been established in recent years, has notably enlarged the number of cases where this examination is indicated. EEG appears both as a technique for study and research in human psychophysiology and as an examination of great practical usefulness. At the threshold of the supersonic age, it is our opinion that, in the years to come, the use of EEG in recruitment and check-up examinations should become generalised among pilots of all airlines.

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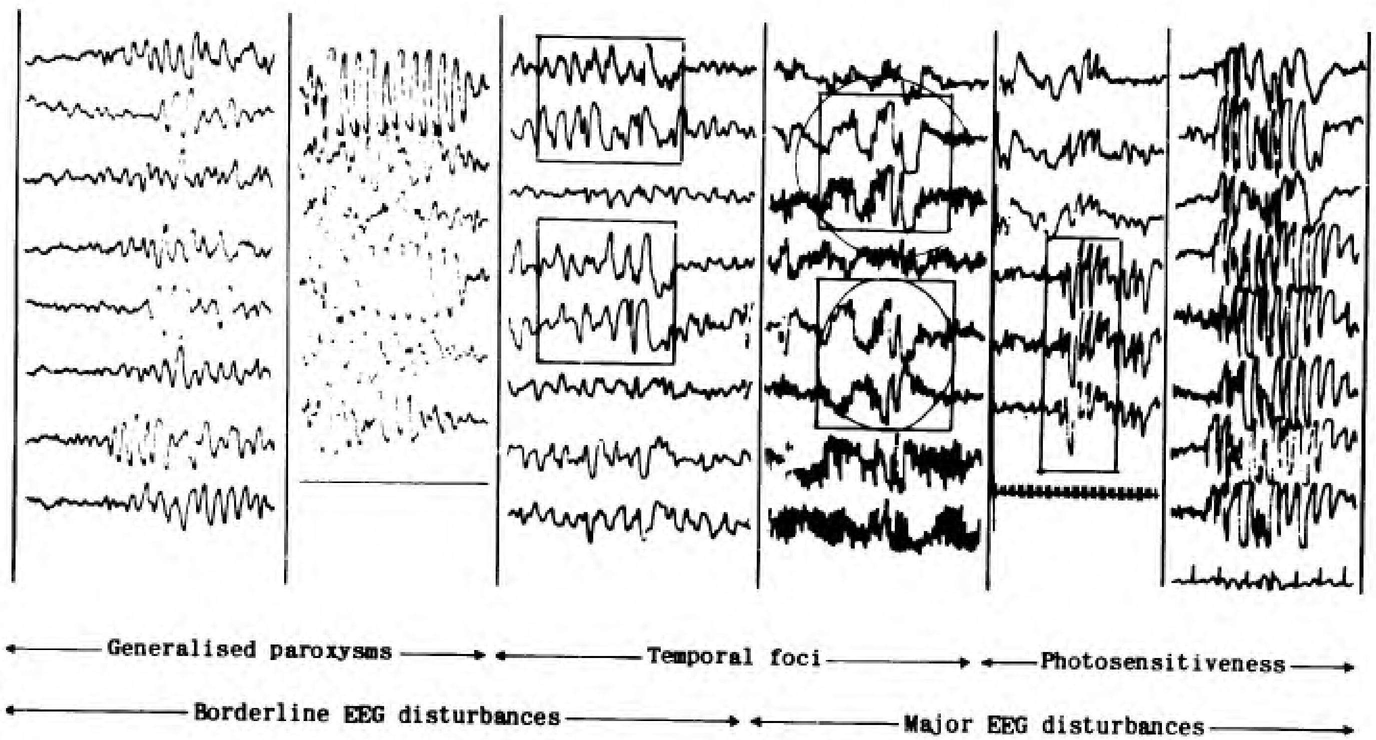

Fig. 1 Borderline and major EEG infraclinical patterns

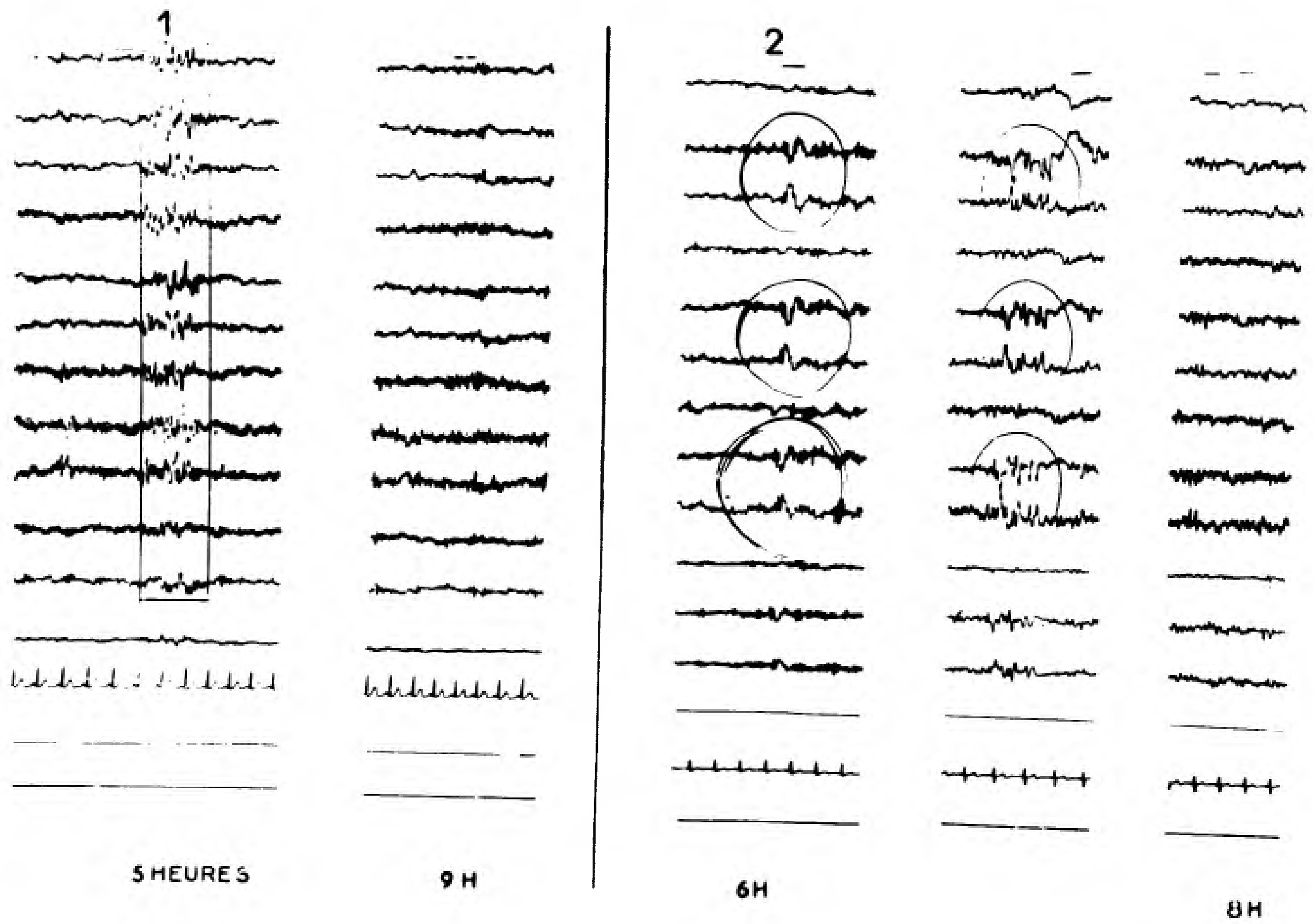

Fig. 2 EEG disturbances and lack of sleep. Observations 101 and 102

	EEG INFRACLINICAL DISTURBANCES		NEUROLOGICAL ANTECEDENTS		PSYCHIATRIC BALANCE	INAPTITUDE ●	TEMPORARY INAPTITUDE ◍	SUPERVISED APTITUDE Ⓒ	APTITUDE ◑
	BORDERLINE	MAJOR	CRANIAL TRAUMATISMS SEIZURES ..	PSYCHIATRIC ANTECEDENTS	NEUROTIC ELEMENTS Ⓝ				
APPLICANT PILOTS	●		●	○	○	●			
	●		○	●	○	●			
		●	○	○	○	●			
	●		○	○	○			Ⓒ	
		●	●	○	○	●			
	●		○	○	Ⓝ	●	◍	Ⓒ	

Fig. 3 Decisions concerning the aptitude of applicants with EEG disturbances. In the applicant pilots' group, major anomalies, even when absolutely isolated, are eliminatory

L'EXAMEN ELECTROENCEPHALOGRAPHIQUE DANS LE CADRE DE LA VISITE D'APTITUDE DU PERSONNEL NAVIGANT DE L'AVIATION

par

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SOMMAIRE

L'examen EEG pratiqué à Paris au Centre d'Expertise Médicale du Personnel Navigant depuis plus de quinze ans D'abord examen à la demande, il est devenu depuis 1958 examen systématique obligatoire pour certaines catégories de personnels militaires (Elèves de l'Ecole de l'Air - Pilotes de Chasse et d'Hélicoptères), dans l'Aviation Civile pour l'admission comme Pilote de ligne.

Le total des EEG pratiqués s'élève à 6700. Ce nombre élevé d'examens permet de se faire une idée juste de ce que peut attendre de cet examen le médecin responsable de la délivrance des licences.

L'EEG est un examen complémentaire indispensable, en particulier pour déceler l'épilepsie, affection redoutable pour les navigants et passant trop souvent inaperçue.

Les tracés doivent être interprétés avec circonspection non pas en tant qu'examen isolé, mais dans le contexte clinique. Ils peuvent se classer en trois groupes:

Groupe I : Tracés habituels, 80%. Ce sont des tracés dits "normaux";

Groupe II : Tracés limites, 17,5%;

Groupe III : Tracés anormaux, 2,5%: rythmes thêta-delta postérieurs et complexe "pointe-onde".

Les plus graves problèmes d'aptitude sont posés par le groupe II.

Ces sujets nécessitent un examen clinique et psychique très complet susceptible de mettre en évidence le rôle de la fatigue, de la tension nerveuse, ou des maladies infectieuses bénignes récentes. Les tracés doivent être répétés à plusieurs reprises car souvent ils se normalisent spontanément.

Enfin, si dans 99% des cas l'EEG ne doit pas être utilisé comme critère isolé d'aptitude, il n'en reste pas moins que dans 1% des cas, la seule découverte de signes électriques franchement anormaux impose une décision d'inaptitude.

SUMMARY

EEGs have been carried out at the Paris Medical Examination Center for Flying Personnel for over 15 years. Originally, these EEGs were effected on request; since 1958 the EEG has become a systematic, compulsory test for certain categories of military personnel (Air Force College students, fighter and helicopter pilots), and, in civil aviation, for airline pilots.

The overall number of EEGs carried out so far is 6700. This high total gives an idea of what the physician in charge of issuing licences may expect from this test.

The EEG is a complementary test, indispensable, in particular, for revealing epilepsy, a dangerous disease for flying personnel, and which frequently escapes detection.

Tracings should be interpreted with caution; they should not be considered as separate tests, but inserted in their clinical context. They can be broken down into three groups:

Group I : Usual tracings, 80%. These are called "normal";

Group II : Borderline tracings, 17.5%;

Group III : Abnormal tracings, 2.5%: posterior theta-delta rhythms and "spike-wave" complex.

The most difficult fitness problems are raised by subjects belonging to Group II.

These subjects must be submitted to a very complete clinical and psychic examination in order to reveal the role of fatigue, nervous tension or recent mild infectious diseases. The tracings must be repeated several times as they often become spontaneously normal.

In conclusion; whereas, in 99% of cases, an EEG should not be regarded as a separate criterion, in 1% of cases, the mere presence of really abnormal signs is sufficient to lead to a verdict of unfitness.

L'EXAMEN ELECTROENCEPHALOGRAPHIQUE DANS DE CADRE DE LA VISITE D'APTITUDE DU PERSONNEL NAVIGANT DE l'AVIATION

A.J.M.Raboutet et G.Soussen

1. INTRODUCTION

Le Centre Principal d'Expertise Médicale du Personnel Navigant de l'Aviation de Paris utilise l'examen électroencéphalographique pour les visites d'aptitude au Personnel Navigant depuis plus de quinze ans. Nous voulons vous exposer ici le bilan de cette vaste expérience, bilan très objectif qui s'efforcera de montrer ce que l'on peut attendre de cet examen dans le cadre d'une visite d'expertise d'un sujet présumé sain.

C'est en 1947 que le Centre de Paris commença à utiliser des électroencéphalogrammes. Pendant une période de dix ans, jusqu'en 1958, ils ne furent pas faits systématiquement mais seulement comme examens complémentairs sur demandes des Médecins Experts. Les motifs les plus fréquemment rencontrés pour justifier ces demandes étaient les antécédents de convulsions, de méningites, de traumatisme crânien et de fracture du crâne. En 1958, le Service EEG fut étoffé en personnel et en moyens matériels, ce qui permit d'utiliser plus largement ce mode d'investigation. Les examens EEG furent alors rendus obligatoires pour l'admission à l'Ecole de l'Air (pilotes de chasse et pilotes d'hélicoptère) et comme le Centre fonctionne également au profit de l'Aviation Civile, ils furent utilisés de façon systématique pour les admissions dans la specialité de Pilote de ligne.

Le total des examens EEG pratiqués s'élève au chiffre de 6700. Grâce à ce nombre élevé et au recul du temps, il nous est possible maintenant de fixer la place de cet examen dans la visite d'aptitude du Personnel Navigant, d'en montrer ses possibilités, mais aussi d'en tracer ses limites.

2. NECESSITE DES EXAMENS EEG

L'EEG systématique pour les candidats au Personnel Navigant est essentiellement justifié par le criblage des épilepsies. L'existance de cas d'épilepsie, chez les postulants à la carrière aéronautique, est une éventualité minimisée par les uns, exagérée par les autres, qui doit être examinée à la lumière des statistiques.

Dans la population générale l'épilepsie est une maladie particulièrement fréquente. D'après les statistiques de l'armée américaine, elle existe, chez les jeunes recrues, dans la proportion de 1 pour 200.

La possibilité de candidats Personnel Navigant porteurs d'une affection épileptogéne, ne doit donc pas être négligée, non plus que l'apparition de crises chez des pilotes en cours de carrière.

Les statistiques établies par l'Armée de l'Air française sont irréfutables à ce sujet, mais pour les exploiter convenablement, il convient de faire une différence essentielle entre

1. les cas d'épilepsie cliniquement confirmés,
2. les cas d'épilepsie suspectés sur des facteurs EEG.

1. Les épilepsies confirmées cliniquement, sont rares mais non exceptionnelles. Sur l'ensemble du Personnel Navigant on a constaté l'apparition de 13 cas depuis 1959. (nombre des examens EEG: 6700).

2. Les épilepsies suspectées sur des facteurs EEG, ou sur des antécédents suspects, a l'admission, sont beaucoup plus nombreuses (1 à 2%). Dans ces cas cependant, des controverses peuvent exister quant à la réalité de l'affection en cause, c'est ce que nous discuterons plus longuement dans la suite de ce travail.

Si nous nous en tenons aux épilepsies *certaines*, s'étant manifestées par des signes cliniques typiques, nous devons constater que, sans aucun doute, leur risque d'apparition pose un problème pour la sécurité des vols.

Voici le détail de chacune de ces observations.

En 1959: 4 cas.

- Une perte de connaissance *en vol* (avec phase tonique) chez un pilote d'hélicoptère de 24 ans (observation Tabusse). Première crise chez un sujet indemne de tout antécédent. L'EEG montre l'apparition de décharges de pointes-ondes à la stimulation lumineuse.

Il s'agit d'une épilepsie "photogénique" déclenchée par l'effet stroboscopique des pales d'hélicoptère.

- Un autre cas est décelé, la même année, chez un pilote d'hélicoptère; il s'agit de malaises répétés, sans perte de connaissance complète avec sensation de raideur des membres.

L'EEG, là aussi, montre une sensibilité excessive à la stimulation stroboscopique.

- Un troisième cas apparaît chez un adjunct-chef, radio de bord qui fait, au sol, plusieurs crises comitiales typiques.

L'EEG ne montre pas d'anomalie.

- Enfin un quatrième cas est décelé chez un PN*, il s'agit d'un commandant de 41 ans, navigateur, qui présente des crises convulsives typiques, survenues après un traumatisme cranien.

L'EEG montre des anomalies en foyer.

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* Personnel Navigant

En 1960: 3 cas

- Une observation spectaculaire est effectuée chez un Sergent chef de 28 ans qui présente une crise épileptique généralisée typique, au cours du vol, à son poste de pilotage sur Dassault 315.

Un passager ayant des notions de pilotage pose l'appareil et permet d'éviter un accident grave.

Il s'agit d'une première crise chez un pilote qui avait éte examiné, un an auparavant au C.P.E.M.P.N. pour troubles caractériels. L'EEG pratiqué à ce moment était normal. Un nouvel EEG, quelques jours après la perte de connaissance, ne présentait également aucune anomalie caractéristique.

- Un autre cas, la même année, consiste en l'apparition d'un malaise en vol grave chez un élève pilote, l'examen médical, repris à la suite de cet épisode, révèle des antécédents de comitialité qui avaient été cachés à l'admission.

L'EEG quelques jours après était négatif.

- Un dernier cas survient en 1960, il s'agit d'un capitaine de 41 ans, pilote de transport, qui fait un "crash" à l'atterissage après avoir perdu connaissance au cours de l'approche.

L'EEG montre des anomalies en foyer.

En 1961: 2 cas

- Un sergent chef de 32 ans, ayant 2300 h de vol, fait au sol une crise épileptique typique, avec phase tonico-clonique et morsure de la langue.

L'EEG, pratiqué quelques jours après, montre des anomalies suspectes.

- Un observateur de 26 ans, présente des crises convulsives à répétition. Terrain psychique anxieux. Intoxication alcoölo-tabagique. Plusieurs EEG sont négatifs.

En 1962: 1 seul cas

- Un élève pilote fait des crises Bravais-Jacksoniennes à répétition.

L'EEG révèle un foyer de souffrance temporal.

En 1963: 3 cas

- Le pilote d'un Chef d'Etat africain fait une crise convulsive typique, lors d'une escale, une demi heure avant la reprise du vol.

Hospitalisé à Paris, au service de Médecine Aéronautique, trois EEG successifs se révèlent négatifs, un quatrième EEG, sous sommeil, montre des perturbations suspectes.

- Un adjudant chef, navigateur, fait plusieurs crises comitiales typiques, de première apparition. L'EEG révèle des anomalies majeures.

- Un commandant, navigateur, fait au sol deux pertes de connaissance avec phase tonico-cloniques.

Plusieurs EEG restent négatifs.

Ces observations s'ajoutent aux nombreuses autres citées dan la littérature médicale ces dernières années, notamment par les médecins de l'USAF et de la RAF (cp. Donald R. Bennett, William et Rock). Elles apportent la preuve que l'épilepsie existe parmi les membres du PN et que des crises peuvent se produire au cours des vols.

En somme 13 cas:

6 épilepsies typiques,
- 3 avec EEG négatifs
- 1 avec EEG suspect
- 1 avec des anomalies provoquées par le sommeil (le 4ème EEG)
- 1 avec EEG caractérisé par anomalies majeures

2 crises épileptoïdes avec anomalies EEG provoquées par stimulation lumineuse intermittente (hélicoptères)

5 cas d'affections cérébrales avec troubles de la conscience ou convulsions localisées (EEG négatif en 2 cas; avec des signes focales en 3 cas).

Les données statistiques correspondent à l'expérience accumulée dans l'utilisation de l'EEG au cours des visites d'aptitude.

Cette technique ne remplace pas l'étude détaillée des antécédents, ni l'examen clinique. Cependant, des anomalies qu'elle met en évidence permettent fréquemment, par l'examen plus approfondi et *orienté* qu'elles provoquent, la mise au jour d'antécédents jusque là ignorés. Cette eventualité se produit dans 7 cas pour 1000.

Il n'est pas non plus exceptionnel que des crises comitiales typiques soient déclenchées par la stimulation lumineuse intermittente (2 fois sur 1000).

Le criblage d'épilepsies authentiques lors de la visite d'admission paraît indéniable aux experts du C.P.E.M.P.N. (Remond-Soussen), il peut être illustré par les deux observations spectaculaires suivantes:

En 1957, un candidat civil à l'aptitude au pilotage, qui désirait obtenir la licence de transport de frêt pour le compte d'une entreprise familiale, était considéré, lors de la visite d'admission comme légèrement suspect d'épilepsie latent pour troubles impulsifs du caractère. Adressé à l'EEG, cet examen montrait des perturbations paroxystiques prononcées qui, jointes au conteste clinique, entraînaient l'inaptitude. Malgré des protestations véhémentes du père de ce candidat, s'insurgeant contre le verdict d'un appareil électrique, cette décision fut maintenue. Or, quelques temps après ce jeune homme avait une perte de connaissance au volant de sa voiture et se tuait.

En 1962, un jeune homme de 19 ans vient en visite d'admission PN.

Les antécédents allégués ne révèlent rien sur le plan neuro-psychiatrique. Il as passé une visite complète avant d'aboutir à l'EEG, tous ses standards d'aptitude physique sont à I.

Le début de son tracé reste dans les limites de la normale; hyperpnée est bien supportée, mais dès le début sa reactivité à la stimulation lumineuse intermittente est anormale: de grandes bouffées lentes apparaîssent à la fermeture des yeux. Très rapidement, en effectuant les stimuli standardisés, on aboutit à une crise clinique typique de grand mal. Phases tonique et clonique se succèdent, on essaye à grand peine de maintenir les électrodes et de protéger la langue, au bout de quelques instants la phase de stertor s'installe. On contrôle alors le ralentissement post-critique des rythmes cérébraux et le sujet émerge peu à peu. Le médecin se penche à ce moment vers lui demande s'il n'a pas eu des crises antérieurement, il signale alors qu'il a eu des pertes de connaissance quatre ans auparavant qui ont été soignées par du gardénal.

La période de stupeur post-critique a servi en quelque sorte, de narco-analyse et les antécédents dissimulés ont pu être retrouvés.

L'ensemble de ces constatations montre bien que la pratique de l'examen EEG, malgré ses limites, et ses incertitudes, reste indispensable quand il s'agit de dépister une affection aussi grave de conséquence pour la sécurité des vols.

3. LIMITES DE LA TECHNIQUE EEG

Les EEG pratiqués *au cours des crises épileptiques vraies*, sont tous perturbés; le type des modifications électrocérébrales permet même d'aboutir à la classification de 3 catégories de comitialité, cliniquement et électriquement différentes:

- le grand mal,
- le petit mal,
- les épilepsies partielles.

Mais entre les crises, il n'est pas rare que les tracé redeviennent entièrement normaux. L'utilité pratique de cet examen en est de beaucoup diminuée car on lui demande essentiellement de diagnostiquer la nature épileptique d'une perte de connaissance antérieure ou les risques d'épilepsie chez un candidat.

Cet écueil est inégal dans les différents types de comitialité.

Dans le grand mal, (l'affection est plus fréquente à l'âge adulte) il faut s'attendre à trouver de 50 à 60% de tracés intercritiques dépourvus d'anomalies.

Dans le petit mal (affection prédominant dans l'enfance) la proportion de tracés négatifs tombe à 20 ou 30%.

Enfin dans les épilepsies partielles, survenant le plus souvent comme symptomes secondaires d'une souffrance cérébrale localisée (post-traumatique, par exemple) la proportion est la plus faible: 15 à 20% de tracés négatifs.

La technique EEG rend donc de grands services diagnostiques dans le petit mal et les épilepsies partielles, mais dans les épilepsies grand-mal qui sont, de loin, celles que l'on risque le plus de rencontrer dans le PN, elle est insuffisante.

Pour pallier cette déficience, on a proposé, depuis longtemps, d'employer des procédés dits "d'activation". Ceux-ci consistent à faire subir au sujet une souffrance cérébrale capable de révéler une anomalie qui serait restée inapparente au repos.

Les procédés d'activation sont nombreux; on peut les classer en:

- procédés physiques,
- procédés chimiques.

- Procédés physiques:

Les plus couramment employés sont l'hyperventilation et la stimulation lumineuse intermittente.

Ils ne créent qu'une souffrance discrète et la plupart des laboratoires les emploient de façon standard. La réactivation par le sommeil est également fréquemment employée.

D'autres procédés sont plus rarement utilisés:

- l'anoxie (par inhalation de mélanges gazeux pauvres en oxygène, ou par montées fictives en caisson) (Gastaut-Rémond-Soussen),
- la fatigue et la privation de sommeil (D.R.Bennett).

- Procédés chimiques:

Ils consistent à l'injection de drogues épileptogènes qui aboutiraient plus rapidement à la crise ou aux anomalies EEG majeures chez les épileptiques que chez les normaux.

Les principales drogues utilisées sont la mégimide et surtout le cardiazol (Remond).

Tous ces procédés ont un écueil, en effet ils sont capables de déclencher des troubles même chez les sujets sains. S'ils criblent effectivement plus d'épileptiques, ils entraînent dans la sélection un pourcentage important de sujets normaux.

Plus ils sont actifs et plus ils risquent de faire classer des sujets sains dans la catégorie des comitiaux. C'est pourquoi ils ne doivent être employés que rarement et avec beaucoup de circonspection.

Enfin, et surtout, l'incertitude de l'EEG réside dans les particularités paroxystiques que l'on retrouve chez les sujets normaux.

Si tous les épileptiques présentaient des anomalies évidentes dans les tracés enregistrés en dehors des crises, si tous les individus sains avaient un tracé absolument identique, indemne de toute perturbation intermittente, le problème serait simple, or il n'en est rien.

L'expérience accumulée jusqu'ici au C.P.E.M.P.N. chez des sujets présumés sains, montre que beaucoup d'entre eux présentent des particularités paroxystiques surtout lors des épreuves de activation habituelles (hyperpnée, SLI) épreuves qu'on est obligé de pratiquer si l'on veut que l'EEG soit rentable dans la détection de l'épilepsie.

Voici les statistiques effectuées.

4. L'EEG CHEZ LES SUJETS NORMAUX

Le point de vue des experts a évolué considérablement depuis les sept dernières années. Au début de l'application de l'EEG à la sélection, on attachait sans doute une importance disproportionnée aux signes électro-cérébraux isolés; à cette époque, tout ce qui ressemblait de près ou de loin aux manifestations électriques de l'épilepsie était considéré comme suspect de maladie latente et entraînait l'élimination du sujet.

Cette attitude a vite été jugée intenable, il était invraisemblable que 20% des candidats soient atteints d'épilepsie cliniquement inapparente, il était difficile d'admettre que des pilotes confirmés soient éliminés du PN sur des particularités EEG isolées.

Aujourd'hui un revirement fondamental s'est produit. Certains experts pensent même que quelle que soit l'importance des signes recueillis, l'EEG n'a aucune valeur dans la sélection en tant qu'examen isolé, mais ne prend de signification que dans un contexte clinique déterminé (Fischgold).

Au C.P.E.M.P.N., nous nous sommes appliqués à juger d'une prétendue anomalie, non pas, principalement, en fonction de sa ressemblance avec une altération pathologique donnée mais également en fonction de sa fréquence d'apparition dans un groupe de sujets en état de bonne santé apparente. Cette attitude nous a amenés à considérer de très près le type exact des tracés rares qui posent un problème d'aptitude, elle nous a conduits également à chercher dans des facteurs physiologiques ou psychologiques une corrélation possible avec de tels aspects.

Devant la masse des tracés considérés, le premier but de cette étude a été d'aboutir à une classification.

En effet, dans le domaine de la sélection, nous n'avons pu conserver la catégorisation adoptée par les cliniciens. Pour eux, deux groupes sont possibles, celui des tracés normaux et celui des tracés altérés. Nous ne reviendrons pas sur la critique du concept de normalité, nous nous contenterons de rappeler que la classification de tracé normal est habituellement attribuée à tout tracé comprenant un alpha bien individualisé, des régions antérieures dépourvues de tout rythme rapide et de tout rythme lent en excès, enfin dans lequel ni l'hyperpnée, ni la SLI ne font aparaître d'aspects paroxystiques.

L'expérience des investigations EEG chez les individus sains nous permet d'adopter une catégorisation différente.

Nous considérons trois groupes de tracés:

GROUPE I - Tracés habituels (sousentendu: habituels dans une position donnée).

GROUPE II - Tracés limites.

GROUPE III - Tracés rares.

Parmi les 6700 tracés étudiés:

1. 80% se situent dans le groupe I, dans cette catégorie nous faisons entrer, à part les tracés dits normaux, les tracés "plats" comportant parfois des activités rapides irrégulières et de faible amplitude (16%).

   Les rythmes theta et delta sinusoïdaux suscités par l'hyperpnée, même s'ils sont très amples et très abondants (25%) et même s'ils présentent un aspect "paroxystique", s'est à dire s'ils apparaissent en bouffées labiles avant de se généraliser (13%).

2. 17,5% des tracés se situent dans le groupe II (tracés limites). Nous classons dans ce groupe:
   - les tracés comportant des rythmes rapides d'amplitude supérieure à 10 microvolts (4%) pouvant apparaître en séquences synchronisées (1,5%);
   - les dysrythmies spontanées discrètes pouvant avoir une répartition asymétrique (2%);
   - les fluctuations vigiles importantes et récidivantes (1%);
   - les réactions asymétriques à l'hyperpnée (2%);
   - les réactivités à l'hyperpnée de morphologie pointue (3%);
   - enfin les hypersensibilités à la SLI: potentiels évoqués occipitaux de grande amplitude et polyharmoniques (3%).

3. 2,5% des tracés se situent dans le groupe III. Dans ce groupe nous classons:
   - les rythmes theta-delta postérieurs continus ou subcontinus (0,4%) les dysrythmies spontanées majeures, théta ou delta abrupt, revêtant parfois une projection localisée (0,6%);
   - les réactivités à l'hyperpnée dont la morphologie reproduit, même épisodiquement, le complexe pointe-onde (0,8%);
   - les pointes-ondes occipitaux et généralisés provoqués par la SLI (1,2%).

5. SIGNIFICATION DES TRACES "LIMITES" ET "RARES" (Groupe II et III)

Depuis que nous suivons le 17,5% de sujets classés dans le groupe des EEG "limites", (groupe II) car nous demandons depuis cinq ans de les contrôler chaque année, nous n'avons vu paraître chez eux aucun cas d'épilepsie.

Que peuvent donc signifier ces particularités inhabituelles du tracé?

En premier lieu, il faut convenir que beaucoup d'entre elles sont physiologiques. Elles correspondent à une "manière d'être" électrique du cerveau, qui n'est pas celle de tout le monde, et qui ne signifie rien de pathologique.

D'autres peuvent représenter des séquelles d'affections infantiles qui ont "léché" les méninges et l'encéphale et n'ont laissé que de petites perturbations électro-cérébrales. Mais, dans certains cas, on a pu mieux cerner le déterminisme des tracés frontières. Les examens répétés effectués au C.P.E.M.P.N., avec contrôle clinique et anamnestique ont permis de mettre en évidence:

1. *Le rôle de la fatigue:*

Le pourcentage de candidats subjectivement fatigués (préparations d'examens, voyages avec privation de sommeil) est significativement plus élevé dans les groupes II et III que dans le groupe I. En outre chez les sujets fatigués, qui présentent un EEG inhabituel, le repos fait disparaître les perturbations électriques dans 60% des cas.

2. *Le rôle de la tension psychique au moment de l'examen:*

Les sujets anxieux, tendus, inquiets peuvent présenter des perturbations paroxystiques; d'autres tracés pratiqués dans une meilleure ambiance, les sujets étant rassurés, révèlent la disparition de ces signes.

3. *Le rôle des troubles psycho-affectifs:*

Nous avons fait souvent les mêmes constatations que Blanc et Lafontaine, qui ont insisté, dans diverses communications, sur le rôle des névroses et des états dépressifs, dans les perturbations paroxystiques temporales.

4. *Le rôle des maladies infectieuses banales en évolution:*

Souvent une légère grippe, une rhinopharyngite, une amygdalite agissent suffisamment sur l'électrogénèse cérébrale pour déterminer un tracé inhabituel.

6. CRITERES ACTUELS RETENUS POUR L'INTERPRETATION

L'incidence des tracés EEG sur le problème de l'aptitude se situe actuellement comme suit.

Une instruction technique relative aux expertises EEG a été diffusée dans tous les Centres français d'examens médicaux du PN.

Cette notice décrit exactement tous les signes électriques qui permettent de classer un tracé dans les groupes I, II ou III.

Instruction Relative aux Expertises EEG des Candidats à un Emploi du Personnel Navigant et des Membres du Personnel Navigant de l'Armée de l'Air

A l'admission l'expert peut conclure:

- soit à l'aptitude
- soit à l'inaptitude temporaire
- soit à l'inaptitude.

I. Sujets déclarés aptes

Sont déclarés aptes les sujets présentant un électroencéphalogramme normal au repos et sous l'influence des activations mineures (hyperpnée, stimulation lumineuse intermittente, compression oculaire). Les tracés comportant une grande quantité de rythmes rapides sont considérés comme normaux, sous réserve que les sujets n'aient pas absorbé de barbituriques dans les jours précédant l'examen*.

* Une instruction particulière précise une technique de recherche rapide des barbituriques dans les urines.

Peuvent être également déclarés aptes, mais en précisant qu'un contrôle électro-encéphalographique sera pratiqué obligatoirement lors de la première expertise révisionnelle, les sujets qui, sous réserve d'un examen clinique entièrement négatif et d'une étude orientée des antécédents, présentent une ou plusieurs des particularités ci-dessous:

(a) Paroxysmes pariéto-occipitaux symétriques provoqués par la stimulation lumineuse intermittente et non généralisés aux régions frontales (pseudo pointes-ondes isolés à signification de "potentie évoqué" en particulier).

L'importance de ces paroxysmes pourra justifier une contrexpertise.

(b) Rythmes delta monomorphes antérieurs en bouffées amples et durables avant la fin de la troisième minute d'une première épreuve d'hyperpnée bien exécutée.

(c) Arrêt cardiaque de plus de 4 secondes (à l'électrocardiogramme de contrôle) sans bouffées de rythmes delta concomitantes à la suite d'une compression oculaire de 30 secondes*.

(d) Remplacement paroxystique et généralisé du rythme alpha par un rythme théta ou d'un rythme théta par un rythme alpha au cours des cinq premières minutes du tracé.

(e) Pointes-lentes ou ondes à front raide sporadiques pariétocentrales (ondes vertex) spontanées ou provoquées par une stimulation auditive banale†.

II. Sujets déclarés inaptes temporaires

Peuvent être déclarés inaptes temporaires les sujets présentant des anomalies considérées comme incompatibles avec l'aptitude mais dont, en raison de l'anamnèse, on peut penser qu'elles s'atténueront avec le temps. Dans cette catégorie entrent par exemple certains sujets ayant subi un traumatisme crânien récent, ayant présenté une affection aiguë (amibiase, grippe...) ou présentant des signes de surmenage.

Il s'agit notamment des sujets dont les tracés comportent une ou plusieurs des particularités suivantes:

(a) Rythme delta polymorphe ou polyharmonique localisé découvert pour la première fois et pouvant être considéré comme une séquelle traumatique ou opératoire.

(b) Rythme théta localisé non occipital permanent, découvert pour la première fois et pouvant être considéré comme une séquelle traumatique ou opératoire.

(c) Rythme delta en bouffées paroxystiques avec ou sans syncope consomitante, survenant au cours ou à la suite d'une compression oculaire précédée ou non d'un arrêt du rythme cardiaque (à l'électrocardiogramme).

(d) Remplacement paroxystique généralisé du rythme alpha par un rythme théta ou d'un rythme théta par un rythme alpha survenant au cours des deux premières minutes d'enregistrement et noté pour la troisième fois consécutive (à un troisième examen) chez un sujet prévenu et reposé.

(e) Pointes lentes ou ondes à front raide pariéto-centrales symétriques, sporadiques (ondes vertex) survenant spontanément au cours des deux premières minutes

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* Cette épreuve sera utilement complétée, dans certains cas, par la vérification du réflexe solaire. L'avis d'un cardiologue sera demandé.

† dans ces deux cas, la constatation de signes de tendance au sommeil au cours d'un premier enregistrement impose un ou deux examens de contrôle dans les jours qui suivent.

d'enregistrement et notées pour la troisième fois consécutive (à un troisième examen) chez un sujet prévenu et reposé.

L'expert est juge de la durée de l'inaptitude temporaire.

III. Sujets déclarés inaptes

Sont déclarés inaptes les sujets dont les tracés présentent toute anomalie autre que celles énumerées aux deux paragraphes précédents (sujets déclarés "aptes" et "inaptes temporaires"). Il s'agit notamment des tracés comportant une ou plusieurs des particularités suivantes:

(a) Rythme de pointe-onde critique, généralisé, à 3 c/s avec ou sans absence clinique, survenant spontanément, ou sous l'action des réactivations mineures (stimulation lumineuse intermittente, hyperpnée).

(b) Bouffées de pointes-ondes généralisées à 1 ou 2 c/s survenant spontanément ou sous l'action de l'hyperpnée ou de la stimulation lumineuse intermittente.

(c) Pointes-ondes isolés frontaux, symétriques, sporadiques, survenant spontanément, ou sous l'action de l'hyperpnée, ou de la stimulation lumineuse intermittente.

(d) Pointes-ondes symétriques rolandiques supérieurs, accompagnés ou non de décharge myoclonique, survenant spontanément ou sous l'influence de l'hyperpnée ou celle de la stimulation lumineuse intermittente.

(e) Pointes-ondes isolés localisés et fréquents mis à part les pointes-ondes isolés occipitaux symétriques provoqués par la stimulation lumineuse intermittente*.

(f) Rythme delta polymorphe localisé survenant spontanément chez un sujet non endormi n'ayant pas d'antécédent traumatique ou opératoire ou s'aggravant à un second examen chez un sujet ayant des antécédents traumatiques.

(g) Rythme delta polymorphe généralisé survenant spontanément chez un sujet non endormi.

Les tracés du groupe I ne posent pas de problèmes.

Les tracés du groupe II entraînent simplement la nécessité d'un ou plusieurs tracés de contrôle, accompagné d'un examen clinique neuro-psychiatrique.

Si les particularités électriques ne se maintiennent pas lors des tracés de contrôle (ce qui est le plus souvent le cas); si aucune suspicion clinique ne subsiste, *l'aptitude est donnée*. Souvent un nouveau contrôle est réclamé, par mesure de prudence, lors de la prochaine visite PN.

Les tracés du groupe III, entraînent, pour les sujets qui en sont porteurs, un contrôle clinique et anamnestique approfondi, complété par un bilan psychologique.

Dans ce groupe peu nombreux (2.5% en 6700 tracés soit 167 cas), deux attitudes sont possibles: si l'on découvre en élément clinique suspect, une contre indication à l'aptitude est émise. Si l'on ne découvre rien et qu'il s'agisse de pilotes confirmés, un contrôle périodique est déclaré nécessaire, mais l'aptitude est maintenue. S'il s'agit de candidats, à l'admission, l'inaptitude est déclaré.

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* La mesure du seuil épileptogène ne pouvant être pratiquée chez des candidats, la constatation de pointes-ondes localisés, quelle que soit la fréquence de ces accidents, entraîne obligatoirement l'inaptitude.

7. CONCLUSION

Si l'EEG ne permet pas à lui seul de séparer les aptes et les inaptes, il n'en reste pas moins un examen indispensable.

Ses incertitudes et ses causes d'erreur peuvent être palliées par deux facteurs:

- la référence constante à la "saine clinique",
- la présence d'experts spécialisés, rôdés à l'examen de milliers de tracés chez des normaux.

Correctement interprêté, l'EEG, outre la détection de l'épilepsie qui reste son objectif principal, permet d'attirer l'attention sur des sujets fatigués, anxieux, caractériels, ou de découvrir des antécédents ignorés, des manifestations névrotiques ou psychopathiques qui avaient échappé à l'examen clinique.

L'EEG entre donc, à juste titre, dans le cadre des examens complémentaires nombreux, dont doit s'entourer toute visite PN bien faite.

Ainsi compris cet examen posera sans doute quelquefois au médecin responsable des problèmes délicats, mais le plus souvent il apportera un élément précieux pour trancher un doute et orienter une décision.

NOTA: Tous les examens EEG sur lesquels repose le travail ont été pratiqués au Centre Principal d'Expertise Médical du Personnel Navigant de Paris.

Directeur: M. le Colonel Robion.
Experts: Dr Remond - Médecin Commandant Soussen.

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PART III

SCREENING AND SELECTION

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FLICKER AS A HELICOPTER PILOT PROBLEM:
USE OF PHOTIC STIMULATION AND EEG AS SCREENING TECHNIQUES

by

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SUMMARY

Interruption of light sources by helicopter rotor blades has been implicated in the occurrence of grand mal seizures and severe vertigo in some pilots. Pertinent to this problem is the current interest in the significance of the abnormal EEG in selection of air crews and the relationship of EEG findings to episodes of altered consciousness. The use of intermittent light stimulation as an activating technique in detecting patients with epilepsy or low convulsive thresholds is well established. The goals of this study were: one, to determine the incidence of flicker vertigo or flicker problems during actual flight operations, two, to determine if any helicopter pilots in an operating squadron would reveal undue sensitivity to flicker as revealed by EEG changes or unusual subjective sensations during photic stimulation in the laboratory, and three, to determine if baseline or photically induced changes in EEG activity were related to flight performance or ability to perform laboratory tasks.

Flicker during flight was reported as a problem for one-fourth of the 102 pilots examined. Generally, this was a minor problem and flicker was described as only annoying or distracting, but, in one instance, a near accident was attributed to flicker. At this stage of the experienced helicopter pilot's career, photic stimulation does not appear to be a useful device to detect those who would show abnormal EEG activity during flicker. Photic stimulation, however, did identify pilots who had subjective feelings of discomfort during the flickering light and perhaps of more importance in at least one-fourth of this sample, their degree of alertness was markedly affected during flicker. Neither baseline EEG data nor induced photic changes in the EEG pattern showed a clear-cut relationship to flight performance or to cognitive motor functioning in the laboratory. The complex problem of the relationship of normal and paroxsymal EEG activity to motor-cognitive functioning is discussed.

SOMMAIRE

On a associé l'interruption intermittente des sources lumineuses produite par les pales de rotor d'hélicoptère aux accés d'épilepsie et de vertige grave affectant certains pilotes. Dans le cadre de ce problème, on s'intéresse actuellement à la valeur significative des électro-encéphalogrammes anormaux dans la sélection des équipages navigants et au rapport entre les données fournies par ces électro-encéphalogrammes et les phases d'altération de la conscience. La technique de stimulation par lumière intermittente est maintenant d'usage bien établi pour diagnostiquer l'épilepsie ou les faibles seuils de convulsion. Les objectifs de l'étude poursuivie étaient les suivants: premièrement, établir la fréquence du vertige ou de tout autre trouble causé par le "clignotement" au cours d'opérations en vol réel; deuxièmement, déterminer si un pilote d'hélicoptère appartenant à une escadrille en opération manifesterait une sensibilité anormale aux intermittences lumineuses, sensibilité révélée par des modifications électro-encéphalographiques ou des sensations subjectives inhabituelles au cours des essais de stimulation photique en laboratoire; troisièmement, déterminer si les modifications de base, ou déclenchées photiquement, survenant dans les activités électro-encéphalographiques étaient liées aux performances de vol ou à l'aptitude du pilote à accomplir certaines tâches en laboratoire.

D'aprés les résultats recueillis, sur 102 pilotes examinés, un quart éprouve des difficultés dues à la stimulation lumineuse intermittente en vol. Il s'agit là, en général, de difficulté mineures, seulement considérées comme désagréable et suceptible de distraire l'attention; cependant, dans un cas précis, il semble qu'il ait failli provoquer un accident. A ce stade de la carrière d'un pilote d'hélicoptère expérimenté, la stimulation photique ne paraît pas aider utilement à déceler les sujets qui présenteraient des électro-encéphalogrammes anormaux sous l'effet du "clignotement". Toutefois, la stimulation photique a permis d'identifier les pilotes qui éprouvaient des malaises subjectifs dûs au "clignotement", et, ce qui est peut-être plus important, dans un quart au moins des cas examinés, le pouvoir de concentration fut réduit de façon sensible par ce phénomène. Ni les données de l'électro-encéphalogramme de référence, ni les modifications photiques introduites dans le tracé électro-encéphalographique ne révélèrent un rapport bien déterminé avec les performances de vol ou le fonctionnement psychomoteur en laboratoire. L'auteur discute du problème complexe que pose le rapport entre les activités électro-encéphalographiques normales et paroxysmiques, et le fonctionnement psycho-moteur.

FLICKER AS A HELICOPTER PILOT PROBLEM: USE OF PHOTIC STIMULATION AND EEG AS SCREENING TECHNIQUES

Laverne C. Johnson

1. INTRODUCTION

The electroencephalogram (EEG) as a screening technique for selection of air crew personnel, especially pilots, has a long but not a very productive past (Bennet and Duvoisin, 1964; Tomkins, 1959). In spite of the generally negative findings and skepticism, the EEG remains very much a part of current discussion and use in the selection of flying personnel. The reasons for this continued use and interest are probably many, but the complexity of both, the problems for which the EEG has been used, and of the EEG itself, is a factor. When, in EEG, both the predictor and the criterion (pilot effectiveness) have so many facets, there is bound to be suggestive evidence of a useful relationship found if enough studies are done. There is also the expectation, or perhaps it is a matter of faith for some, that if a better criterion is found, or if the EEG is analyzed a little differently, or if it is combined with certain activating procedures, it will become a more sensitive predictor. It is in this last area, the use of EEG combined with an activation procedure, that this paper is primarily concerned.

EEG activation techniques are those procedures utilised to enhance the appearance of seizure or other types of abnormal EEG activity, that may not have appeared in the resting record. Commonly used techniques are sleep, hyperventilation, sleep deprivation, fasting, use of certain drugs, and photic stimulation. Our interest has been in the use of photic stimulation with helicopter pilots.

While there is much anecdotal evidence of flicker being a problem for helicopter pilots, little real data are available. Berry and Eastwood (1960) contribute to this anecdotal evidence and focus on the problem of flicker produced by light intermittently passing through rotating helicopter blades. This interruption of the light source by the rotor blades reportedly produced grand mal seizures in two air force personnel and severe "flicker vertigo" in a helicopter passenger. Intermittent light, therefore, could be the source of two potentially serious problems for the helicopter pilot: vertigo and impairment of consciousness.

Pertinent to this problem is the current interest by Dr Ades, as well as others, in the significance of the abnormal electroencephalogram in selection of aircrew and the relationship of EEG findings to episodes of altered consciousness in aviators (Ades 1962; Sem Jacobsen, Nilseng, Patten, and Erikson 1959; Lennox-Buchthal, Buchthal and Rosenfalck 1960). The use of photic stimulation as an EEG activating technique in evaluating patients with epilepsy is well established (Buchthal and Lennox, 1953; Gastaut, 1950; Ulett and Johnson, 1958). It is also known that seizures can be produced in control subjects as the result of exposure to flashing lights (Daly, Siekart, and Burke, 1959). While the incidence of flicker-produced *convulsions* on non-seizure patients is unknown (but probably less than one percent), the incidence of epileptic-like EEG discharges during photic stimulation is well established (Buchthal and Lennox, 1953; Munday Castle, 1953; Ulett and Johnson, 1958). In young adults, samples marked to extreme electroencephalographic photic activation have been found in four to six percent of the subjects examined. Of direct interest is the finding by Watson (1959) that approximately six percent of pilot candidates for Army helicopter training demonstrated abnormal electroencephalographic discharges during photic stimulation. Based upon these findings, Watson has recommended examination of all helicopter pilots for sensitivity to flickering light.

Though the clinical significance of these photically activated discharges is still a matter of conjecture, evidence has accumulated indicating that some of those persons showing abnormal discharges have a family history of epilepsy (Daly, Sickart and Burke, 1959; Davidson and Watson, 1956). Many neurologists are of the opinion that these discharges are indicative of a lowered seizure threshold and even latent epilepsy. The degree of impairment of functioning during photic activation also seems to vary; however, in certain subjects there is loss of consciousness and inability to function during the abnormal discharge (Kooi and Hovery, 1957; Davidoff and Johnson, 1964). Thus research evidence indicates that individuals showing sensitivity to flickering light might be poor candidates for positions where they are exposed to an intermittent light source.

The second problem produced by intermittent light stimulation, "flicker vertigo", may be less serious from a purely medical prognostic viewpoint in the individual case, but may have the same expensive and tragic consequences if it is reponsible for an aircraft accident. In addition to the sensations of spinning and turning, flicker vertigo is also described as a feeling of dizziness, and/or nausea occurring during exposure to intermittent flickering lights. Various subjective descriptions have been applied to the symptoms: "uneasiness", "nervousness", "dizziness", and in some instances, a feeling of severe panic. In most cases, especially where exposure to flicker is of short duration, the sensations are reported to be only mildly disagreeable, but in the case reported by Berry and Eastwood the subject was in a state of uncontrollable panic. In addition to the symptoms of nausea and dizziness, psychic phenomena have been reported by Ulett (1953). After continued exposure to photic stimulation over a two-year period, a physician in Ulett's laboratory manifested chronic symptoms of gastroentestinal discomfort. A complete medical examination was negative but with an eight-week vacation from the laboratory the symptoms cleared, only to reappear upon reexposure to flicker. Ulett further reported that some of the symptoms may persist for several hours after stimulation.

Thus there is ample evidence to indicate the possibility of serious consequences on exposure to intermittent photic stimulation. Whether flicker is a serious problem for helicopter pilots is as yet undetermined. Anecdotal reports continue to be received by flight surgeons that flicker does cause discomfort and that it may have been a factor in a fatal accident. The importance of the flicker research to helicopter pilots is made more pertinent when it is realized that the most crucial frequencies for producing EEG activation and subjective sensations are in the 9-15 flashes *per second* (fps) range. The pertinence of this frequency range is indicated by converting the 9-15 fps to flashes *per minute*. This gives a figure of 540-900 flashes per minute. Then dividing this by the number of blades in the helicopter, e.g., three, you obtain a figure of 180-300 which includes the revolutions per minute (r.p.m.) operating range of most helicopters.

The goals of this study were: one, to determine the incidence of flicker vertigo or flicker problems during actual flight operations, and two, to determine if any helicopter pilots in an operating squadron would reveal undue sensitivity to light as revealed by marked EEG changes or unusual subjective sensations during exposure to photic stimulation in the laboratory. A subsidiary goal was to obtain baseline resting EEGs on the pilots, as recommended by current Navy Bureau of Medicine and Surgery Instructions. The incidence of abnormal EEGs in such a field sample would be highly pertinent to the findings reported by Ades.

2. METHOD

2.1 Subjects

The subjects for this study were 102 pilots stationed at the Ream Field Naval Air Station. This is an operational helicopter field and all pilots assigned to this field have completed basic helicopter training, as well as having 200 to 1000 hours of fixed-wing aircraft experience. Thirty-five of the pilots were examined during their first weeks at Ream Field. These pilots, though varying in amount of fixed-wing time, all had less than 100 hours of helicopter flight experience. The remaining 67 pilots were from operating squadrons. Their helicopter flight time ranged from 50 to 1200 hours with a mean of 500-600 hours. The average age of the sample was 26.3 years with a standard deviation of 4.40 years.

2.2 Procedure

The pilots were scheduled during both morning and afternoon hours depending upon their flight schedule. No pilot was scheduled after a night or day flight. Examinations were made in an electrostatically shielded, semi-soundproof, temperature controlled room located in the Neuropsychiatric Service, US Naval Hospital, San Diego. The pilots were seated in an overstuffed chair and were viewed through a window from the adjoining equipment room. The equipment was instrumented for the recording of 6 channels of EEG, one channel each of heart rate, respiration rate, skin and room temperatures, and galvanic skin resistance (grs). Skin and room temperatures were recorded on the same channel, with room temperature being recorded only at the beginning and end of the record. The autonomic responses during photic stimulation are not pertinent to this paper and have been reported elsewhere (Johnson, 1963). The remaining two channels were used for recording photic stimulation flash frequency and for stimulus onset and subject response. All variables were recorded simultaneously at a paper speed of 25 mm/sec on a 12 channel Offner Type R Dynograph.

Needle electrodes were employed for the EEG. Electrodes were placed in the frontal, parietal, occipital, and midtemporal regions of the scalp and bipolar recordings were used routinely with occasional monopolar runs for comparison purposes. A vertex lead was used as a reference in the latter case. Care was taken to keep the lead placement comparable from pilot to pilot. A Grass PS-2 photic stimulator was used for intermittent light stimulation. This stimulator gives a high intensity light, up to 1,000,000 candle power of brief duration, 10 microsec. The pattern of stimulation was from 2-20 fps in an ascending order with electronically controlled periods of 30 seconds on and 30 seconds off.

In addition to evaluating EEG changes during flicker, possible impairment of cognitive and motor performance during flicker, regardless of EEG changes, was also studied. Can flicker itself interrupt functioning? To answer this question, 43 of the pilots were asked to perform the following tasks before flicker and during flicker: repeating digits (adapted from Wechsler Adult Intelligence Scale), a series of addition problems of increasing difficulty, serially subtracting 7 from 100, and finger tapping on a key for three minutes at a constant rate. To reduce practice effect, two comparable, but not identical, sets of problems were used, i.e., if a pilot subtracted 7 from 100 without flicker he subtracted 7 from 99 during flicker. Also some pilots were given the tasks first during flicker and others were given the tasks first without flicker. The tapping measure was included to see if varying the flicker rate would change the pilot's tempo. After the examination each pilot was questioned as to his subjective sensations, feelings, and possible symptoms during the test. He also completed a questionnaire, which included items dealing with a personal history of head injury, loss of consciousness, headaches, epilepsy, and a family history of neurological problems and epilepsy.

3. RESULTS

None of the pilots reported a history of seizures, but one reported that a brother had epilepsy and another noted that an uncle had seizures. Seventeen of the pilots reported head injury and, of these, seven were unconscious for periods of time ranging from one minute to four hours. Fourteen reported that they had had a spontaneous loss of consciousness or fainted. These episodes occurred within an age range of 8-31 years with the mode at age 14.

3.1 EEG Classification

TABLE I

EEG Classification of Helicopter Pilots

EEG Classification	*N*	*Percent*
Normal Alpha	76	74
Low Voltage Fast (LVF)	11	11
Low Voltage Slow (LVS)	10	10
Mixed Fast Slow (MFS)	2	2
Slow (S)	1	1
Abnormal*	2	2

* These two pilots were examined twice with similar results. The borderline abnormal record is included here.

Each of the EEG records was classified according to Gibbs' criteria with the results listed in Table I. Reliability of this classification was evaluated by having a neurologist read 20 of the records. There was 90% agreement between the evaluation by the author and the neurologist using Gibbs' criteria. One record was read as abnormal and one as bordering on the abnormal by two neurologists at the US Naval Hospital, San Diego. The abnormal record had bursts of high voltage seizure activity compatible with a seizure disorder*. The pilot, however, reported no personal history of head trauma, loss of consciousness, or family history of epilepsy. The pilot with the borderline record reported that he was unconscious for an hour at the age of 19 following a head trauma. Both of these pilots have good flight records to date.

3.2 Problems with Flicker During Flight

Twenty-five of the pilots reported on the questionnaire that they had been bothered by flickering light, but helicopter flight time appears to be a factor here. Only two of the new pilots reported that they had been bothered by flicker. The common complaint was that flicker was "annoying", "irritating" or "distracting". One pilot reported a near accident because of flicker, but no pilot reported that he had aborted because of flicker. Problems with flicker arose most often when the aircraft was heading into the afternoon sun or when the afternoon sun was behind the aircraft. One pilot reported that it was particularly noticeable "when hovering in late afternoon sun over the water at approximately 500 feet altitude". The impression of most pilots was that fatigue tended to increase the annoying quality of the flicker.

Half of the pilots reporting a problem with flicker stated that the rotating anti-collision beacon was also "irritating", "distracting" or "annoying". This was particularly true at night when flying in fog or under low clouds. Most pilots indicated that they either turned the beacon off or put it on steady in these situations.

3.3 Response to Photic Stimulation

The EEG response to photic stimulation was evaluated clinically and by use of the photic activation scale reported by Ulett and Johnson (1958). Clinically, there was no record when indicated a response that could be classified as even bordering on the abnormal. The pilot whose resting record was read as abnormal did show high voltage bursts at the onset of the light, but this appeared to be an augmentation of the basic abnormal pattern and not a pattern initially produced by flicker. The EEG response to each of 19 flicker frequencies was evaluated for each record to allow quantitative comparison of these data with those reported earlier by Ulett and Johnson. The possible scale range is from one (no change due to flicker) to five (markedly abnormal response). No record was given an overall rating greater than two. A three response, denoting moderate activation, was given only occasionally to.the EEG response for a specific flicker frequency. Thus this sample of pilots did not show the expected pattern of photic activation. Ullett and Johnson reported that 13% of their sample was given an overall rating of 3, 4.4% a 4 rating, and 4.4% an overall rating of 5. Most pilots, however, did show photic driving. Photic driving refers to the condition of the EEG frequency following that of the flicker. This phenomenon is almost universal and no clinical significance is attached to this response.

The usual subjective sensations during flicker were reported. These consisted of colors, designs, and various lights. Sixteen of the pilots also reported feelings of either tension, apprehensiveness, inability to think, disorientation, a hypnotic effect

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* See Paper 3 of this volume by W.B.Matthews (p.25 et seq.) [Editor's note].

or of just being bothered. There were no feelings of nausea, or dizziness, reported. Nine of the pilots who reported discomfort during photic stimulation also reported that the flicker had bothered them during flight, suggesting that these nine pilots may be unusually sensitive to the annoying qualities of a flickering light.

An interesting observation that has been noted in the literature but not mentioned before in connection with helicopter pilots, is that some subjects (Ss) when exposed to repetitive flicker may become drowsy (Alexander and Chiles, 1959; Bach, Sperry and Ray, 1957). To determine the susceptibility of these pilots to the somnolent qualities of flicker, each pilot's EEG before and during flicker was rated with respect to the degree of sleep using a 5-point scale (Lindsley, 1957). To determine the reliability of these ratings, two raters independently rated 35 records. There was an 88% agreement with respect to degree of sleep seen in the 35 records.

Twenty-two of the pilots, as indicated by their EEG, became drowsy or went into light sleep during flicker. The sleep activity was indicated by the presence of EEG slowing, 4-7 c/s of moderate voltage or activity of 2-4 c/s with some sleep spindles. No 2-4 c/s high voltage waves indicative of deep sleep were seen. To make certain that these EEG changes were not due to the flicker itself and were due to the pilot becoming drowsy, the EEG indicators of sleep had to be present between flicker frequencies as well as during the flicker. When the pilot was in light to moderate stages of sleep, the onset of flicker generally produced the "K-complex", a high voltage burst of sharp waves. If a pilot's EEG indicated that he was drowsy or in light sleep before the flicker survey began, he was not included in the above figure of 22. Thus for 21.5% of this sample the degree of alertness, as seen in the EEG record, changed markedly during flicker.

3.4 Performance during Flicker

As indicated above, after the resting flicker survey, each pilot was given a series of tasks and then reflickered with a comparable set of tasks being given during flicker. There was no significant difference between performance with and without flicker on repeating digits, addition or serial subtraction, and no change in tapping rate could be associated with either an increase or decrease in flicker frequency. As found in other studies (Alexander and Chiles, 1959; Bach, Sperry, and Ray, 1957) performance was not affected by photic stimulation when the subject's attention was deliberately focused on the task.

4. DISCUSSION

Flicker does seem to be a source of annoyance or irritation to about one third of experienced helicopter pilots. This problem is usually reported to be only minor or moderate in degree, but on occasions it may be severe enough to cause an accident or near accident. The two chief sources of flicker appear to be the rotor blades interrupting the afternoon sun and the Grimes rotating anticollision beacon. The latter appears to be most distracting when flying under clouds, near water, or in fog. The susceptibility to flicker and the degree of irritation appears to be directly related to fatigue.

EEG examinations with photic stimulation, demonstrated that some of the pilots experienced the same subjective sensations during photic stimulation that they had experienced during flight operations. Several pilots offered suggestions as to how the procedure could be modified to make their experience in the laboratory more similar and thus perhaps, increase the diagnostic effectiveness of the task as well as its use as a flicker simulator for new helicopter pilots.

Of interest are the twenty-two pilots who were awake until flicker began. Boredom was listed as a possible explanation for this phenomenon by Alexander and Chiles, (1959), but boredom does not seem to be an adequate explanation for these 22 pilots. In addition to being alert before flicker, many of these pilots were unaware that they were going to sleep. Those who did realise what was happening indicated they could not prevent it. "I felt myself getting sleepy but couldn't stay awake" was a remark by nine of the pilots. Two described the flicker effect as hypnotic. It is a safe assumption that the EEG clearly reflected a state of lowered vigilance in these pilots (Roth, 1961), a condition of which 11 were unaware. Bach et al. (1957) also were impressed by the consistency of the sensations of sleep, drowsiness and hypnotism produced in subjects who were awake and alert before flicker. Bach noted that while actual sleep was never produced "some state approaching sleep can be achieved using flickering lights on human subjects..." (Bach et al., p. 40). Stern has recently commented on the appearance of drowsy or sleep EEG patterns during flicker in 10 of his 68 subjects even though his subjects were told to stay awake and to report their subjective sensations after each flicker frequency.

Gastaut (1960) in a study concerned specifically with the EEG detection of sleep induced by repetitive sensory stimuli, found that EEG signs of sleep appeared in as high as 68% in some of his subjects and that repetitive visual stimuli was more effective than auditory stimuli. With each repetition of the procedure, the EEG signs of sleep would appear earlier in the session. Gastaut attributes the appearance of this drowsy state to "internal inhibition". He suggests that the EEG may be used for the possible identification of individuals with marked "internal inhibition" and a tendency to fall asleep when exposed to repetitive rhythmic stimuli. It would thus seem that any discussion of flicker reaction in helicopter pilots should stress not only the problems of vertigo, distraction, nausea, and the possible alterations of consciousness but also the possible hypnotic or somniferous potentialities.

The absence of any paroxysmal EEG response during flicker in these 102 pilots is of theoretical as well as practical interest. It is possible that the technique used was not effective. It is also possible that the pilots have become adapted to flicker but it is most likely that this sample represents a highly selected group with regard to both medical and technical screening and background. In a sample of subjects with so-called convulsive EEG patterns, our technique of stimulation has been effective in producing seizure discharges in 30%, an expected proportion in a sample of subjects with clinical convulsive disorders. To date in a non-clinical sample, 5% have exhibited extreme photic activation, with one of these non clinical subjects having a grand mal seizure. Thus our technique seems to be effective. Adaptation also does not appear to be a significant factor. Many of our pilots, especially those with little helicopter experience, reported that they had had no experience with flicker and thus no opportunity to adapt. Research and clinical findings indicate that while the abnormal EEG response to flicker may not appear on each examination, adaptation does not occur (Davidoff and Johnson, 1964; Ulett and Johnson, 1958). In contrast, the reverse effect is more common.

That these pilots are different from the samples generally studied is obvious. All of these pilots have survived a rigid preflight medical examination plus yearly medical examinations and most of them have had ma[illegible] hours in fixed wing planes before coming to helicopters. These pilots are those who have been left after the various medical casualties, lost in flight training and who gave up flying soon after graduation.

Some may hypothesise that, with the addition of the cockpit noise of actual flight, flicker may be more activating; while the results of this study cannot answer this question, the work by Stern suggests that noise is not a potentiating factor. Augmenting photic stimulation with various types and frequency of auditory stimuli had no effect on either increasing the incidence or severity of activation nor on producing activation in a greater percentage of subjects.

The results of this study suggest that photic stimulation as a screening technique for latent seizure disorders at this stage of a helicopter pilot's career, is not very useful. It does, however, appear to have value in identifying those who find flicker irritating or confusing. It also identifies a group of pilots in whom flicker, and perhaps any repetitive stimulus, produces a lowered state of vigilance. Whether photic stimulation would be more effective in detecting latent seizure patterns or persons likely to experience periods of unconsciousness if used earlier in the pilots career, is questionable. In a select sample, as beginning helicopter pilots would be, it is unlikely that the percentage of abnormal responses to flicker would be as high as the three to four percent reported in unselected samples; one percent would be more likely. The significance of these photically induced discharges, with respect to etiology and prognosis, is at present unknown. Certainly many subjects, with no history of seizures or other neurological problems, activate during flicker and their performance in their chosen field be it theology, medicine or flying, does not seem to be impaired. That there is no inevitable impairment in performance or even a change in the autonomic nervous system during extreme photic activation has been reported in recent work by Davidoff and Johnson (1964) and Johnson and Davidoff (1964). Examples of this seeming divergence of central nervous system activity and behavior and autonomic activity are illustrated in Figures 1, 2, 3(a) and 3(b). The morphology of the discharges associated with breaks in performance could not be differentiated from discharges not associated with breaks in performance. Whether the discharges were evoked from seizure or non-seizure patients was also not the differentiating factor. Many of our patients and subjects, of course, did show a break in performance during their photically induced discharges. This lack of a one to one relationship between paroxysmal discharges and performance, however, may explain why some pilots with "abnormal" EEG patterns have good flight records. Certainly more information on the etiological, neurophysiological, and behavioral significance of abnormal EEG patterns is necessary before the status of the EEG as a screening technique can be enhanced.

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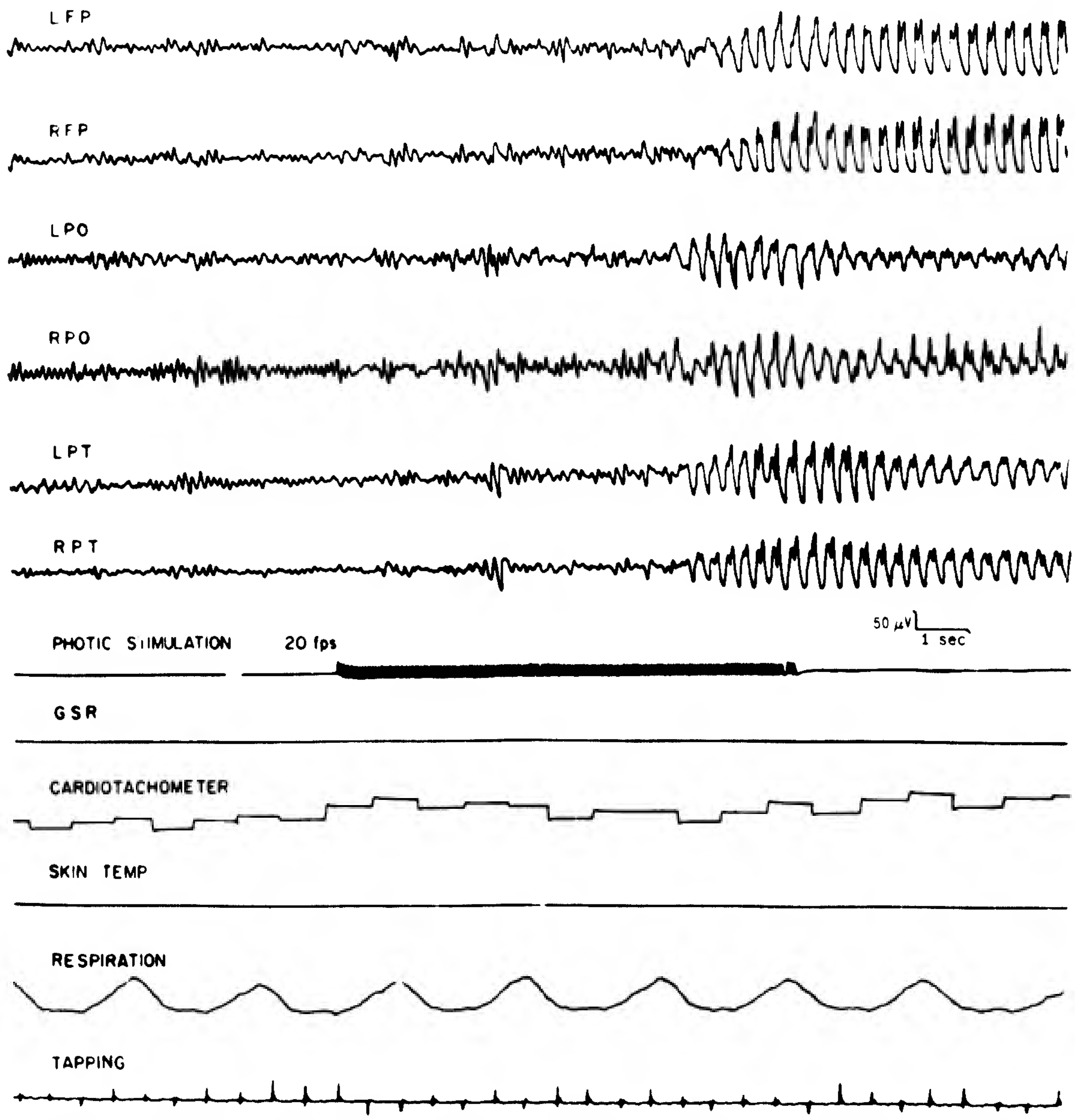

Fig. 1 Photic activation response in an epileptic patient illustrating absence of autonomic change and no break in tapping during discharge. The autonomic response to the onset of flicker had disappeared long before this 20th presentation. Abbreviations in this and subsequent tracings: LFP-REP, left and right fronto-parietal; LPO-RPO, left and right parieto-occipital; LPT-RPT, left and right parieto-temporal. GSR: galvanic skin response

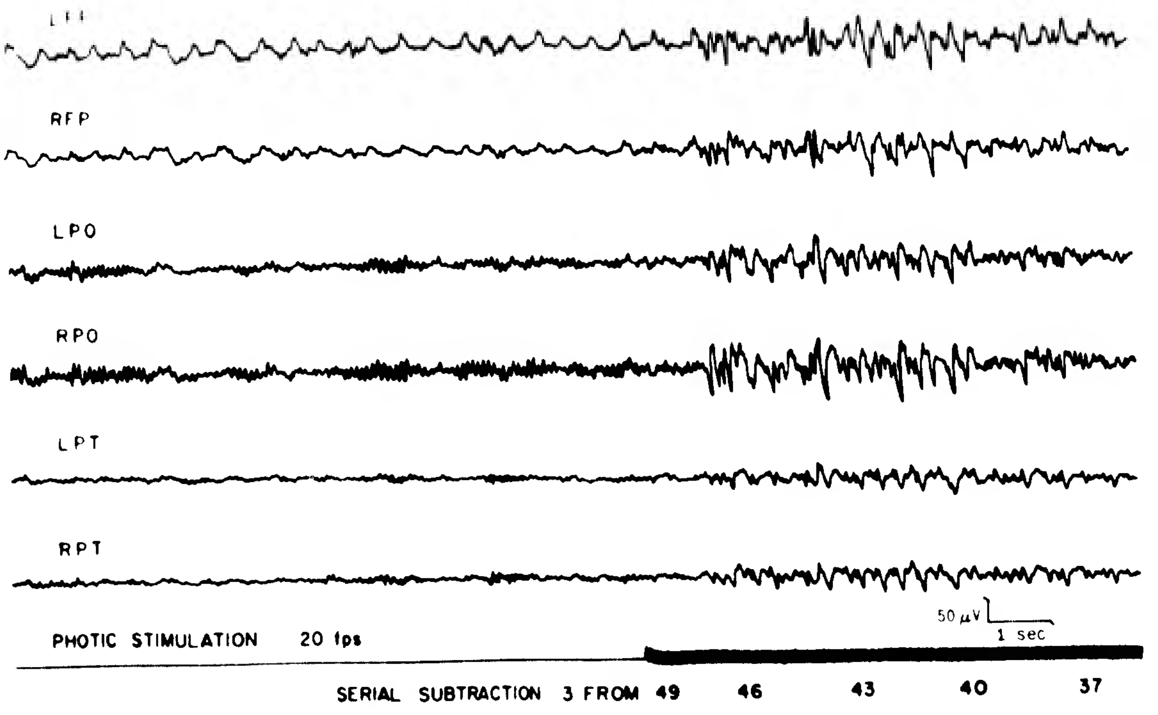

Fig. 2 Illustration of ability to do serial subtraction task during photically induced discharges in non-epileptic subject

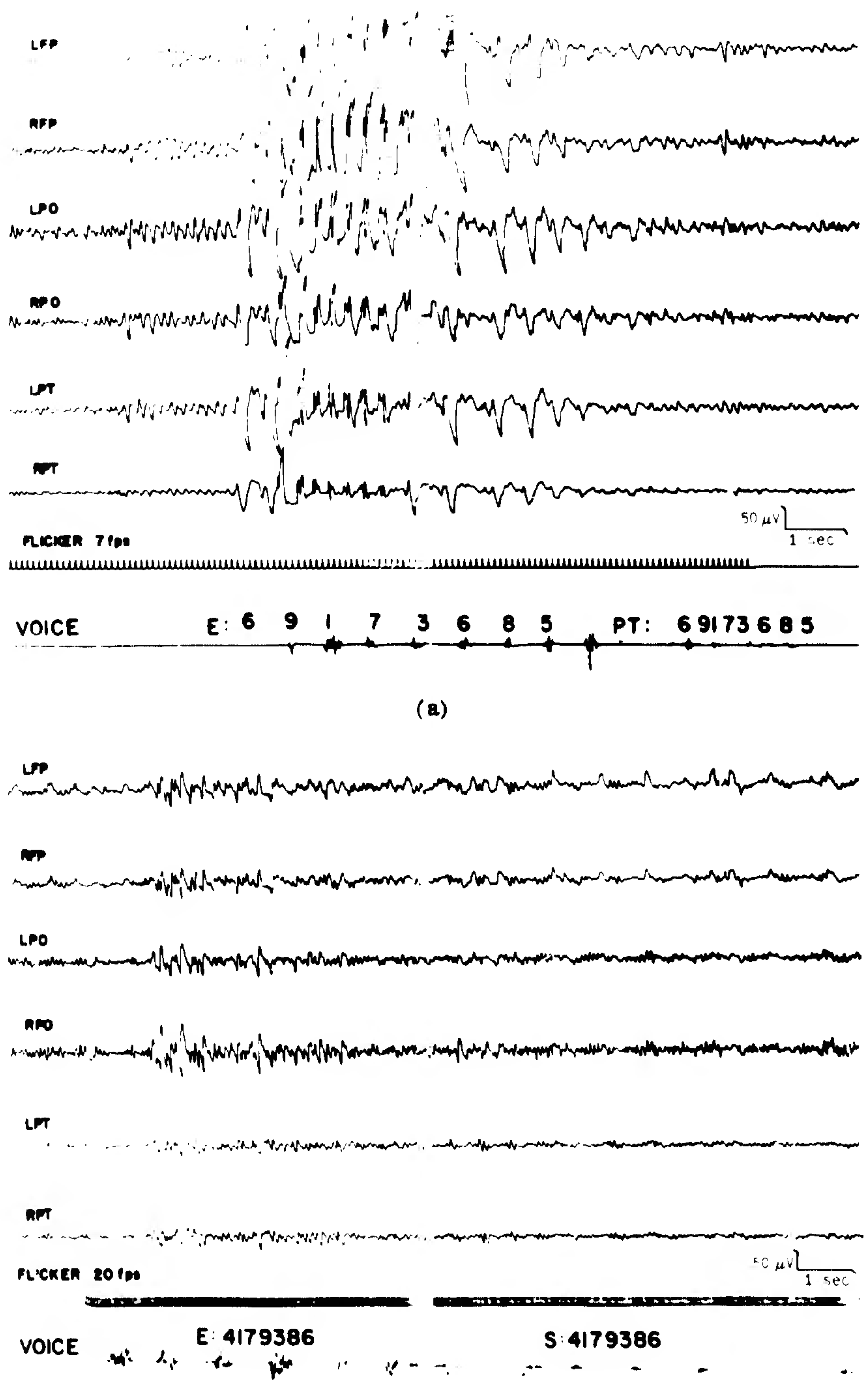

Fig. 3 Illustration of ability to repeat digits given during photically induced paroxysmal discharges. A is from an epileptic patient; B is record of seizure-free subject

E = experimenter. PT = patient. S = subject

THE INFLUENCE OF FLICKER ON THE LEVEL OF CONSCIOUSNESS

by

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SUMMARY

A lowering of the level of consciousness caused by flicker, as found elsewhere on the strength of subjective symptoms, could not be proved, using the Bourdon-Wiersma Stipple Test as an objective research method in a small population of young healthy subjects.

The influence of hyperventilation in sensitive subjects of a comparable group could be measured objectively with the stipple test and shown in a concomitant electroencephalogramm as related to fluctuations in the level of consciousness. However, an identical EEG pattern can have a different meaning.

SOMMAIRE

Un abaissement du niveau de conscience sous l'influence d'une stimulation lumineuse intermittente (fréquence 9 et 17), décrit dans la littérature en se basant sur des symptômes subjectifs ne se montre pas objectivement à l'épreuve de Bourdon-Wiersma (stipple test) dans une population d'un nombre restreint de jeunes gens sains.

L'influence d'une hyperventilation volontaire dans un groupe comparable de jeunes individus très sensitifs peut être mesurée objectivement par le stipple test et démontrée dans le tracé concomitant de l'électro-encephalographe comme un indice de fluctuation du niveau de conscience. Ne'amoins des tracés identiques n'ont pas toujours la même signification.

THE INFLUENCE OF FLICKER ON THE LEVEL OF CONSCIOUSNESS

G.J.Puister*

1. THE PROBLEM

It is a well known fact that intermittent photostimulation may cause abnormal psychic reactions. There are either cases of photogenic epilepsy, reacting with a seizure on flicker, or those individuals who, although being free from all epileptic stigmata, are affected by the flicker to such an extent that they may be incapacitated.

The greater part of the latter cases were pilots, flying towards or away from the rising or setting sun, on whom light flashes, generated by the revolving propeller, had a deteriorating effect. These effects varied in intensity from nausea to complete unconsciousness.

The "Erdl-Tulane symposium on flicker", edited by L.M.N.Bach (April 1957), gives a detailed review concerning the influence of intermittent photostimulation on the human behaviour.

One of the ideas put forward in this symposium was the possibility of using flicker in the field as a tactical weapon in order to create a mental disturbance in the enemy, using the above-mentioned pathological reactions as the theoretical starting point.

The Tulane studies "On the effects of flickering light on human subjects" (Bach) in this symposium deal especially with the effects of lowering consciousness by flicker on normal test subjects. In the general summary and conclusion it is stated that: "it was not possible to show *objectively* that cognitive (conscious) processes are significantly affected by flickering light, with the techniques used in these investigations".

Again: "the outstanding consistent finding in the investigation was the product of sensations indicating some degree of loss of consciousness". So in this paper it is assumed that flickering light may affect the level of consciousness in normal persons. Elsewhere in the symposium this same note is sounded, although the opinion is expressed that, to achieve a disturbing effect on the enemy, the flicker should be given on top of another stress, e.g., battle fatigue or loss of sleep.

The question that arises, is whether it would be possible to objectivate subjective sensations pointing to lowering the level of consciousness. A contribution to the solution of this question may be found in the results of the Bourdon-Wiersma stipple

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* Dr Puister, Head of the Medical Examinations Department, prepared this paper for an AGARD meeting but had no occasion to read it. After his untimely death the Editor considered it appropriate to include this contribution on an EEG subject in the present volume as a tribute to this eminent expert in aviation medicine.

test, when this test is performed while the test subject is offered intermittent light flashes.

Publications during the past few years, mainly by van Wulfften Palthe, showed that fluctuations in the level of consciousness, caused by hyperventilation, were objectivated in the EEG pattern by this test.

In his article* "The stipple test: a follow-up study" he gave examples of the performance on this test during hyperventilation (Fig. 1) which showed clearly that sometimes consciousness was lowered, as expressed in the concomitant EEG as "slowing" or as "high, slow waves". This applied only to very sensitive subjects who showed subjective and objective (behavioral) symptoms during voluntary hyperpnoea; moreover there did not exist a *constant* time relation between the polymorphic delta's and the signs of impaired consciousness in the stipple test. Sometimes, after two minutes hyperventilation, stipple test and EEG pecularities appeared, while after three minutes (Fig. 3) the stipple test showed an excellent pattern of unimpaired vigilance but, for a time, the delta's persisted (see Figures 2 and 3) (as a homoiostatic mechanism).

2. METHODS

Our test subjects were all student-pilots with an average age of 22. The tests were done on a glass-topped table. Underneath this top the stroboscope was placed, monochromatic yellow light being used, so that the test paper and its surroundings, including the subject's face, were intermittently illuminated.

The room lighting was subdued day light. Every test subject performed 4 stipple tests, one after the other, without interruption. In this way the whole test was completed within an hour.

The test leader, being in all cases the same experienced technician, indoctrinated every subject before the test in exactly the same way. The first stipple test was done without photostimulation. During the second and third test intermittent light flashes were given with a frequency of 9 and 17 per second respectively.

These frequencies were selected because the subjective sensations seemed to be most pronounced at these particular flicker frequencies. The fourth and last test was performed without flicker. In 10 subjects an EEG was taken while performing the tests. These EEGs showed no abnormalities and were identical to the EEGs taken before the test. In the other 6 cases only routine pretest EEGs (with hyperventilation and flicker activation) were taken. All were within normal limits.

In a control group of 10 student-pilots, 4 stipple tests were done in the same way, but all 4 without light interference. A routine EEG was classified as "normal" for all subjects.

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* Aeromedica Acta, V, 1956/1957, pp. 327-346.

3. RESULTS AND DISCUSSION

The Bourdon-Wiersma scores*, compared with the initial test, were as a rule higher, not only in the second and third test (i.e., with the 9 and 17 flashes per second), but also in the last test, done again without flicker interference (Table I).

In one case (E) the fourth test score was lower than the first one but the second and third were higher than either I or IV.

In two cases (M and N) the scores showed no relevant change. Only once, subject O, the results while flickering were lower than those without.

The results from the control group pointed in the same direction (Table II). The spreading of the numbers in the four columns of Tables I and II does not exceed the usual limits of variation.

From these figures, the conclusion may be drawn that intermittent photostimulation under test conditions, as described in this paper, does not lower the level of consciousness of non-fatigued young people in good physical and mental condition. Rather, it can be said that the rhythm of the flicker has a stimulating effect on the hand movements, which in themselves are rhythmical while executing the stipple test. Such a stimulating effect is also seen in mild hypoxic hypoxia and under moderate alcoholic influence.

The question arises, however, whether to make an arbitrary change of frequencies or to use light of a stronger intensity, both in combination with another stress, e.g. fatigue, may not influence the level of consciousness in an unfavourable way.

This assumption is not so unlikely, as a few cases of epilepsy, non-photogenic, showed a significant lowering of the Bourdon-Wiersma score under photostimulation conditions.

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* (a) Total time 10′
(b) Omissions 15
(c) Mistakes 2
(d) Dispersion 6
} (average of 1193 aviation applicants)

60 was - arbitrarily - taken as a convenient figure of reference, i.e. when a, b, c and d equal the overall average, 60 is scored: merits and demerits are added to or deducted from this 60.

TABLE I

Subjects	*I*	*II*	*III*	*IV*
A	52	56	54	65
B	58	64	69	67
C	66	80	80	78
D	70	88	78	80
E	78	89	81	69
F	66	74	66	79
G	63	78	79	93
H	85	89	93	104
I	79	80	81	81
J	65	68	71	72
K	55	73	63	75
L	50	56	59	60
M	63	62	62	63
N	63	63	63	67
O	76	65	69	81
P	75	78	80	80
MEAN	67	73	72	76

I = no flicker
II = 9 per sec
III = 17 per sec
IV = no flicker

TABLE II

Subjects	*I*	*II*	*III*	*IV*
A	65	62	66	67
B	79	79	81	71
C	78	82	83	83
D	85	85	78	76
E	88	71	70	76
F	85	75	66	66
G	66	79	79	81
H	64	77	79	77
I	78	75	78	90
J	76	92	70	92
MEAN	76	78	75	78

I, II, III, IV = no flicker

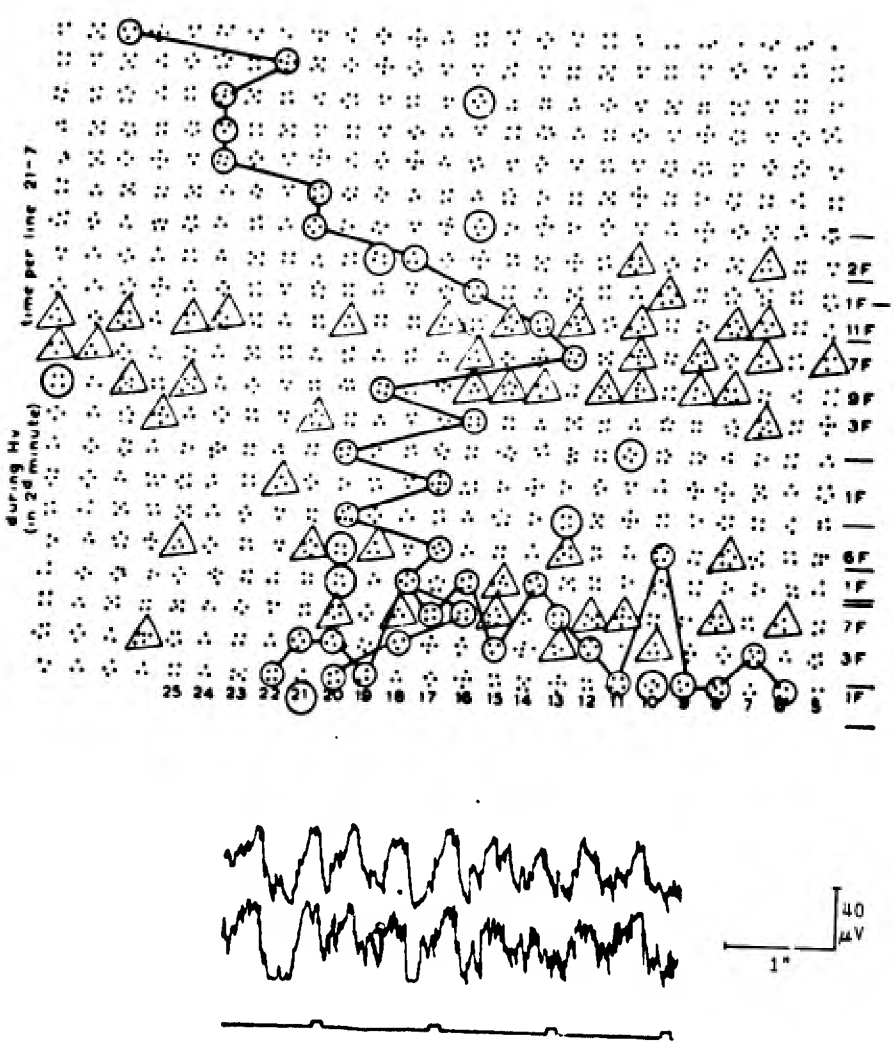


Fig. 1 In the second minute of hyperventilation. Stipple test: times per line very irregular; considerable spreading in distribution curve indicating semi-consciousness. EEG occipital leads: (eyes open) multiform delta's

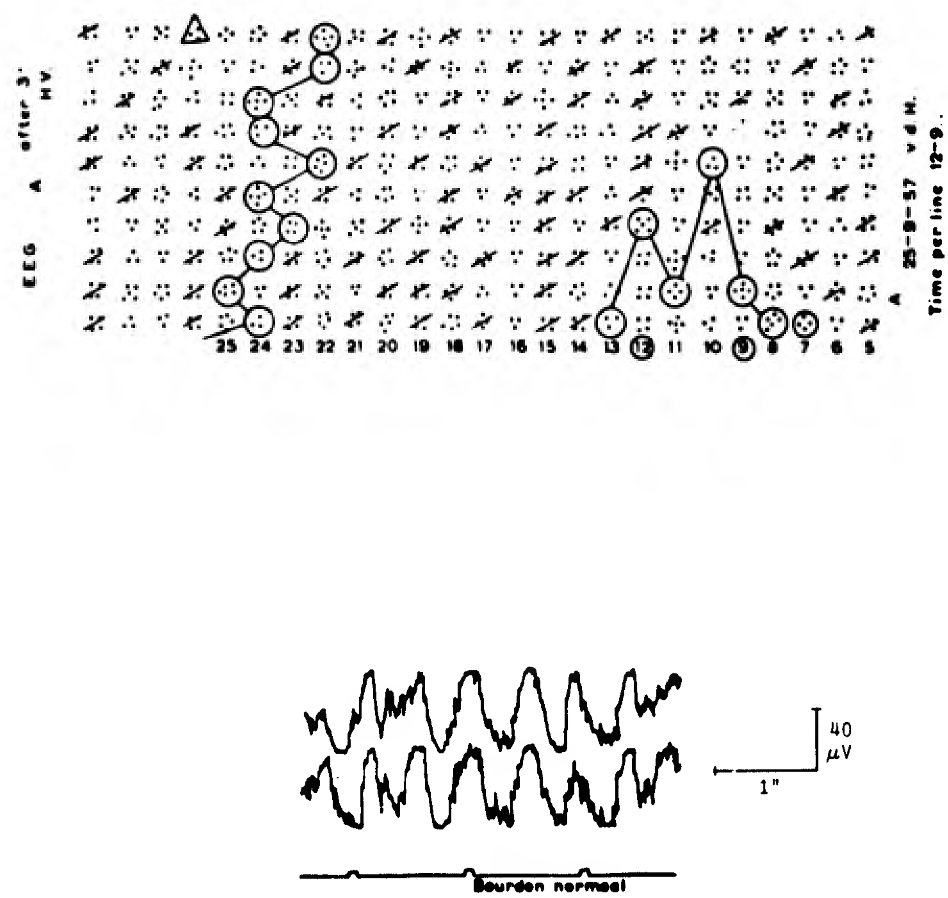
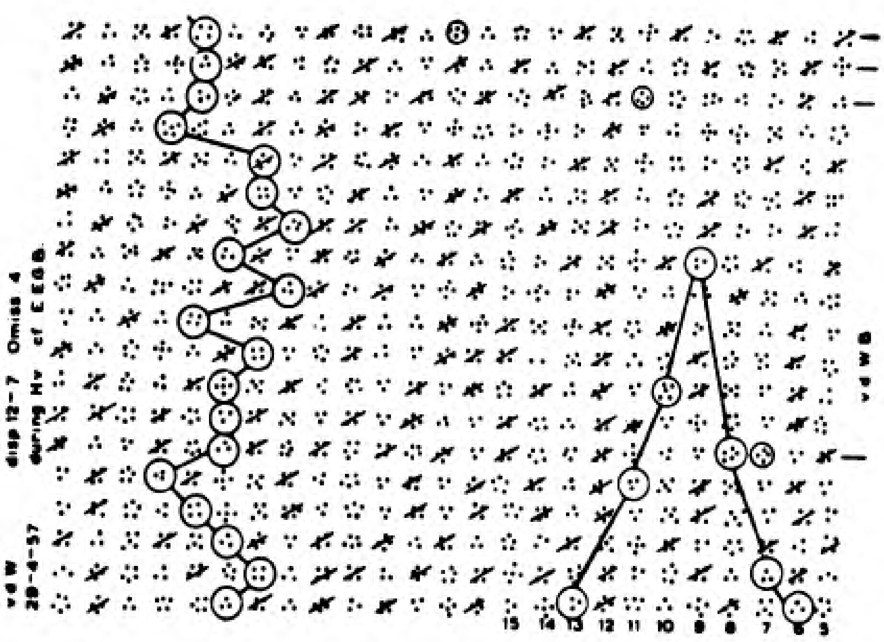


Fig. 2 Nearing the end of the third minute of hyperventilation. Stipple test: slightly irregular two peaks. EEG: irregular (multiform) delta's



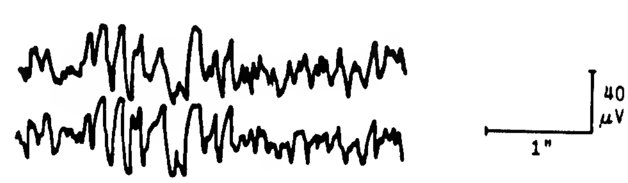


Fig. 3 After three minutes hyperventilation. Times per line at left (O) at right: distribution curve (as in Figures 1 and 2). Bottom: concomitant EEG (occipital leads) *Normal* stipple test. EEG: irregular high slow and low fast waves, characteristic after-effects of hyperventilation

THE ELECTROENCEPHALOGRAM IN THE SELECTION OF FLYING PERSONNEL

by

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SUMMARY

When making an empirical study the author observed that the EEG of the large majority of well-known civil pilots showed a monorhythmic alpha (category I). A small majority had a flat, reduced voltage or a polyrythmic EEG without alpha activity (category II). Their professional performance was almost always considered as "sub-standard". Flight engineers on the other hand had an EEG which showed almost no monorhythmic alpha. The large majority, who had a similar EEG (category II or III), were considered better than the others (category I).

In the case of trainee pilots an immaturity factor is probably responsible for their lower standard of professional performance as well as for the fact that their EEG shows no alpha activity (category II).

With regard to flight engineers as compared with licensed pilots, pupil pilots and those offering themselves for training as pilots, the psychological analyses of the personality structure would seem to indicate a correlation between the predominance of a polyrhythmic EEG and outstanding technical ability (mechanical comprehension tests).

The EEG may constitute a factor in the selection of aircrew. A flat or polyrhythmic EEG is an unfavourable sign in the case of a future pilot; an EEG which shows no alpha activity is an advantage when predicting the career of a flight engineer.

SOMMAIRE

Dans une étude empirique l'auteur a constaté que les pilotes civils renommés montrent, en grande majorité, un EEG qui se caractérise par une alpha monorythmique (classe I). Une petite minorité fait voir un EEG plat, de voltage réduit ou un polyrythmique sans alpha (classe II). Leur performance professionnelle était presque toujours considérée comme "sous-standard". Les mécaniciens de bord, au contraire, avaient un EEG presque sans alpha monorythmique. La grande majorité, qui montrait un EEG pareil (classé dans la catégorie II ou III) était considerée comme supérieure aux autres (classe I).

Il est probable que pour les aspirants pilotes un facteur d'immaturité est responsable pour leur moindre succès professionnel aussi bien que pour leur EEG sans alpha (classe II).

Pour les mécaniciens de bord, comparés avec les pilotes licenciés, les élèves pilotes et les candidats au pilotage, la prépondérance d'un EEG polyrythmique sans alpha paraît, selon les analyses psychologiques de la structure de la personnalité, en corrélation avec une prominence technique (épreuves de compréhension mécanique).

L'EEG peut être un élément dans la sélection du Personnel Navigant. Un tracé plat ou polyrythmique est un signe défavorable dans le cas d'un future pilote; un EEG sans alpha est un avantage au sujet de prédiction pour une carrière d'un mécanicien de bord.

THE ELECTROENCEPHALOGRAM IN THE SELECTION OF FLYING PERSONNEL

G. J. Puister*

This paper emphasises the threefold importance of the EEG in aerospace medicine:

(i) To detect abnormalities, such as epilepsy, which disqualifies the subject on medical grounds.

(ii) To record brain activity in the healthy individual, to use as reference in the event of possible later brain disturbances.

(iii) As an aid in the selection of aviation candidates.

This paper is restricted to point (iii): the EEG in the selection of flying personnel.

Many articles have been written about the relationship between electroencephalographic and psychological data in normal adults and a countryman of mine, Dr Werre, devoted his Doctor's thesis to this subject. He gives a list of authors who wrote about this problem, among whom we find the names of Gastaut, Walter and Mundy Castle.

The trouble with these investigations is that there is no uniformity in classification of the EEG and, for this reason, comparison of the results is very difficult. Therefore I felt free to choose my own classification as shown later.

Moreover, the number of subjects in these studies is rather small, sometimes even below 50, which makes me feel somewhat insecure with regard to the conclusions.

Thirdly, as far as I know, all these analyses are done with groups of people who were already incorporated in a special job, whether as a pilot or as a truck driver. So selection has taken place already and nobody can tell whether there was a difference in the EEG's of those who were rejected and those who were elected for the specific job.

In this study I have tried to escape the last two objections. I used relatively large numbers and I made the EEG's of all applicants *before* their pilot selection. I based the classification of the EEG mainly on the *qualities* of the alpha rhythm, disregarding the alpha *frequency* in the pattern.

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* Dr Puister, Head of the Medical Examinations Department, prepared this paper for an AGARD meeting but had no occasion to read it. After his untimely death the Editor considered it appropriate to include this contribution on an EEG subject in the present volume as a tribute to this eminent expert in aviation medicine.

I chose this particular system of grouping because it struck me, from a study of van Wulfften Palthe's work[1], that among the 300 EEG's of pilots and student pilots, which he revised on account of variations in the normal EEG, 11% showed either a poor polyrhythmic alpha pattern or a nearly flat record.

Of these 300 EEG's, 78 were from student pilots, 10 of whom showed a flat or polyrhythmic record. Nine of this group of 10 failed in their pilot training. From the 68 with an average to good alpha pattern, 32 were discarded. These figures gave - statistically speaking - sufficient reason to start an investigation on a larger scale.

Using the quality of the alpha rhythm as a parameter, I divided the analyzed EEG's into two classes.

Class I includes all EEG's with a good alpha pattern, independent of the time percentage. My only criterion was the presence of a more or less monorhythmic alpha. Figures 1 and 2 illustrate two extreme possibilities in this class.

In the EEG's of class II, there is either no manifest alpha activity, the EEG showing a flat low voltage record, or the pattern is polyrhythmic without a monorhythmic alpha. The Figures 3 and 4 are examples of EEG's of class II.

After this introduction, I arrive now at the gist of my argument. The hypothesis, after cognisance of van Wulfften Palthe's paper[1], was as follows.

A good alpha rhythm is required for a successful pilot. You have to emphasise successful because anybody can learn to fly, just as anybody can learn to drive a car, but not everybody is a success on the road.

The converse of the tentative proposition is: a very poor or lacking alpha rhythm is incompatible with the qualification "successful pilot". Those are the subjects with an EEG in class II.

Could I prove this hypothesis?

I think there are indications in the following which at least support my assumption.

As subjects for this study, I used applicants for the Netherlands National Aviation School for Civil Pilots. Their selection procedure gives good results and includes, apart from a medical examination during which an EEG is taken, psychological testing and a fortnightly grading, including Link-training and flight tests. Those, who did not fail this procedure, are seen by a selection board, which allots the available places from personal interviews and test marks. It stands to reason that up to now the EEG, made purely for medical reasons, played no part in this process.

About 97% of the pupils, selected in this way, obtain their licence as a civil pilot. Most of the 3% who do not finish the course, leave prematurely for medical reasons (1%) or on their own volition.

The number of candidates admitted to this selection procedure was 360. The division according to my EEG classification was as follows:

Class I:	76.4%	Figure 5
Class II:	23.6%	

Out of these 360 candidates, 71 were admitted to the school. The EEG of only three of the admitted candidates belong to class II (4.2%) (Fig.5).

As I said before, my appraisal of the EEG was not known to the selection board and I predicted "failure" for those in class II before the selection was made.

The next thing I was interested in, was the answer to the following question:

"Is there a common trait in the psychological profile of those candidates coming under the EEG classification II?"

I must disappoint you - I could not find a conclusive answer to that question.

The only trend the psychologist came across was that there were slightly more immature candidates in class II than in class I. So I can only give you the facts as I found them.

My proposition that a well organised alpha pattern is required for a successful pilot is supported by a survey from the EEG's of 700 licenced pilots (Fig.5(c)).

I found that 4.6% belong to class II, a very low percentage if you compare it with the 23.6% found in the unselected candidate pilots (Fig.5).

Only a few of these 4.6% came originally from the National Aviation School for Civil Pilots; most of them were either former military pilots or foreigners flying for a Dutch company. With regard to their flying performance, it appeared that almost everybody in this (class II) group was assessed by "standard minus".

Summarising, I have come to the conclusion that it may be justifiable to use the EEG in the selection of candidate pilots. However, there is the restriction that on the one side a flat or polyrhythmic EEG pattern might be used, in combination with other selection items, to reject a candidate pilot, but that on the other hand a good alpha pattern *alone* is no guarantee that the subject will become a successful pilot.

Continuing this empirical investigation we considered the EEG documents of pilots in comparison with those of flight engineers[2].

Taking the amount of monorhythmic alpha activity as a parameter, the analysed EEGs were now divided into three classes.

Class I includes all the EEGs with a clear alpha pattern independent of the time percentage of alpha waves. The only criterion for placing an EEG in this class was the presence of monorhythmic alpha waves. The EEGs of class II are polyrhythmic without a dominant alpha frequency. Class III includes the EEGs with a flat, low voltage, fast pattern, without a manifest alpha activity.

We tried to prove the assumption that, the good pilots are the ones with a well developed monorhythmic alpha pattern and on the other hand a polyrhythmic EEG or an EEG lacking manifest alpha activity is incompatible with the qualification of a successful pilot.

In our opinion there were quite strong arguments to sustain this assumption but, as we suspected a common trait in the psychological field of those falling under the heading class II and/or class III, we thought it justifiable to investigate the possibility of a correlation between EEG pattern and psychological profile.

The provisional results were rather disappointing, the only trend being that slightly more immature candidate pilots were found in class II - those with a polyrhythmic EEG - than in the two other classes.

This fact was not unexpected, as the EEG's of class II very often resembled EEG's normally found at a much younger age. Going over the selection results once more, it struck us that all candidates with good psychological end results in combination with a flat, low voltage, fast EEG (class III), had failed on the flight simulator and/or in the practical flying tests at a later stage of the selection procedure. It appeared that these candidates reached such a high final score on their psychological tests because the results of the *technical* insight test (mechanical comprehension) were always very favourable and it was presumed that technical insight was a very important asset for a future pilot.

A factorial analysis now done by one of us (J.Modderaar, psychologist), produced a factor showing a relation between the EEG and the mechanical comprehension test, with the effect that an EEG class II or III was more often met with in those candidates having a higher score on this test than the mean. In other words: candidates with an EEG class II or III showed more technical insight.

Could we verify this information along other lines?

There is a group of aircrew members where a higher technical insight than average may be expected. We mean the flight engineers. Therefore the next hypothesis was drawn up.

"Flight engineers will show a higher percentage of class II and III EEG's than licenced pilots or even unselected pilot candidates (aspirants)."

To that end the EEG's of 350 KLM flight engineers were analysed. In Figure 6 the result of this analysis is shown and compared with licenced pilots, student pilots and candidate pilots (aspirants). If the percentage class II and III in group 4 is compared with the other groups, we feel convinced that this hypothesis is confirmed.

The next question now arising is

"Are flight engineers coming under the EEG classification II or III better than average, just as the pilots in these categories were on the average rated lower than their colleagues in class I?"

It was found that flight engineers with an EEG class III - no alpha activity - were rated slightly better than average and that those falling under the heading class II - polyrhythmic patterns - were rated somewhat lower than average.

Probably an immaturity factor, as found in the candidate pilots with a class II EEG, overshadows the technical insight factor to such an extent that in practice his proiciency is below average.

Summarising, it may be concluded that the results of this study seem to justify the use of electroencephalography as an item in the selection of aircrew members. The finding of a flat or polyrhythmic EEG should then be considered as a liability in the case of a future pilot and as an asset (at least with regard to those EEG's without alpha activity) in the flight engineers.

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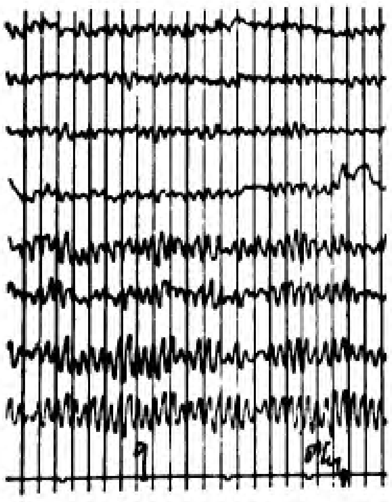

Figure 1

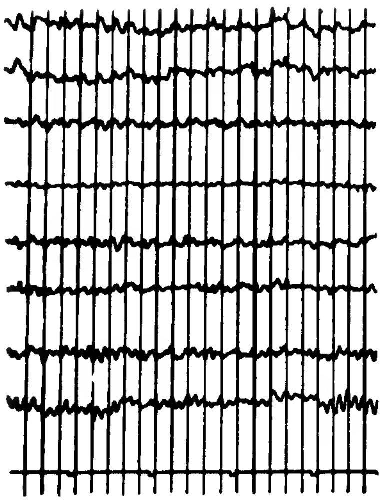

Figure 2

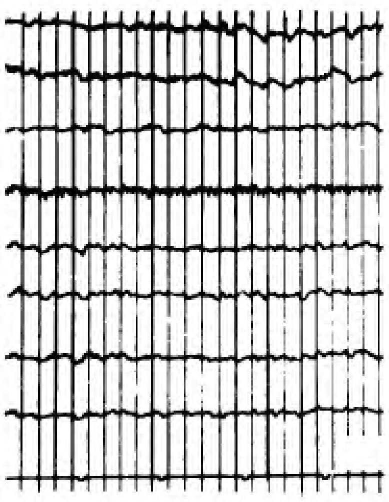

Figure 3

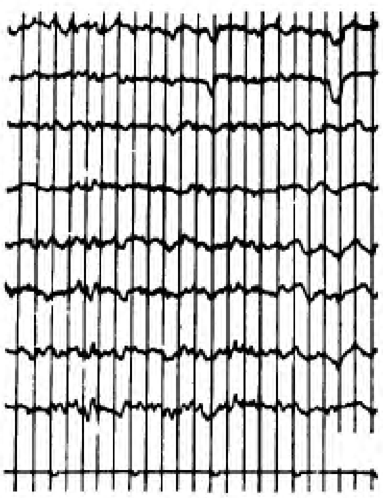

Figure 4

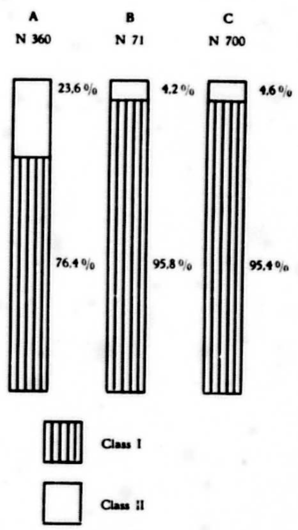

Figure 5

A = 360 aspirants admitted to the *selection* procedure
B = Student pilots (admitted to the school: 71)
C = Licenced pilots (700)

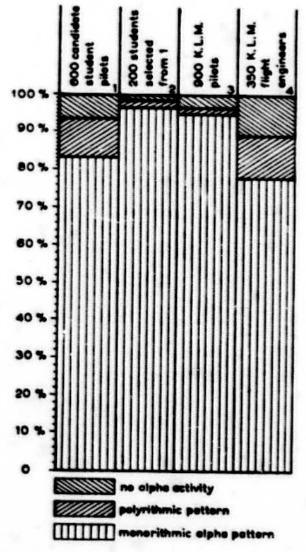

Figure 6

P A R T IV

SOME SPECIAL PROBLEMS

ELECTROENCEPHALOGRAPHIC CHANGES IN HUMAN SUBJECTS DURING BLACKOUT PRODUCED BY POSITIVE ACCELERATION

by

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SUMMARY

Each of 13 human subjects was subjected alternately to a set of peak accelerations of 6 and 7G on two separate occasions. Peak G was attained in approximately 30 seconds after the initiation of a symmetrical, sinusoidal acceleration profile. One channel of EEG was recorded by placing two active electrodes, one on the right and one on the left side of the calvaria, approximately 2 cm above and lateral to the occipital protuberance. The indifferent electrode was placed over the forehead in the midline.

Analysis of the taped EEG signals was accomplished by a 14-channel, continuous frequency analyzer using bandpass filters manufactured by Epsco. The voltage output of each bandpass filter was rectified and passed through a smoothing filter in order to obtain a direct current voltage proportional to the amplitude of the frequency band passed by each filter.

Frequency analysis showed characteristic changes during visual greyout and blackout. An increase in beta frequencies, 16-36 c/s, occurred which showed the same general amplitude pattern as the acceleration profile. The lower beta frequencies, 16-19 c/s, had a tendency to level out or to decrease during each blackout coincident with an increase in the lower frequency components. The alpha frequencies, 8-13 c/s, often appeared during greyout and blackout, but may disappear during very deep blackout when bursts of high amplitude, low frequency components appear. The best index of the level of consciousness appears to be the inverse relationship between the depth of blackout and the amplitude of EEG frequencies in the range of 5 c/s. The lower delta frequencies were not used since artefacts due to electrode displacement resulting from head movement were seen most frequently in this range of frequencies. Moreover, the 5 to 7 c/s frequency band is associated with cerebral hypoxia which occurs during positive acceleration. This frequency band was also shown to be related to performance of specific performance tasks.

SOMMAIRE

Treize sujets furent soumis à tour de rôle à une série d'accélérations maximales de 6 et 7G à deux occasions différentes. L'accélération maximale fut atteinte environ 30 secondes aprés le début d'un profil d'accélération symétrique et sinusoïdal. On enregistra un canal d'électro-encéphalogrammes à l'aide de deux électrodes actives, placées l'une à droite et l'autre à gauche du sinciput, à environ 2 cm au dessus de la protubérance occipitale, et latéralement à cette dernière. L'électrode indifférente fut placée au-dessus du front, sur la ligne médiane.

L'analyse des signaux électro-encéphalographiques enregistrés sur bande fut effectuée par un analyseur à fréquence continue et 14 canaux, utilisant des filtres passe-bandes fabriqués par Epsco. La puissance de voltage de chaque filtre de bande fut rectifiée et passée à travers un filtre régulateur afin d'obtenir un voltage de courant continu proportionnel à l'amplitude de la bande de fréquence traversant chaque filtre.

L'analyse de fréquence révéla des changements caractéristiques au cours du voile gris et du voile noir visuels. Une augmentation des fréquences béta (de 16 à 36 cycles par seconde) se produisit, qui révéla la même courbe générale d'amplitude que le profil d'accélération. Les basses fréquences béta (de 16 à 19 cycles par seconde) marquèrent une tendance à rester stationnaires ou à décroître pendant chaque phase de voile noir coïncidant avec une augmentation des composantes de basse fréquence. Les fréquences alpha (de 8 à 13 cycles par seconde) apparurent fréquemment pendant le voile gris et le voile noir; toutefois, elles peuvent disparaître au cours d'un voile noir trés intense lorsque surviennent des phases soudaines de composantes de forte amplitude et de basse fréquence. L'indice qui révèle le mieux le niveau de conscience semble être la rapport inverse entre l'intensité du voile noir et l'amplitude des fréquences électro-encéphalographiques de l'ordre de 5 cycles par seconde. On n'a pas eu recours aux basses fréquences delta car les résultats sont trés souvent faussés pour ce domaine de fréquences du fait des déplacements d'électrodes occasionnés par les mouvements de la tête. En outre, la bande de fréquence comprise entre 5 et 7 cycles par seconde est associée à une hypoxie cérébrale qui survient au cours des accélérations positives. L'expérience a également démontré que cette bande de fréquence est liée à l'accomplissement de tâches spécifiques.

ELECTROENCEPHALOGRAPHIC CHANGES IN HUMAN SUBJECTS DURING BLACKOUT PRODUCED BY POSITIVE ACCELERATION

R. D. Squires, R. E. Jensen, W. C. Sipple and J. J. Gordon

1. INTRODUCTION

The use of the electroencephalogram (EEG) as an index of the level of consciousness for human subjects undergoing severe environmental stresses, such as would be experienced in high performance air or spacecraft and various flight simulators, has attracted the attention of a number of investigators[1-5].

The correlation between levels of consciousness and/or alertness and EEG activity has been fairly well established by others - particularly with regard to levels of anesthesia, sleep, hypoxia, visual attention, etc.[6-11]. However, it still remains to be shown that a lowered level of consciousness in a subject, as reflected in his ability to perform a specific task, can be ascertained from real time EEG information. Equally important is the early prediction of impending loss of consciousness, which again depends on the detection of variations in the levels of consciousness, well above the threshold of complete loss of consciousness.

When continuous performance information is not available from a subject on a hazardous environment, which is most often the case since he must be free to perform other required tasks, it is felt that the EEG may furnish a useful index of his performance capabilities for medical monitoring purposes.

The Aviation Medical Acceleration Laboratory (AMAL) centrifuge provides a useful platform for varying the level of consciousness of human test subjects in an environment which is similar to actual flight conditions. It has the advantage over in-flight recordings in that experiments can be controlled and reproduced with a maximum of safety to the participants. Consequently, a study was undertaken on a series of subjects undergoing positive acceleration centrifuge runs, at a level sufficient to lower head blood pressure to a point where visual grey and blackout conditions would occur. The purpose of the study was to evaluate the use of the EEG information on these subjects as an index of their level of consciousness, their depth of visual blackout and their performance capabilities under acceleration.

2. METHODS

Each of 13 human subjects was subjected alternately to a set of peak accelerations of 6 and 7G on two separate occasions. Peak G was attained in approximately 30 seconds after the initiation of a symmetrical, sinusoidal acceleration profile. The resultant inertial force vector was directed toward the feet, i.e., positive acceleration.

Subjects consisted of six Navy pilots and seven experienced centrifuge functionaries selected from laboratory personnel. One channel of EEG was recorded by placing two active electrodes, one on the right and one on the left side of the calvaria, approximately 2 cm above and lateral to the occipital protuberance. The indifferent electrode was placed over the forehead in the midline. The description of the electrodes used and the method of restraint employed has been previously described[12]. A standard Navy flight helmet was worn over the elastic electrode restraint.

The EEG signal was first amplified by a modified Litton* preamplifier carried in the breast pocket of the subject's flight suit before passing the signal through the centrifuge slip-rings to an Offner type R dynagraph and a Precision Instrument type 207 tape recorder.

Additional instrumentation included was a sensitive 50 kc bridge circuit attached to the EEG electrodes so as to evaluate electrode movement as a possible source of artifact in the EEG trace due to head movement during acceleration.

The experimental procedure called for an eyes-closed period before and after each acceleration. The appearance of the alpha frequencies served as a check on the intactness of the system, and served to set the gain of the recorder amplifier to full scale deflection in terms of the amplitude of the eyes-closed alpha pattern for each subject. The system required approximately three seconds to obtain 95% of maximum deflection for a change in frequency amplitude.

Analysis of the taped EEG signals was accomplished by a 14-channel continuous frequency analyser using bandpass filters manufactured by Epsco†. The voltage output of each bandpass filter was rectified and passed through a smoothing filter in order to obtain a direct current voltage proportional to the amplitude of the frequency band passed by each filter. The channels, with their bandwidths as determined by calibration, are given in Table I.

Then the tapes were played back into the frequency analyser. The amplitude of the centre frequency for each bandpass filter was adjusted to this same magnitude of deflection for maximum eyes-closed alpha amplitude for each subject, by adjusting the gain of the recorder amplifiers. This method of scaling does not take into consideration the increase in bandwidth of the higher frequency filters, which could allow as much as 10 times the contribution from a uniform frequency distribution signal at the highest frequency.

3. RESULTS

Useful EEG records were obtained for more than 90% of the centrifuge runs. Good eyes-closed, alpha patterns were obtained before and after accelerations. Freedom from large amplitude head motion artefact due to electrode displacement was shown by the absence of large fluctuations in the output of the bridge circuit (Figure 1(a) and (b)). Large amplitude fluctuations from the bridge circuit, however, did result from forced, voluntary head movements prior to acceleration. In addition the signal

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* Litton Industries, Electronic Equipment Division, 336 N. Foothill Rd, Beverley Hills, California.

† Epsco, Worcester, Massachusetts.

levels during acceleration were less than or comparable in amplitude to the pre-acceleration eyes-closed alpha pattern, while signal fluctuations associated with forced, voluntary head motions were frequently greater.

The appearance of noise, while the centrifuge was turning, due to electrical and mechanical interference from the slip-rings was minimised by sufficient pre-amplification of the signal prior to sending it through the slip-rings. That this was satisfactory was shown by the fact that, although most runs showed an increase in signal level sometime during acceleration, there were some that failed to do so and, in the poor performing groups, the signal level fell to baseline levels during loss of consciousness at peak G. The contribution of the neck and jaw muscle potentials, during acceleration to the high frequency analysis channels, is difficult to evaluate or separate from increase in high frequency beta EEG activity; however, even if present it supports the conclusion of increased subject activation, which decreases or disappears during decrease in the level or loss of consciousness (Figure 3, Subject R. Mc.II).

4. EEG FREQUENCY ANALYSIS

Analysis of a typical EEG pattern during acceleration is shown in Figure 2. This 14-channel analysis shows the characteristic changes observed during visual greyout and blackout conditions. The increase in high frequencies (16-36 c/s) shows the same general amplitude pattern as the acceleration profile. The lower range of beta frequencies (16-19 c/s) have a tendency to level out or to decrease during early blackout, coincident with an increase in the lower frequency components. The alpha frequencies (8-13 c/s) often appear during greyout and blackout but may disappear at very deep blackout, when bursts of high amplitude low frequency components appear. The amplitude of alpha frequencies seen during visual blackout was much less than seen during eyes-closed before acceleration.

5. EEG DURING BLACKOUT

For routine real-time monitoring and ease of presentation, three characteristic frequencies were chosen: delta, 5.0; alpha, 10.0; and beta 28.0 c/s. These frequencies are shown in Figure 3 for three runs showing visual greyout, blackout and unconsciousness. The mean changes in these three frequencies are shown in Figure 4 during the time course of acceleration, along with the mean blackout characteristics of the three groups. The mean percentage amplitude change during the run as a whole on each of the frequency bands is given in Table II. This table shows that among the three blackout groups the high frequency activity was different, i.e., the poor subjects often had the highest initial beta frequency levels and the appearance of alpha during blackout was low in amplitude. The best index of the level of consciousness appears to be the inverse relationship between the depth of blackout and the amplitude of EEG frequencies in the range of 5 cycles per second. This frequency band will be shown later to be related in the same way to performance level. The lower delta frequencies (5.5 c/s) were not used since artefacts, due to electrode displacement resulting from head movement, were most frequently seen in this range of frequencies. Moreover, the 5 to 7 frequency band is very often seen in cerebral hypoxia, which occurs during positive acceleration (Fig.5).

The increase in the low frequencies may, however, disappear along with the disappearance of all frequencies when loss of consciousness occurs and therefore, its value as a monitoring criterion lies in the detection of situations *leading* to unconsciousness or greatly reduced consciousness levels, rather than the occurrence of unconsciousness.

6. EEG AND PERFORMANCE

Relating EEG with blackout, by itself, represents an indirect correlation with the level of consciousness since it is most probably an indication of the head level blood perfusion pressure common to the eyes and brain. Consequently, a correlation of the EEG with the performance of the subject during acceleration was desirable, independent of his visual condition. Subjects unable to respond during deep visual blackout and unconsciousness have already been discussed (Group III). In order to study less severe impairment of performance, all subjects were subjected to two additional accelerations. They were instructed to respond, by depressing the finger switch once if the sum was odd or twice if the sum was even, to pairs of numbers given by voice every five seconds. The time between the maximum audio signal corresponding to the second number and the response of the finger switch was taken as the response time. If an error was made the response time was scored as one second. These errors, however, were rare. Approximately two-thirds of the subjects showed a marked increase in response time during accelerations from the 0.5 second control level to over one second during acceleration. The other third of the subjects responded with essentially no increase in response time during acceleration even though in prolonged blackout. This group is characterised in Table III as Group IV and the poorly performing group is Group V. The time course of their EEG and performance pattern is shown in Figure 6.

Several major points of comparison arise from these two groups. In the first place the good performers had, on the average, longer blackout times and lower G thresholds for blackout than the poor performers. This may possibly be explained by the second point. The good performers were all operational Navy pilots with little centrifuge experience, while the poor performers were largely laboratory personnel with considerable centrifuge experience but with very little experience with performance tasks. Thirdly, the good performing subjects (Group IV) showed less of an increase in the 5 and 10 cycle per second frequencies than the poor performing subjects (Group IV) and the short-blackout subjects (Group I). It would, therefore, appear that a closer relationship exists between the appearance of the slower frequencies and performance than between the slower frequencies and blackout. The EEG response of the poor performers fell between that of the first and second groups as would be predicted on the basis of their blackout duration.

The poor performers could be subdivided further on the basis of the pattern of their prolonged response time. Half of this group made errors at the start and end of the run while performing well during blackout and the other half showed their worst performance at peak acceleration.

7. DISCUSSION

There was a large amount of variability demonstrated on the EEG patterns of subjects subjected to positive acceleration. Consequently, attempts to demonstrate significant statistical differences between mean frequency amplitudes in the control and acceleration periods, never exceeded the 0.1% level. Such a statistical analysis, even when not showing high probabilities, does show a trend in the type of EEG patterns which may be associated with greyout and blackout conditions and the ability to perform a mental activity task. This trend may be emphasized by further refinement of technique and by further study of the factors involved.

For real-time monitoring purposes it is necessary to know, not the probability of the mean of a population but the probability of a single individual falling into a particular group. This probability decreases, depending on how finely the medical monitor wants to classify the condition of the subject and increases if all that is wanted is an indication of incipient loss of consciousness. In the case of the groups analysed such probability is 3 or 5 to 1 that a subject showing a certain EEG pattern will fall into a low or high blackout threshold group, while the probability may be as high as 10 to 1 that loss of consciousness can be predicted from his EEG pattern.

These studies clearly show that the satisfactory recording of the microvolt level EEG signals can be accomplished by using monitorised equipment on subjects undergoing high environmental stresses, with little inconvenience to the subject. The electronics involved are readily compatible with miniature low power telemetry systems, which can transmit the EEG from remote locations. The use of a single channel has been found to give useful information with a minimum of equipment, while the use of standard bandpass filters at three control frequencies has allowed the real-time low speed recording, 1 mm per second, of the single channel EEG data with sufficient information content to determine, with a fair probability, the level of consciousness of the monitored subject.

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TABLE I

Calibration of Band Pass Filters

CENTER FREQUENCY	2.5	4	5.5	7.5	8.5	9.5	10.5
50% down frequency	1.9 – 2.9	3.5 – 4.5	5.2 – 5.9	7.0 – 8.0	7.7 – 9.2	9.1 – 10.3	9.7 – 11.2
90% down frequency	1.6 – 5.0	3.0 – 5.5	4.5 – 6.2	5.5 – 8.5	7.0 – 10.5	8.0 – 11.5	8.7 – 12.0
CENTER FREQUENCY	11.5	13	16	19	23	29	36
50% down frequency	11.0 – 12.5	12.6 – 13.5	14.0 – 17.0	18.0 – 21.0	20.0 – 26.0	26.0 – 30.0	32.0 – 38.0
90% down frequency	10.3 – 13.5	10.5 – 15.0	12.5 – 20.0	15.0 – 25.0	16.0 – 29.0	22.0 – 34.0	24.0 – 48.0

TABLE II

Average Responses to Acceleration of 5 Subject Groups[1]

	No. of Subjects	*No. of Runs*	*Grayout[3] Onset Time (sec)*	*Blackout Onset Time (sec)*	*Duration of Blackout (sec)*	*Duration of No Responses (sec)*	*Mean Performance Response Time (Control = 0.52 sec)*
Group I	7	11	26	29	6	–	–
Group II	6	13	20	24	18	–	–
Group III	4	6	23	25	6	21	–
Group IV[2]	3	5	21	26	15	–	0.56
Group V[2]	7	10	24	27	9	–	0.69

1 Classed according to each run. Subjects can appear in more than one group.

2 Grayout and blackout information was obtained from subjects during their non-performance task runs.

3 Peak G attained 30 seconds from start.

TABLE III

Average Change in the Amplitudes of 3 EEG Frequencies in Subject Groups During Acceleration

	Duration of Blackout (sec)	*Mean Performance Response Time (Control = 0.52 sec)*	*Percent Increase in EEG Amplitude at*		
			5 cps	*10 cps*	*28 cps*
Group I	6	–	27	9	17
Group II	18	–	67	18	42
Group III	27[1]	–	170	33	54
Group IV	15[2]	0.56	20	3	36
Group V	9[2]	0.69	36	12	27

1 No response or unconsciousness included as blackout.

2 Grayout and blackout information was obtained from subjects during non-performance task runs and from verbal reports during performance runs.

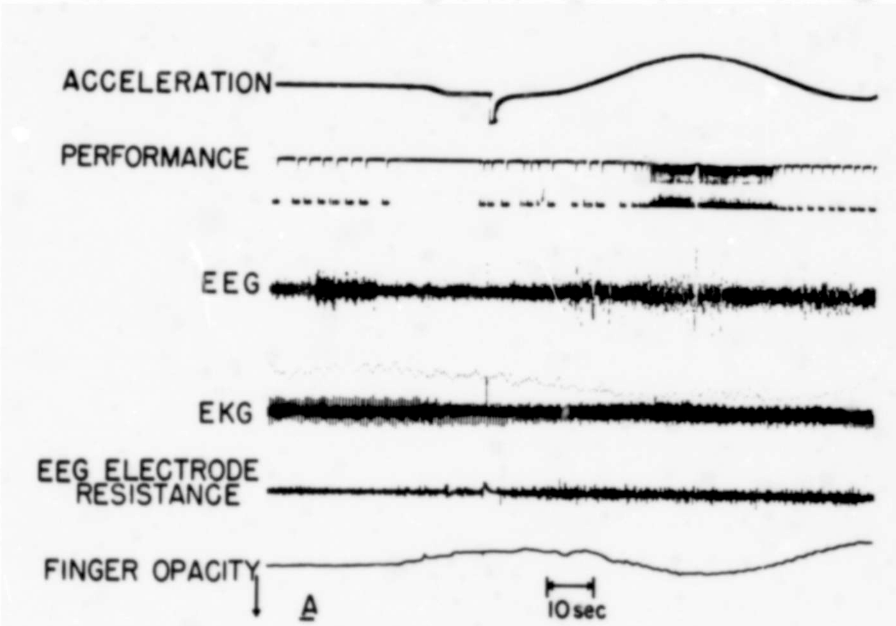

Fig. 1(a) A 6G centrifuge run during which the subject experienced a 25-second period of visual blackout indicated by the period of rapid depression of the finger switch on the performance trace.
(Note the increase in amplitude of the unfiltered EEG without concomitant increase in change of electrode resistance indicative of electrode resistance)

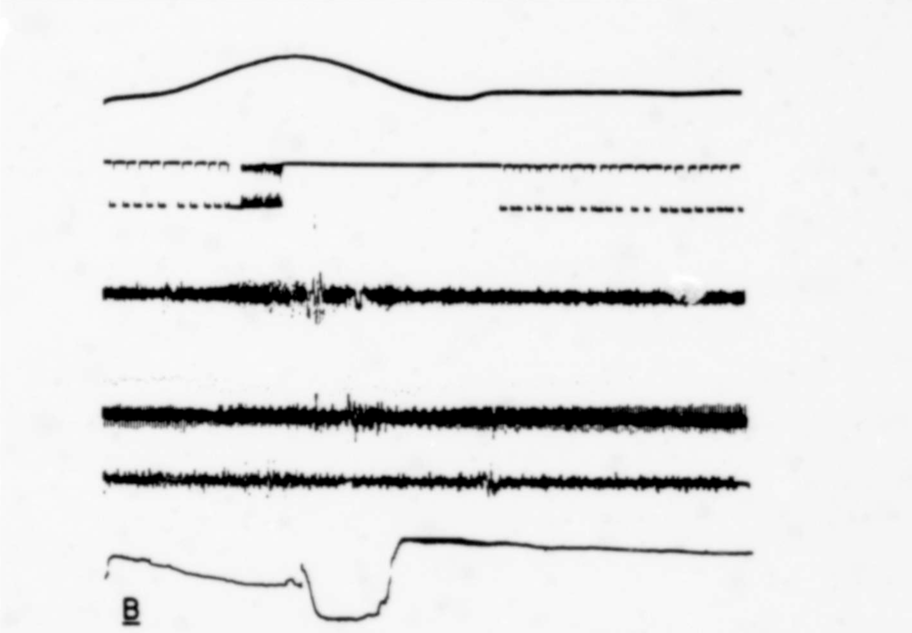

Fig. 1(b) A 6G centrifuge run during which the same subject experienced a 9-second period of visual blackout followed by unconsciousness indicated by the period of no switching immediately following blackout. (Note lack of evidence of change in electrode resistance.) There is a marked fall in finger opacity at the onset of unconsciousness due to displacement of blood from the finger fixed at the level of the right atrium

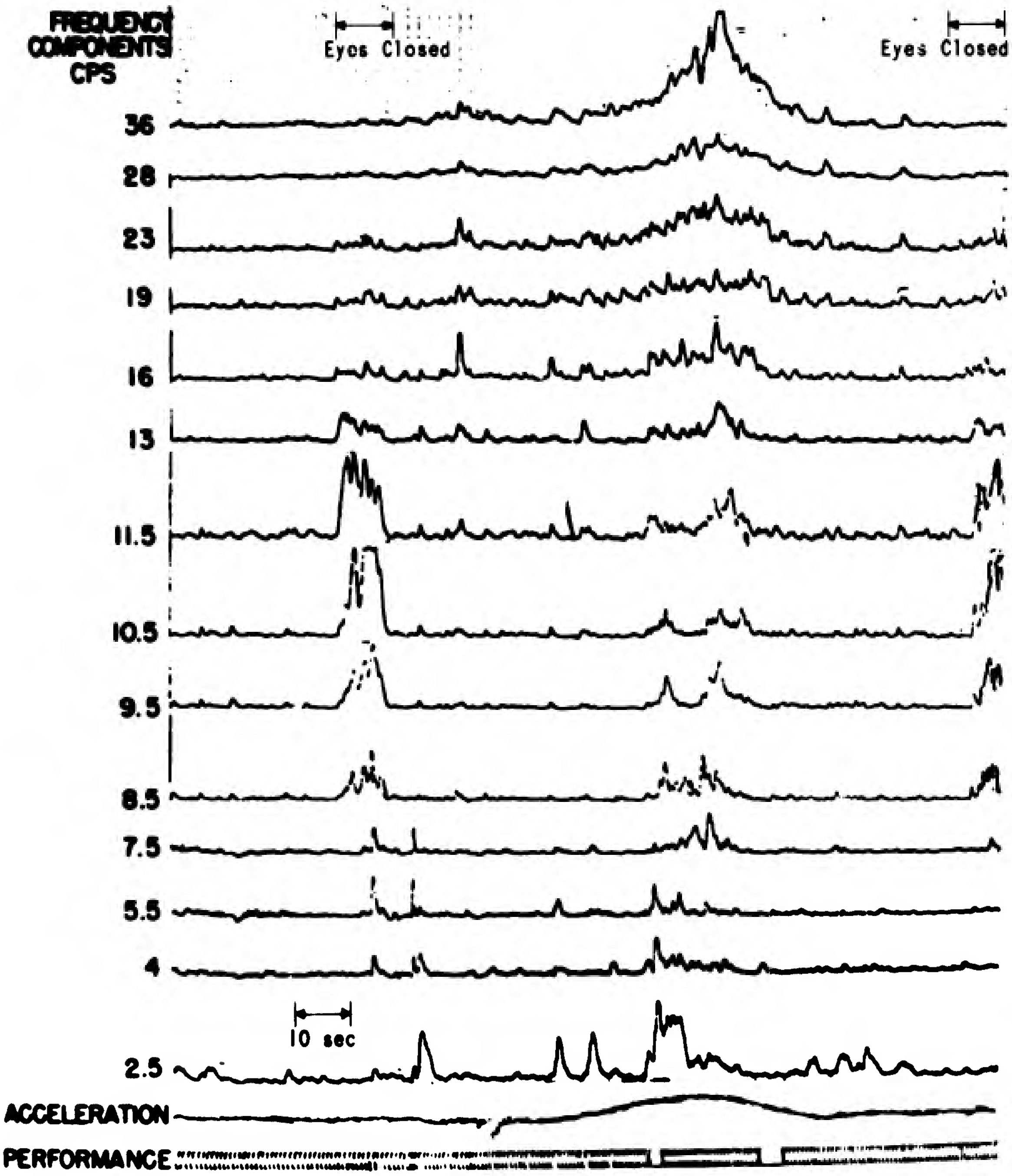

Fig. 2 Multiple filter EEG frequency analysis showing changes occurring during positive acceleration

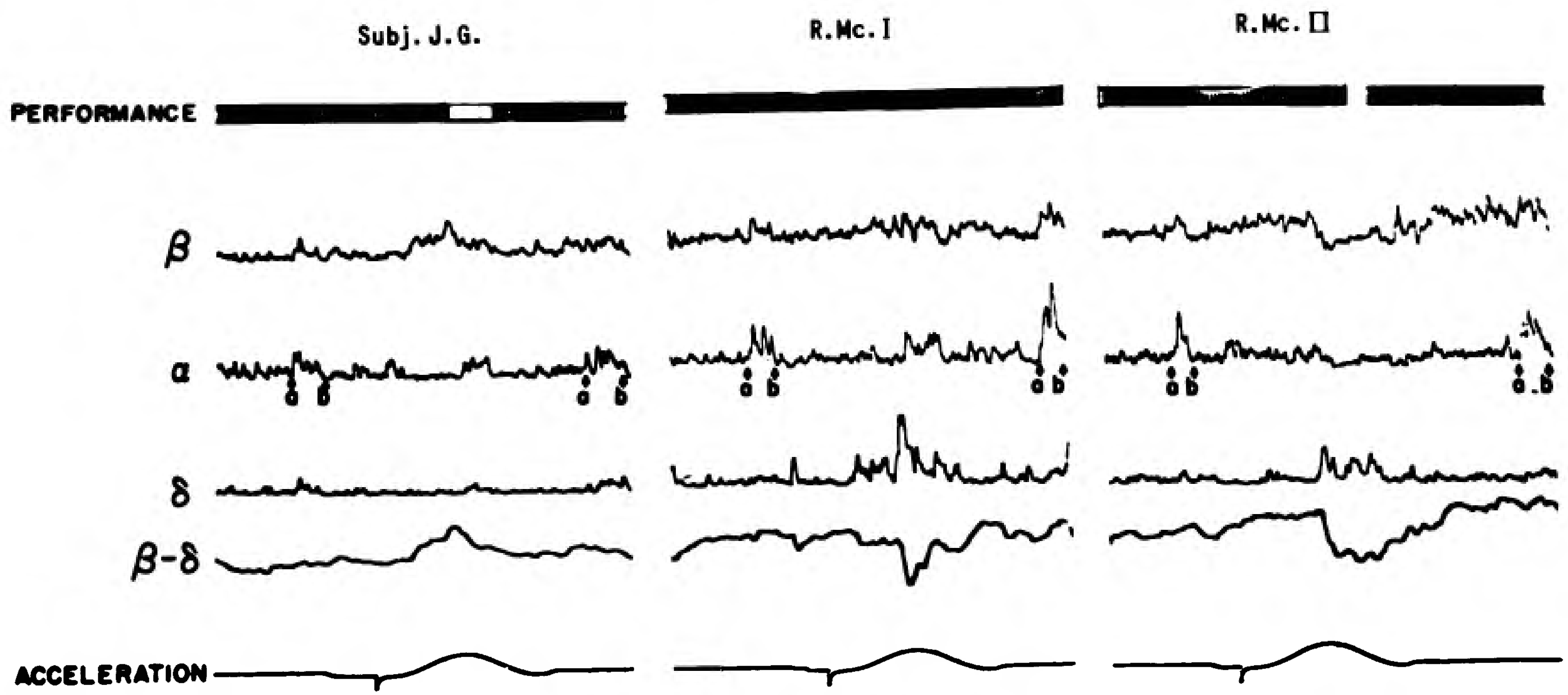

Fig. 3 EEG effect of positive acceleration

Subject J.G. experienced greyout during the *blank* period in the performance task.
Subject R.Mc.I experienced blackout during the *black* period in the performance task.
Subject R.Mc.II experienced blackout during the *black* period and unconsciousness during the *blank* period in the performance task.

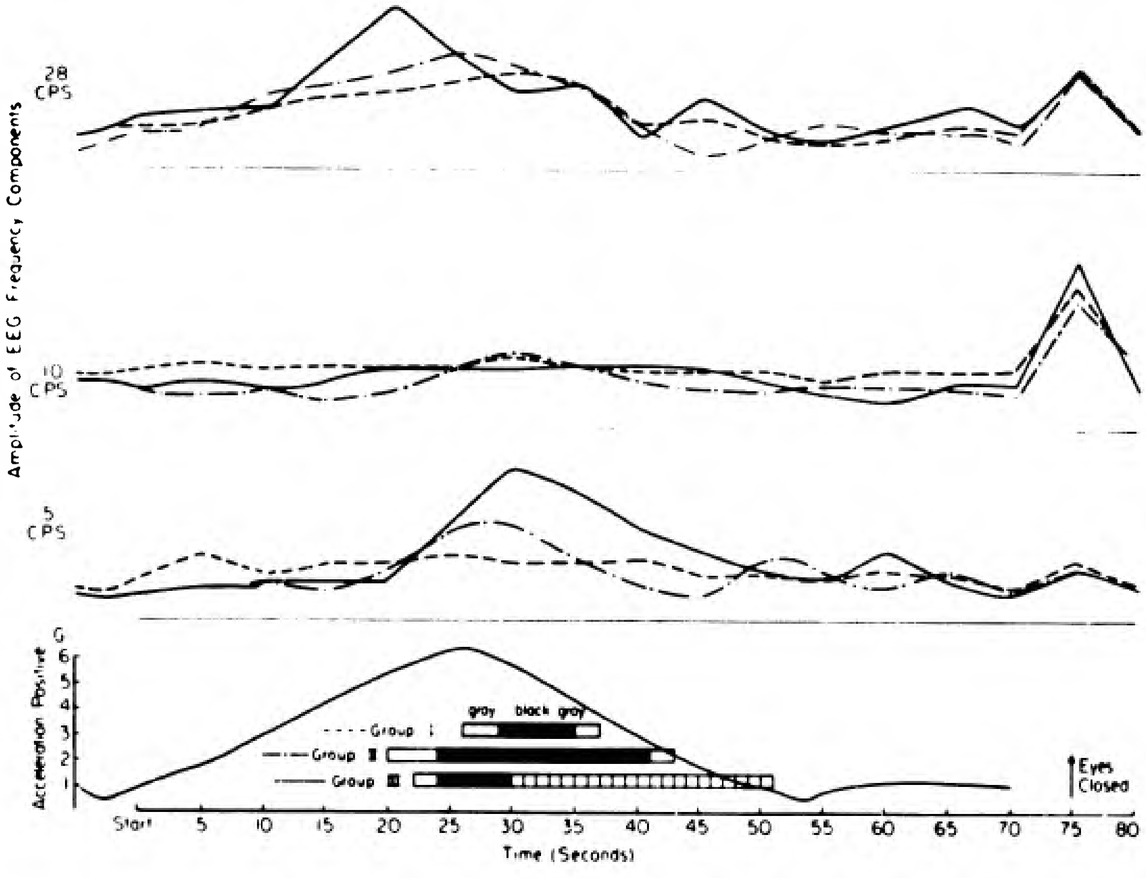

Fig. 4 Mean changes in the three frequencies (shown in Figure 3) during the time course of acceleration along with the mean blackout characteristics of the three groups

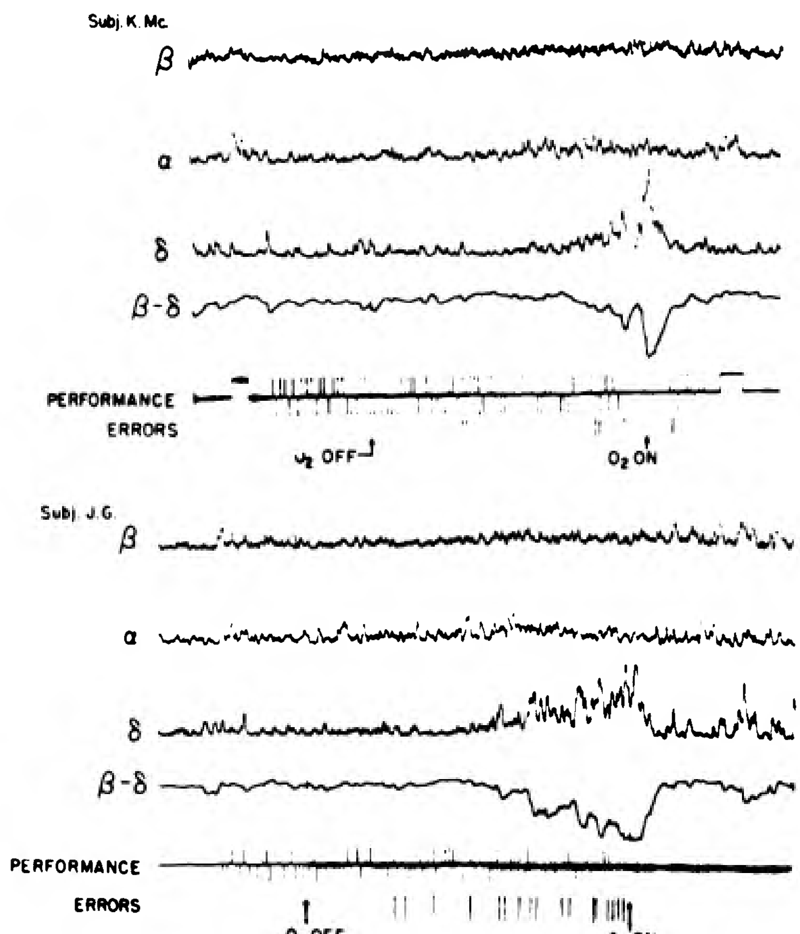

Fig. 5 EEG 27,000 ft effects of hypoxia

The 5 to 7 frequency band is frequently seen in cerebral hypoxia which occurs during positive acceleration.

Hypoxia results in increase in delta activity without apparent changes in the alpha or beta activity.

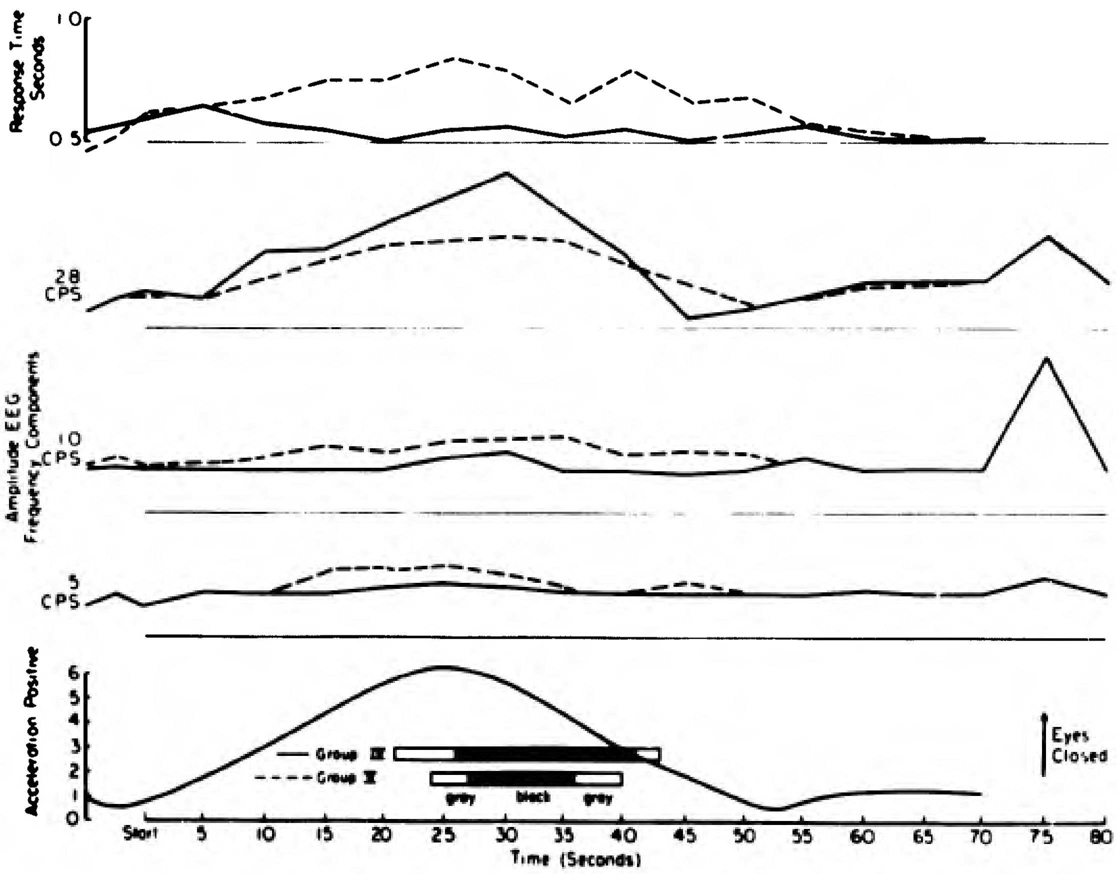

Fig. 6 Groups IV and V. Time course of EEG and performance pattern

ELECTROENCEPHALOGRAPHY AND FLUCTUATIONS IN THE LEVEL OF CONSCIOUSNESS

by

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SUMMARY

Basic investigations of short duration (3 hours) have been carried out at the Aero-Medical Centre at Soesterberg on 48 subjects of different ages and different occupations.

Extreme conditions of isolation, obscurity, and silence were combined with a restriction on mobility and a complete absence of contact with other people.

With the exception of three cases of near panic the subjects withstood these tests very well, which were even considered pleasant by several subjects (lying on their back in a cylinder or in a box in the decompression chamber).

In addition to the EEG, the eye movements, the electrocardiogram and respiration were recorded throughout the test. Before the beginning of complete isolation and at the end of this period the pulse rate was measured during three minutes of voluntary hyperpnea, together with the results of a performance test (Bourdon Stipple test). The vegetative functions showed a slight but constant lowering of performance. In several subjects the bladder which was empty at the start of the test subsequently (that is, three hours later) contained a considerable amount of urine of a specific gravity tending to zero (1002-1003). Interest was centred round the phenomena of consciousness recorded on the EEG. The large majority of subjects (those who were not tired) showed variations in their level of consciousness. Subjectively they spoke of sleep in the sense that they were not aware of the approach of sleep, but they realised with some surprise, after being touched, that they were coming up to "the surface". They did not therefore experience the irresistible desire for sleep (described elsewhere in the case of automobile feelings of uneasiness) for the simple reason that they did not perceive its onset.

These periods of being alternately awake and in reduced state of consciousness were repeated several times during the period of complete isolation. They began even after the first few minutes.

The EEGs showed all the stages of sleep at night, but the short term variations during isolation lacked the regularity of the sequences of such sleep which occur during the normal hours of rest from evening to morning.

Slight snoring, which synchronised with the appearance of multi-form deltas in the EEG was rare but not entirely absent.

Research carried out in connection with flight incidents was less rigorous and more realistic.

The subjects, trainee pilots and pilots (40 in all), sat in an ejector seat in a cockpit simulator, which was itself in a decompression chamber in front of a brightly lit tunnel (230 candela/m^2), devoid of all reference points and without visible boundaries. (The inside of the cockpit was in semi-darkness, ±0,5 candela/m^2.) A ventilation pump produced a background noise and the subject was in the position of looking at an empty space, vaguely seeing the outline of the instrument panel but unable to distinguish anyt ing outside.

The same variations in consciousness occurred as soon as human contact was cut off, with individual differences according to their respective tendencies to sleep. These were constitutional tendencies which showed up when a routine EEG was taken in normal circumstances. In the EEG Laboratory about 18% of the subjects slept for short periods after some time, while the majority were already showing electrical signs of various stages of sleep at the very beginning of the test. Almost without exception they referred to this vacillation between cortical vigilance and predominance of the sub-cortical centres (reticulated formation of the cerebral trunk) in their reports. All those who had been involved in a flight incident showed fluctuations both during the test (but with certain variations) and during the routine EEG recording.

These flight incidents - described in French terminology as "malaise en vol" (Missemard et Gelly) - are investigated in detail (it is more than probable that a large number of cases are not reported for fear of the pilots being unacceptable for medical reasons!). We consider such cases a calculated risk.

Provided appropriate checking, preventive (activity) and indoctrination measures are taken, such cases do not justify a verdict of incompetence.

A warning system in the event of the onset of sleep, based on the psychogalvanic reflex seems preferable to the use of voltage changes or of changes in the frequency of the electroencephalic waves.

Other methods of waking subjects are to call the pilot by his name or by a nickname (not by a code), to play some well-known music (national anthem for example) or to play a tape recording of familiar and evocative sounds (particularly for astronauts who are on long journeys).

One attempt, during short missions, to induce temporary hyperglycemia gave good results in experimental conditions.

The author assumes the psychic phenomena brought about by solitude and the lack of information. It should also be mentioned that the concept of the time which has elapsed in isolation is always disturbed in the direction of an under-estimate. As a general rule in our experiments with a cylinder, a box or the cockpit simulator, the subjects estimated the hour they had spent in complete isolation as forty minutes (i.e. 66% of the time alone).

This under-estimate also occurs in other similar long duration tests, particularly in the Marcel Siffre experiments (Ref. 12). Thus a male subject isolated in a cave for 27 days thought, when liberated, that he had been under-ground for 72 hours (57% of the actual elapsed time). A female subject, isolated for 87 days, reckoned this time as 52 days (60% of the actual time).

This disturbance of the rhythm - in solitude, with no reference points - is found constantly, but as yet is not fully understood.

SOMMAIRE

Des investigations fondamentales de courte durée (3 heures), sur 48 sujets de tout âge et de diverses occupations, sont exécutés au Centre Aéromedical à Soesterberg.

Des conditions extrêmes d'isolation, d'obscurité et de silence étaient combinées avec une restriction de mobilité et d'un manque absolu de contact interhumain.

Exception faite de 3 cas de panique imminente ces épreuves étaient supportées très bien, même considerées agréables par plusieurs sujets (couchés sur le dos dans un cylindre ou une boîte dans la chambre de décompression).

Hors l'EEG étaient enregistrés: les mouvements des yeux, l'électrocardiogramme et la respiration pendant toute la durée de l'épreuve. Avant le début de l'isolation absolue et après la fin de celle-ci la réaction du pouls durant 3 minutes de hyperpnée volontaire était enregistrée ainsi que les résultats d'un test de Performance (Bourdon Stipple test). Les fonctions végétatives montraient un abaissement léger mais constant; chez plusieurs sujets la vessie, vidée au début contenait après l'épreuve (c.à.d. après trois heures) une quantité considérable d'urine d'une gravité spécifique tendant à zéro (1002-1003). L'intérêt était centré sur les phénomènes de la conscience enregistrés par l'EEG. La grande majorité des sujets (non fatigués) montrait des fluctuations du niveau de la connaissance. Subjectivement ils parlaient de sommeil dans ce sens qu'ils ne se rendaient pas compte du sommeil imminent mais ils se réalisaient, après coup, avec une certaine surprise qu'ils surgissaient à la "surface". Ainsi ils n'éprouvaient pas cette tendance invincible au sommeil (décrit ailleurs pour les malaises en automobiles) par la simple raison, qu'ils n'apercevaient pas son imminence.

Ces périodes alternantes de vigilance et d'abaissement de la conscience se répétaient plusieurs fois pendant la durée d'isolation complète; elles commencaient déjà après quelques minutes.

Les tracés électroencéphalographiques montraient tous les stades de sommeil de nuit mais la régularité des séquences de ce sommeil, au lit du soir jusqu'au matin, manquait dans les fluctuations de courte durée en isolation.

Rares mais non absents étaient les ronflements de quelques minutes, synchrones avec l'apparition des delta multiformes dans l'EEG.

Les recherches appliquées en relation avec des incidents en vol étaient moins rigoureuses et plus réalistiques.

Les sujets, des élèves-pilotes et des pilotes (au nombre de 40), étaient maintenant assis dans un siège éjecteur mis dans un fuselage (cockpit simulator), le tout dans une chambre de décompression devant un tunnel fortement illuminé (230 candela par mêtre carré) mais vide de tous points de repère et sans limites visibles. (L'intérieur du cockpit était dans une demi-obscurité ± 0,5 candela/m^2). Une pompe à ventilation produisait un bruit de fond et le sujet était dans une situation de regarder une espace vide voyant vaguement le décor du tableau d'instruments mais ne pouvant distinguer rien en dehors.

Les mêmes fluctuations de la conscience se produisaient aussitôt que le contact humain était coupé, avec des différences individuelles selon leurs tendances au sommeil, tendances constitutionelles qui se montraient aussi pendant la prise d'un électro-encéphalogramme de routine en circonstances normales. Au laboratoire EEG environ 18% des examinés sommeillaient après quelque temps pour de courtes périodes tandis que la majorité de nos sujets montrait déjà au commencement des signes électriques de divers stades de sommeil; ils mentionnaient presque sans exception, cette vacillation entre vigilance cortical et prédominance des centres sous-corticaux (formation réticulée du tronc cérébral) dans leurs rapports. Tous ceux qui avaient été impliqués à un incident en vol avaient des fluctuations, aussi bien (mais avec quelques nuances) pendant l'épreuve qu'en la situation EEG de routine.

Ces incidents en vol - selon la terminologie française "malaise en vol" (Missemard et Gelly) - sont profondément étudiés (c'est plus que probable qu'un grand nombre de cas ne sont pas rapportés par crainte d'élimination médicale!). Par nous ils sont considérés comme un risque calculé.

Pourvu que des mesures appropriées de contrôle, de prévention (activité) et d'indoctrination soient prises, ils ne justifient pas un verdict d'inaptitude.

Un mécanisme d'alerte en cas d'endormissement imminent à base du réflexe psychogalvanique semble préférable à l'utilisation des changements de voltage et de la fréquence des ondes électroencéphaliques.

D'autres moyens d'éveillement consistent à appeler le pilote par nom ou sobriquet (pas par code), à présenter de la musique populaire (hymne national par exemple) ou à faire entendre un bout de bande recorder avec des motifs familiers et émotionnants (plutôt pour des missions des cosmonautes en voyages de longue durée).

Une tentative, dans les missions de courte durée, d'induire une hyperglycémie temporaire a donné des résultats dans les circonstance expérimentales.

J'assume les phénomènes psychiques en relation avec la solitude et le manque d'information révélante, il faut encore mentionner que la notion du temps écoulé en isolation est dérangée toujours dans le sens d'une sous-estimation. Comme règle generale dans nos expériments en cylindre, en boîte et dans le "cockpit simulator", les sujets estiment le temps d'une heure en isolation complète à quarante minutes (c.à.d. 66% du temps seul).

Cette sous-estimation existe aussi en d'autres épreuves analogues de longue durée notamment dans les expériments de Marcel Siffre (Ref.12). Ainsi un sujet masculin isolé dans une cave pendant 27 jours croyait, quand il fut libéré, que son séjour sous terrain avait duré 72 jours (57% du temps écoulé en realité); une femme, isolée pendant 87 jours, les prenait pour 52 jours (60% du temps reel).

Ce dérangement du rythme - en solitude et sans points de repère - est constamment trouvé mais jusqu'à présent mal compris.

ELECTROENCEPHALOGRAPHY AND FLUCTUATIONS IN THE LEVEL OF CONSCIOUSNESS

P.M. van Wulfften Palthe

1. BASIC RESEARCH

In previous experiments[2,3,4] the influence of so-called sensory deprivation was studied without any attempt at a realistic approach. The purpose was primarily to place subjects in surroundings without light, noise and vibration, lying on a semi-inflated rubber mattress in a confined space and to cut off any interhuman communication. Thus, practically all exogenous stimuli - except some feeling of the body weight by touch and deep sensibility on the underlying surface - were absent, while only endogenous factors like respiratory movements, heart action, bowel noises, autochthonous sense impressions in retina and cochlea and some small movements - which could not be prevented - remained as "information", which was hardly useful for adequate sensing of the physical and mental situation.

The experiments, of relatively short duration (as a rule 3 hours), consisted of a one-hour complete isolation preceded and followed by two periods where interhuman relations were present and physiological tests (performance tests and auditive projection tests) could be made.

It was in the middle period, that of complete deprivation, that symptoms of altered consciousness occurred.

In semi-isolation, i.e. at the start and finish of an experiment, we had occasion to hear and to learn by other means about important symptoms, but during the time of complete isolation we had only two sources of perception of what happened. During this period we had to rely on registering vegetative functions and movements (especially eye movements) and on taking, during the whole period, the tracing of the potential changes of the EEG. Directly *after* the complete isolation we put questions to the subject and took his answers on a tape recorder, while at the end of the whole experiment and before any contact was allowed with others, he was placed in a closed room, to make a written report, spontaneously and without any instruction or indication about what it ought to contain. After the completion of the report he was asked to fill in a questionnaire and to comment on his report, answering questions put by the organiser of the tests.

In these extreme conditions of reduced sensorial input, restricted mobility and without verbal contact with the outer world, special attention was paid to alteration of consciousness. Related symptoms on the neurophysiological level were evident in a small but constant reduction of heart and respiration rate, in abundant urine secretion of very low specific gravity and, in the psychological field, in disturbances of the body image, in not knowing whether eyes were open or closed, in illusions and pseudo-hallucinations with a hypnagogic character and sometimes in derealisation and de-personalisation. Finally there was a puzzling disturbance in time-estimation; it regularly fell short of actual time, so that estimation was always around 60% of elapsed or "watch" time. This was valid for our subjects whether their one-hour period was spent in the cylinder (Fig. 1), the box (Fig. 2), or in the cockpit simulator. Their estimation of an hour was around 40 minutes in each case.

In long-term isolation experiments (Siffre[12]) this under-estimation was also noticed: one male subject stayed underground for 127 days and thought, when he was released, that he had been in the cave for only 72 days (57% of the actual time); a female subject, in another cave for 87 days, took it to be 52 days, i.e. 60% of the actual time. In short and long term experiments there seemed to be a fixed rule for the under-estimation of the actual isolation time.

Contrary to expectations, there was an astonishing absence of anxiety or fear, at least in our population of 58 subjects mostly without aviation experience and - with 3 exceptions of near-panic - unwary of the awe-inspiring set-up of the experiment with which they were confronted without a word of explanation.

In Pavlov's terminology "sleep" phenomena are labelled as Internal Inhibition. Magoun and Moruzzi[6] developed another working hypothesis derived from EEG observations. The state of consciousness depends on the activating influence of the brainstem recticular formation upon the cortex. In the submerged condition there is left what we called, in an earlier publication[4], a vestige of consciousness.

Several factors made us decide that it was preferable not to speak of decreased consciousness but of two kinds of consciousness. On the one hand there is a cortical consciousness which can be handled, directed and "focused", thus leading to adequate action; it is discriminating and selective in the sense that one is conscious of *something*, so that there is adaptability to the ambient world. A condition for keeping intact this cortical consciousness is an exertion of an influence upon the upper brainstem and upon the diencephalic autonomous and endocrine systems by adequate sensorial input which gives meaningful information and brings about arousal of the cortex and maintains this state of arousal. This creates the condition for an active and "conscious consciousness" with a more or less high level of vigilance. This is difficult to define but is subjectively familiar to us as a feeling of "being present" and "being free" to do what we want to.

In order to be "activating", the brainstem (formatic reticularis) must possess a certain degree of "own" activity brought about by sufficient sensorial input.

If, by lack of adequate stimulation, the neurotonus of the organically intact brainstem becomes subliminal, the cortex is insufficiently aroused, its diffuse facilitation gets below par and the specific cortical consciousness becomes vague or dissappears. This does not mean unconsciousness, but it can better be described as a low level of consciousness or brainstem consciousness as against cortical-discriminating vigilance. When the cortex is insufficiently aroused (manifested by a transition low-slow pattern in the EEG, Figure 3), there is still some general consciousness left of a primitive, global and unspecific character, a passive awareness which cannot be handled and is best defined as "not unconscious" but mentally absent. Seen from the subjective angle there is a kind of *unconscious consciousness* (like in sleep with dreams and in some cases of coma vigil). The relevant pathways are illustrated in Figure 4.

Objectively such periods manifest themselves as akinesia and mutism and sometimes one is told, i.e. in the subject's written report, that, in fact, some perceptions had penetrated to which they were unable to react.

Organically of course, the brainstem remained intact and the exogenous information of superficial and deep sensibility, although strongly reduced, was not entirely absent in our non-weightless subjects while endogenous or intrinsic stimulation remained unchanged due to vital physiological processes. Integration of brainstem and cortex was not totally disrupted.

Restriction in mobility was constantly present in our set-up. There was no physical restraint (other than the confinement) but the electrodes on the head, around the eyes, on the wrists (for ECG) and on the soles of the feet (galvanic skin resistance) and the connecting wires had a symbolic value which, combined with a suggestive request to remain motionless, resulted in a kind of Totstell reflex (sham death) which effectively prevented any movement of body and limbs (except, sometimes, wandering movements of the eyes) and put the subject, at the start of the experiment, in a relaxed state (visible as high, regular alpha in the EEG) followed very soon by a lowering of consciousness expressed as a "transition" pattern in the EEG*.

The onset of this lowering of consciousness, this tendency to change over from cortical to brainstem level was rather sudden; once the subject was confined in the cylinder or the box and the double doors of the compression chamber were closed, it was a matter of a few minutes after communication was cut that we saw the changes in the EEG (Fig. 5) and sometimes heard the subject snoring. It made the impression of an initial mental shock by the sudden incommunicado and the aloneness, which sooner or later invariably alternated with electrical signs of restored cortical consciousness.

Personally, when acting as a subject, I experienced this waxing and waning twice in half an hour of isolation, *noticing* the rise to cortical level but only guessing at the preceding submerged level. In nearly all reports of the other subjects this sequence of events was mentioned; hence the term "fluctuations of the level of consciousness" seemed most appropriate.

Two extracts from the reports are given here as examples:

Pilot RNAF, 37 years. Complete isolation for 50 min.

"The position in the tank is rather comfortable and the test subject has therefore every opportunity of concentrating upon any sounds. To assess the time is particularly difficult [estimated as approximately 55% of the real time]†... I found the period without any contact with the outside world agreeable to such an extent that, at a given moment, I did not know whether I was sleeping, whether I had slept or whether I might fall asleep any moment now."

* Something analogous can be seen in ordinary EEG in routine circumstances. In our population (± 1000 medical EEG's per annum) about 8% of the examinees had spells of drowsiness or light sleep which was induced by a combination of factors analogous to, but not identical with, those of our experiments.

† Square brackets denote author's comments throughout.

F., 28 years, no flying experience. Complete isolation for one hour.

"--- I did not feel like playing the little games of these gentlemen [the test supervisors]; I was resentful at the start. Caught myself getting into a sudden panic: they will pump out too much air ... If a jet were to crash into the building now they will flee. Images of being buried alive, lasting fractions of seconds only but very unpleasant. Although I resisted violently, I did drop off and slept. [*Clearly visible in EEG as a transition pattern*]. Upon waking, either under pressure or in vacuo, I had a feeling of drowsiness." [F. was one of the three near-panickers].

In Figures 3 and 5 these alternating states of consciousness are illustrated. It seems that in the hypodynamic state, in isolation and confinement, the range between sleeping and waking has shrunk until the two states are practically indistinguishable; initially the EEG picture is neither that of fully awake nor fully asleep, but a transition pattern. Later on there appear true signs of sleep: sigma rhythms (or sleepspindles) flat slow curves and finally high slow waves (polymorphic delta's). It appears that the states of well-developed, regular and high alpha of relaxed wakefulness alternate rhythmically with all the patterns of light and deeper sleep. Electroencephalographic studies on sleep added much to our knowledge and when we now write on the subject of fluctuations in consciousness, it is not surprising that we do so in terms of sleep. There are differences in comparison with an undisturbed night's sleep in bed but also striking agreement with our basic, short-term, experiments in extreme "unnatural" circumstances (Figures 6(a) and (b)). The differences are in the rapid changes in the sleep-wake alternation, concomitant with the EEG signs, but these are not essential. One of our subjects, a psychologist, gave a clear and concise description of his one-hour isolation period, of which an abstract follows:

"--- I was frequently between dreaming and waking." [A "transition" pattern appeared twice in the EEG]. "I believed I received a slight electric shock whenever I really fell asleep." [*On the verge of falling asleep many people have a similar experience in bed*]. "If this had lasted any longer, and particularly if I had not felt the urge to urinate, I would have achieved a Nirvana-like state similar to that reached in the LSD situation." [The subject had personal experience with LSD]. "The feeling of floating was particularly strong - I tried to stay awake for I was afraid to make water into my pants. I dreamt indeed that I made water from the balcony of a friend's house whom I was visiting but then I was frightened into wakefulness again." [Freud's idea: the dream as a protector of sleep]. The subject's time estimation was 30 minutes for an actual time of one hour. The bladder was emptied at the start (50 ml, specific gravity 1026); at the end of the experiment, one and a half hours later: 610 ml of urine was passed, with a specific gravity of 1003.

It may be that in essential points, sleep and fluctuations in consciousness are analogous processes; nevertheless the apparent characteristics show analogy but not identity.

In our short experiment the onset of the lowering of consciousness is more sudden, the different stages, cyclic variations in EEG, as we know them in sleep, have a shorter rhythm and seldom reach the high-slow stage of wave form, nor did we see with certainty the Rapid Eye Movements (REM) associated with dreams in the early stages (R.L. Williams et al.[8]). [From experience we found that a number of subjects did not spontaneously mention "sleep" in their reports, although they were heard snoring and their EEGs were characteristic (either there was faulty self-observation, or reluctance to acknowledge sleep as with elderly people when they are caught catnapping in the daytime). We suspected sometimes that our younger applicants denied sleep purposely because they feared that such a weakness would influence their chances unfavourably.

I am fully aware that levels of consciousness may vary independently of sleep. Behavioural criteria should take precedence in determinating the presence of sleep or wakefulness and the EEG is more closely related to different levels of consciousness (Dement and Kleitman[9]).

Sleep and wakefulness can be objectively observed and distinguished by inspection and by observation of behaviour. At this time, in the absence of television facilities, we relied on analysing eye and body movements with the EEG apparatus and registering heart and respiration rate combined with EEG tracings in various derivations.

However, we continued to use the term "sleep" simply because the subjects experienced it as such. They mentioned this word either spontaneously in their report or when interviewed and questioned after the experiment. When denied, we always had the objective evidence in the EEG as proof of the absence or presence of fluctuations in consciousness.

2. APPLIED RESEARCH AND IN-FLIGHT INCIDENTS

In actual flight there occur situations where, in modern aircraft, a pilot is confronted with many of the elements which were realised in our basic experiments, except that in flight, the presence of light and sound and the sitting position gave a little more information from superficial and deep sensibility.

When in level flight with no turbulence at great height with haziness underneath, when flying between two layers of featureless cloud, or when an aircraft in high moon flies under a thinly overcast sky and above a whiteish ground fog or over a mirror-like sea with no reflections and no visible horizon, over limitless snowfields or over a flat sand-desert - in all these instances the pilot gets no meaningful information from his senses, although considerable light and sound energy is present.

For experiments with a more realistic set-up it seemed necessary to simulate the essential conditions of these situations and so a mock-up of a cockpit was constructed with an ejection seat, an instrument panel, low internal light level ($\pm$ 0.5 cd/m^2) and an overall hood covered with semi-transparent white paper.

This cockpit was placed in a large decompression chamber in front of a wide, 5 m long, tunnel indirectly illuminated by strong (230 cd/m^2) fluorescent tubes, invisibly positioned, with no shadows and evenly lighted, so that the concave end of the tunnel could not be perceived as such.

The subject, when placed in the seat could only see a white, even, and limitless void in front of him and the dimly lit instrument panel in the cockpit.

The hood made a white granulated impression and the rear of the cockpit was pitch black (Fig. 7).

Vegetative functions were registered on the electroencephalograph. One channel each for heart rate (ECG), respiration (using an oxygen mask measuring temperature differences of exhaled and inhaled air) and the influence of hyperventilation on pulse rate.

In the period of Total Isolation, one channel was used for the detection of eye movements (electrodes near the outer canthi give pen deflections by potential differences between cornea and retina when the eyes move in the orbits). In Partial Isolation, instead of the auditive projection test used on the supine subject, we could use, as a performance test on the sitting subject indirect measurement of the time per line in performing the Bourdon-Wiersma Stipple test[5] by registration of the eye movements (Fig.8).

The other channels of the electroencephalograph were used in the conventional way; as a rule, temporal and occipital tracings were taken.

With the necessary changes, the same test procedure and time were followed in this series with non-patterned light and background noise.

We did fifty experiments with this cockpit simulator. The relevant data of most of the subjects were very similar and - what is more astonishing - like those of the experiments in basic research using the cylinder or the box in complete darkness and silence. It will be enough to give in detail one example of an uncomplicated test on a sitting subject, in non-patterned light and background noise, and in total isolation (Fig.9).

The same system is followed, giving full detailed captions, so that the illustrations speak for themselves. A graph is added (Fig.10) with the results of pre- and post-isolation Bourdon-Wiersma Stipple tests and of pulse and respiration relations during hyperventilation.

Finally a short abstract of the report is given, written by the subject, a candidate pilot:

> ".... during the experiment I noticed, I believe four times, an episode of drowsiness or dozing off; with a start I came back to complete consciousness .... usually this was preceded by a floating away of my thoughts while I was sitting with closed eyes.
>
> .... many times I could not resist the tendency to fantasy and that was the time when the first moments of drowsiness appeared ... but in the intervals I was wide awake and completely clear in my mind. Honestly, I was glad that the test was over. It became difficult to imagine pleasant happenings and forcibly all kinds of unpleasant ideas came up. If it had lasted longer I definitely would have become irritated."

In a last example of this category a military pilot described his state of mind with remarkable insight:

> ".... the noise seemed to become an element of the silence, as if it was not a sound any more. When I looked right in front of me I asked myself how the distant space was created so that it looked infinite.

.... all the time I felt "happy", busy to think on various subjects; in between I was blank, not thinking at all but trying to forget. This was successful for a minute or two but then, suddenly, all the thoughts came back."

In overall traits this case and these reports are paradigmatic of the majority of subjects who were not involved in In-Flight incidents.

The applied research was then centred on In-Flight incidents, of which we observed five cases (and suspected many more!).

Of these we selected two examples: the first one concerned a pilot who was referred to our Aeromedical Centre some days after an incident, while solo flying on a mission with a colleague in a second plane.

A jet pilot, age 27 years, made an armament practice flight (solo in a jet plane) in May 1959. On that occasion he experienced a mental absence. He did not notice that he had passed out but deduced this from the fact that he recovered at a certain moment and became aware of his situation again. He then felt "unwell" but acted in a completely co-ordinated way. In retrospect the last thing he remembered was a radio communication to his sergeant (the leader on this mission). Thereafter, the sergeant endeavoured to establish contact with him by calling him by his number [not by name, which usually has a much more awakening effect]; he did not hear that. When he came to, he sat upright, postural reflexes unimpaired, his hands and feet at the controls in the normal position, on his original course and at the same altitude (20,000 ft) with his aircraft in straight and level flight. At that time he was in full possession of his faculties, he reacted to the call and to instructions from his sergeant, asked for his position and flew back, landing normally.

Afterwards he was able to calculate that he must have been "unconscious" for about five minutes or a little longer.

Relevant points of the flight:

(1) He had breakfasted at 8 a.m. and had not eaten any food before the flight, which began at 1 p.m. (He cannot stand an empty stomach as a rule because he gets pain and his stomach begins to rumble. If he does not eat anything right away, he cannot get any food down later.)

(2) He flew at 20,000 ft above a cloud cover upon which the sun was shining and through which a shallow sea could be perceived; there were no visual or auditive reference points. At the moment of the incident (approximately 1.20 p.m.) the situation could be characterised as a "straight and level flight in non-turbulent air" when the pilot has little or nothing to do, and hardly any visual contact with objects or surfaces outside the aircraft.

(3) There was no loss of muscular tonus and, during the episode in question, there was a certain amount of adequate reflex control. At the end of a second interview he told me: "Of course I have been thinking a great deal about this absence but couldn't it be that I just dozed off for a moment?" His history did not reveal any kind of fainting. Internal examination did not show orthostatic instability. The stipple test (Bourdon) indicated an excellent attentional function.

Nosologically, the "mental blank" which had evidently occurred could best be fitted into terms of akinesia, coupled with mutism and brief obnubilation. He no longer realized what he was doing or where he was. At that moment he had nothing to do and sat comfortably in his sun-warmed cockpit with preserved brainstem consciousness. He retained muscular tonus and postural reflexes and continued to perform adequate actions automatically.

Aetiologically, we must consider his individual disposition; he had an empty stomach (which he tolerated badly) and the situation was characterised by a considerable reduction of sensorial stimuli and by restricted mobility.

To put it plainly, it seemed as if at a certain moment he dozed off or fell asleep (lightly), a "sleep" from which he woke spontaneously after a brief period, in which he was still able to carry out the primitive control functions according to requirements.

This incident occurred before we instituted routine EEG's on entry; we therefore had no "control" record. Shortly after the incident his first EEG was taken at the Aeromedical Centre (Soesterberg) in normal laboratory circumstances (very comfortable bed, semi-darkness, low noise level). He did not eat or drink in the morning of the test and his blood sugar was 89 mgm per 100 ml.

At the start he showed a low rapid pattern (not relaxed) followed after some time by short and infrequent periods of low, slow waves (transition) and polymorphous deltas but no sleep spindles. In between, the pattern was characterised by high regular alpha. Thirty minutes after administration of 50 gm glucose (orally) the blood sugar rose to 119 mgm/100 ml and the somnolence pattern no longer occurred.

Five days later he had a test in the cylinder. During the one hour of complete isolation with minimum sensorial input, the EEG showed, after a few minutes, a transition curve alternating with a high alpha content of 10 per second, interspersed in the course of the test with all the signs of more or less deep sleep. The pulse dropped during these periods from 72 to 54, and blood sugar rose from 125 mgm/100 ml to 165 mgm/100 ml.

In an interview after the whole test it became clear the he had been dimly aware of periods of low level consciousness (which he called "sleep").

In a second example we had known the pilot involved since 1959 and had serial electroencephalograms in normal circumstances, as well as those taken in the cylinder and the cockpit simulator.

In 1959 he was first noticed for an unusual tendency to fluctuations in the level of consciousness; then in 1961 he was examined after an In-Flight incident and finally - as a control measure - in 1965, when he had done more than six years of normal flying after his first symptoms.

His case history is as follows.

A jet pilot of 31 years and 1000 flying hours was referred to the Aeromedical Centre for neuropsychiatric examination in August 1959. Sometime ago he complained of "vertigo" at low altitude in a calm flight and an insecure feeling. An interview revealed that he had had sensations of an impending "faint". He could successfully fight this feeling but, not knowing what was wrong with him, he became apprehensive and came for advice. There was no question of vertigo but the phrasing of his complaints pointed to drowsiness. This interpretation was confirmed by his EEG (5-8-59) which showed sleep spindles and later a rather flat pattern; when roused by a loud call he had a period of mild jerks during 17 seconds, noticed in all channels of his EEG, and immediately thereafter he was wide awake and absolutely clear in his mind. His Bourdon Stipple test was above average and showed no signs of epilepsy or of any other pathology. Half an hour after taking 50 gm glucose, orally, his EEG became normal throughout. The situation was talked over with him and he was shown how to fight oncoming drowsiness. He was put at ease and allowed to continue flying (Fig. 11).

Fourteen months later this experienced pilot (now with 1500 jet hours) had an In-Flight incident. On a mission in a two-seat aircraft at 35,000 ft (cabin altitude 27,000 ft) from Holland to Scotland over a flat sea he asked his companion to take over the controls whilst he carried out a radio procedure and adjusted the oxygen supply (demand regulator). Then, having nothing more to do and enjoying sitting in the sunshine high above the clouds, he experienced a feeling of suffocation and general malaise; that was the last he could remember. According to the navigator he then passed out and was seen slightly slumping with his head bending forward and limply hanging down over his chest. He did not react to a call. The navigator, now acting as a self-styled co-pilot, brought the aircraft down through the clouds and then noticed (at 32,000 ft) wild jerks of the pilot on the stick. At 20,000 ft the pilot raised his head to an upright position and said someting that was not understandable. The "co-pilot" kept talking to him and rapidly the pilot recovered.

The duration of the lowered consciousness was approximately 24 minutes. Then the pilot took hold of the controls, carried out a radio procedure, flew, descended and landed faultlessly. At a RAF hospital in the UK, by way of elimination, "anoxia" was diagnosed and indeed the sequence of events was more complicated than a mere lowering of consciousness. Back in Holland the oxygen system was checked; it functioned impeccably.

Going over the successive phenomena of this incident it was suggested that the pilot had initially become drowsy and limp: in this condition his head (loose shoulder harness?) had slumped downward, displacing his mask (at a cabin height of 27,000 ft) so that it was no longer tightly fitting the face and thus leaking. This could explain the combination of first dozing and muscle hypotony and then hypoxia from which he recovered quickly at lower altitude.

Some days afterwards there was a complete re-examination in Soesterberg. First of all he was tested in the decompression chamber and remained 10 minutes at a simulated height of 27,000 ft without O_2. There was the usual increase of respiration and pulse rate but all functions remained adequate, writing test and EEG as at ground level, spontaneous complaints of sleepiness (no objective signs). Aeromedically nothing remarkable.

The EEG in the laboratory (4-10-61) (Fig. 12) under routine circumstances showed periodical high voltage bursts, paradox reaction on opening of the eyes, transition, sleep spindles with intermittent, regular high alphas of 10 per second continuous high alphas during periods of voluntary hyperpnoea; induced hyperglycaemia produced the disappearance of "sleep" signs.

One month later he was examined in isolation in total darkness and silence (alternating with background noise). After five minutes, snoring was heard and, with irregular intervals, all the sleep signs appeared now, with low, slow activity and high, slow polymorphic deltas (Fig. 13).

With much hesitation and after careful instruction about habits and diet, with recommendations for regular control by his flight surgeon on the base, he was returned to flying duty. Every 6 months he was aeromedically re-examined, alternately on his base and in the medical centre.

All remained well and after four years we decided to have another check in a more realistic set-up, i.e. in the cockpit simulator with a special arrangement of lighting which had a provocative character (Fig. 7). This took place when the subject (now 37 years old with 2350 flying hours) felt perfectly all right and had not had any symptoms during these years. The test period in non-patterned light and background noise lasted one hour and continuous EEG was performed, with registration of heart and repiration rate (Fig. 14). From the record we computed also the alpha content in every minute (Fig. 15). The graphical representation of the number of seconds in every minute, where alpha was present, showed fluctuations which ran a parallel course with the 60 minutes EEG: periods with alpha content roughly above 30 seconds per minute showed no "sleep" signs; with lower or total absence of alpha there appeared signs of light or deeper sleep.

Immediately after this period was added (without interruption) a half hour of total darkness and silence. Generally he was much more "awake" than in bright light and noise, and his alpha content remained high; only in the last minutes was there a period of drowsiness with practically no alpha visible in the record (Fig. 16).

An extract of his report and of the interview is given here (3-9-65 in cockpit simulator):

> ".... thinking became erratic, probably I dozed off .... The experiment in total darkness and silence was, contrary to expectation, more pleasant; it lasted less time, [30 minutes, instead of one hour, in non-patterned light and background noise] and I do not think that in that period I was drowsy, although dozing was near" [Figures 16 and 17].

In answer to questions asked after his report, it appeared, that the whole session was tedious and lasted endlessly [he estimated the time to be 70% of the actual time one hour plus half an hour in darkness and silence]; that he was not always wide awake but dozed frequently; that in the first period he had often sensations of emerging, i.e. coming up to "consciousness"; that he though he had dreamed but did not know what about and that there had been sleeping spells and daydreaming or mere fantasy.

As this AGARDograph is approved for publication by the Aerospace Medical (formally Aeromedical) Panel it is rational for a few words to be added on the subject of space flight. In the field of true space flight all is yet conjecture but there is now some experience of orbiting flights.

EEG experiments, so far as I know, are not made on the already overloaded astronauts and cosmonauts but there is some anecdotal evidence that they - alone in their capsules - sometimes meet the conditions which are analogous to these studied in our experiments, i.e. lack of meaningful information through insufficient input, solitude (of the solo cosmonaut), and that boredom and not continuous verbal communication apparently cause fluctuations in consciousness (commonly referred to as naps, spells, catnapping or plain sleep). Without commenting on them, two experiences will illustrate what can happen in orbit:

(i) NASA* reports on the 34½ hour orbital flight of Gordon Cooper (May 15 and 16, 1963) as follows:

page 207 ".... there is also some question concerning the effect of such a relaxing condition as weightlessness† because a number of unscheduled naps occurred, ---- He found *even early in the flight* that, when he had no tasks to perform and the spacecraft was oriented such that the earth was not in view from the window, he easily dozed off for brief naps .... This dozing did not occur during times when there were tasks to perform or items to see through the window."

Cooper in his own words:

".... when you are completely powered down and drifting, it is a relaxed, calm, floating feeling. In fact, you have difficulty *not* sleeping. I found that I was catnapping and dozing off frequently; you sleep completely relaxed and very very soundly to the point that you have trouble regrouping yourself for a second or two when you come out of it.

".... However I noted that I was always able to awaken prior to having a task to do .... I did not encounter any type of the so called "breakoff phenomenon."

(ii) The Russian paper "Iswestja" (17th June 1963) was the only source we had about the two (separate) astronauts Valja Tereshkowa and Valeri Bykovsky. Apparently Valja had a short period of unscheduled sleep and threw the control tower into a panic. They sent an urgent message to her colleague in space and told him that there was no answer on repeated summons. Bykovsky tried to reach her by using her call-name "Sea Gull" (which is more "awakening" than the usual code call). This was successful and "Sea Gull" communicated with "Sunset" (the control tower), saying that all was in order but that apparently she had slept a while; she certainly was sorry but promised to do better in the future.

3. CONCLUSIONS

In the basic research of an extreme character, short term isolation from interhuman contact with reduced sensible and sensorial stimulation, and with restriction in movement of the supine subject in a cylinder or box, produces fluctuations in the level of

* NASA SP-45 Mercury Project: Summary: Results of the 4th manned orbital flight.

† It seems that weightlessness is not the sole condition for the appearance of a relaxed and floating feeling. Subjects in isolation in the cylinder or in the box lying on a soft underlayer also mentioned it in the same words. It seems a condition of insufficient information from superficial and muscle and tissue sense (and possibly from the otoliths). (Author's comment.)

consciousness. They start very soon and alternate with periods of normal vigilance. From the EEG pattern, it is deduced that the lack of neural input favours the predominance of brainstem "consciousness" over cortical vigilance.

In more realistic circumstances, with a subject sitting in a cockpit simulator with non-patterned light and background noise, practically the same waxing and waning of consciousness could be observed. The neural input apparently must have a meaningful and effective character (looking without seeing and hearing without distinguishing is not effective).

The study of In-Flight incidents showed that pilots who had experienced sleeping spells in the air showed, in experimental isolation, signs of altered consciousness; these signs were analogous though not identical with EEG patterns in the various stages of ordinary, undisturbed night sleep. *Uncomplicated* sleeping or dozing spells are of short duration and do not affect the body's "righting reflexes" nor the ability to effect semi-automatic routine manipulations. Immediately after waking, mental capacity is then proved unimpaired. This akinesis with mutism is a calculated risk in solo jet interception pilots (possibly more acceptable as in participants of terrestrial traffic). The hazards can be reduced or minimized by indoctrination, e.g. familiarisation with this possibility, fighting monotony and inactivity and by clear and reliable radio communication. Fatigue is hardly a factor here; the initiation of sleep is seldom noticed and therefore no subject ever compalined of an unconquerable urge to sleep.

Possibly - on short missions - glucose (which impressed us as having some preventive influence in our experiments) can be given as an innocuous chemical.

Electroencephalography on flying pilots is a cumbersome procedure for a warning system; using the principles of galvanic skin resistance seems more promising, with music and familiar human voices as the alerting stimulus.

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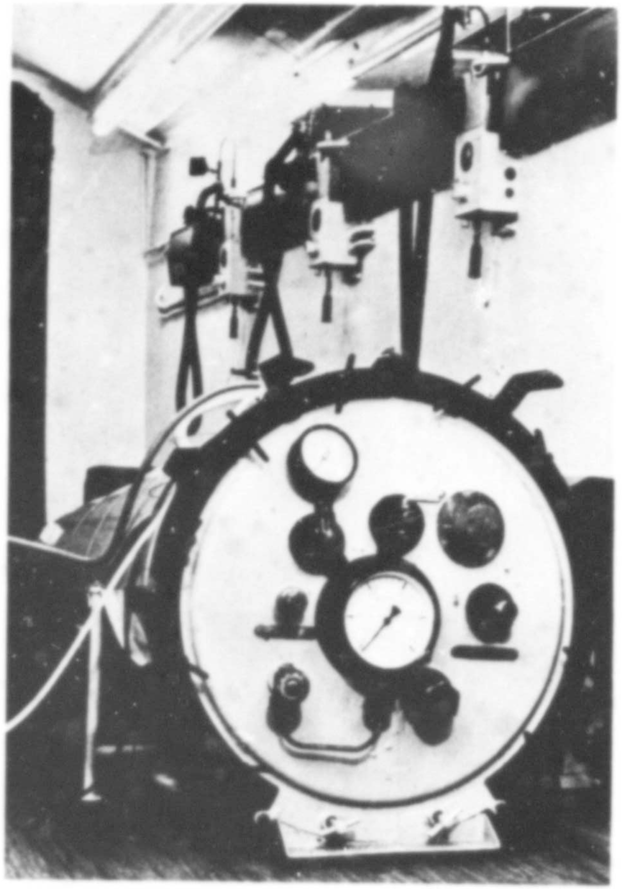


Fig. 1(a) The isolation cylinder, 2 m × 50 cm, located in the decompression chamber

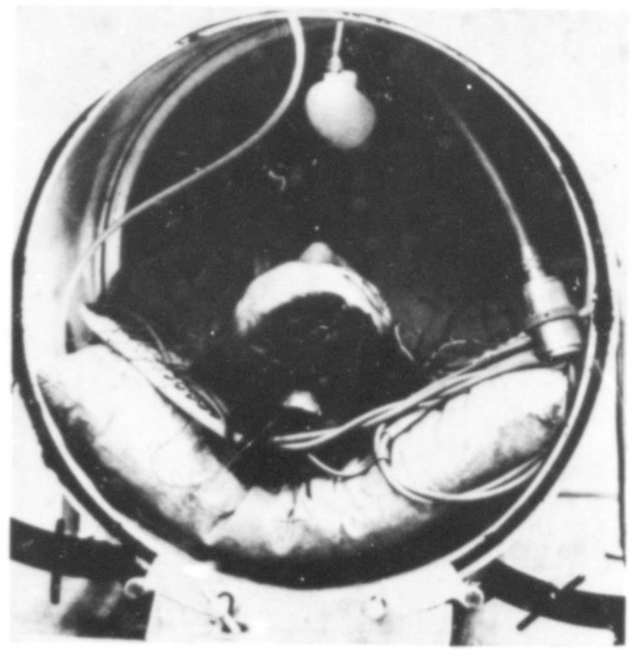


Fig. 1(b) Cylinder with end door removed, showing instrumented subject in place

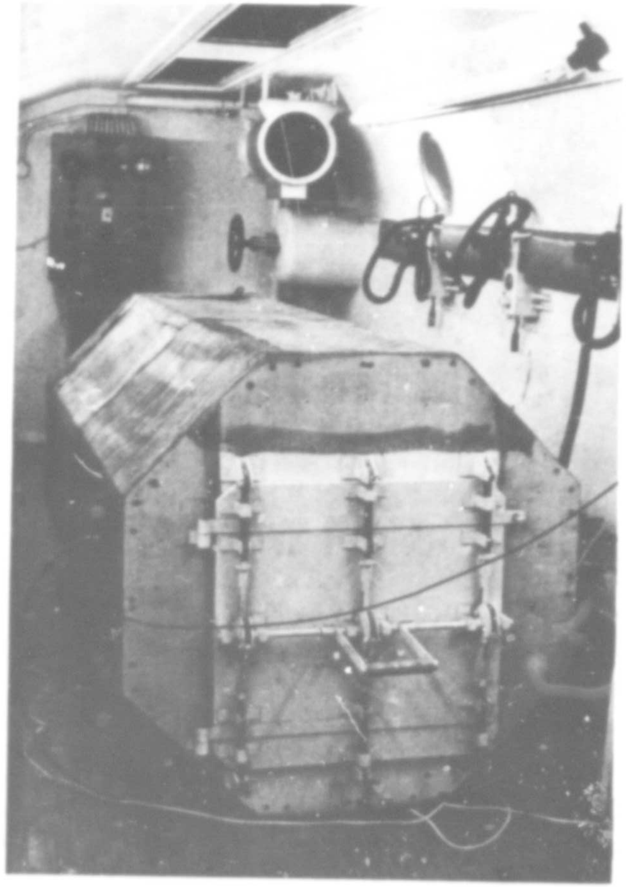


Fig. 2(a) The isolation box, 2 m × 1.1 m × 1.1 m, located in the decompression chamber

Fig. 2(b) Subject being placed in the isolation box

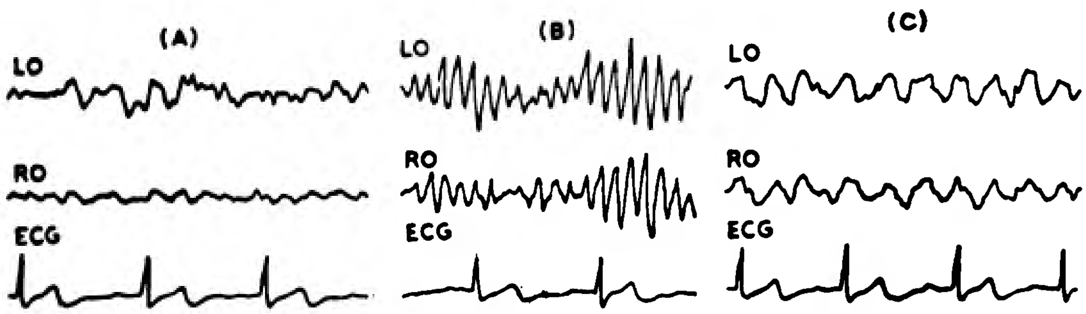


Fig. 3 The usual EEG pattern, seen in 58 subjects during isolation in the closed box.

(a) 14 min after complete isolation: drowsiness or light sleep

(b) 5 min later, awake and relaxed: alpha waves at 10 c/s

(c) 5 min later, drowsiness: typical low, slow transition pattern, 4 c/s.

Records from above down: left occipital EEG, right occipital EEG and ECG

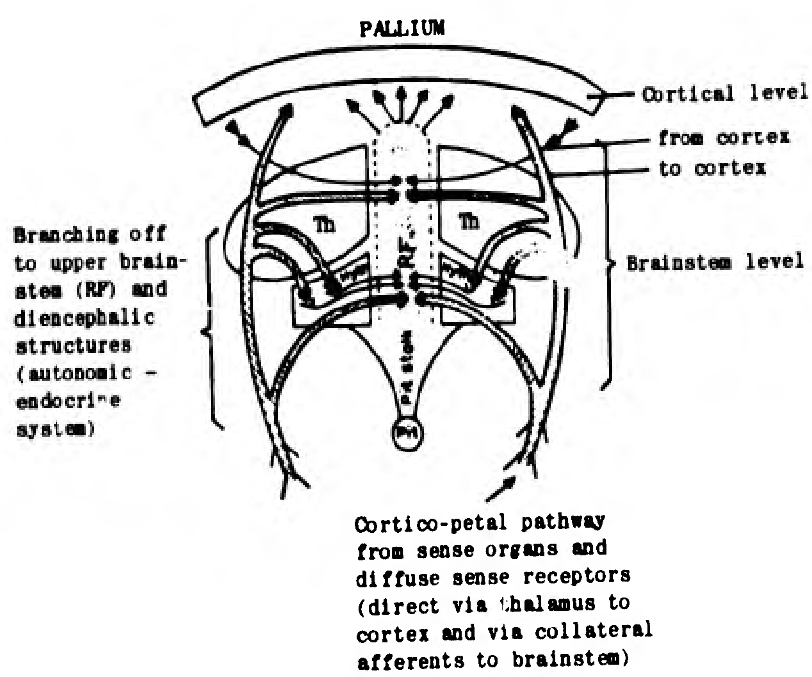


Fig. 4 Schematic representation of functional connections (postulated from neurophysiological and electroencephalographic data)

(a) from sense organs and receptors to cortex and to brainstem recticular formation (and from there to cortex)

(b) from cortex to thalamus (Th.) hypothalamus (Hyth.) and to brainstem

Cortical and brainstem levels of consciousness related to sensorial input of an informative, affective character

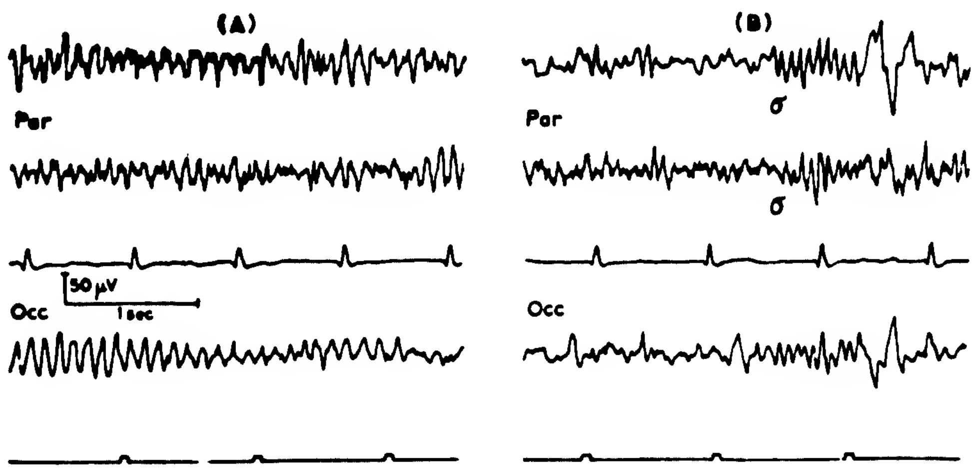
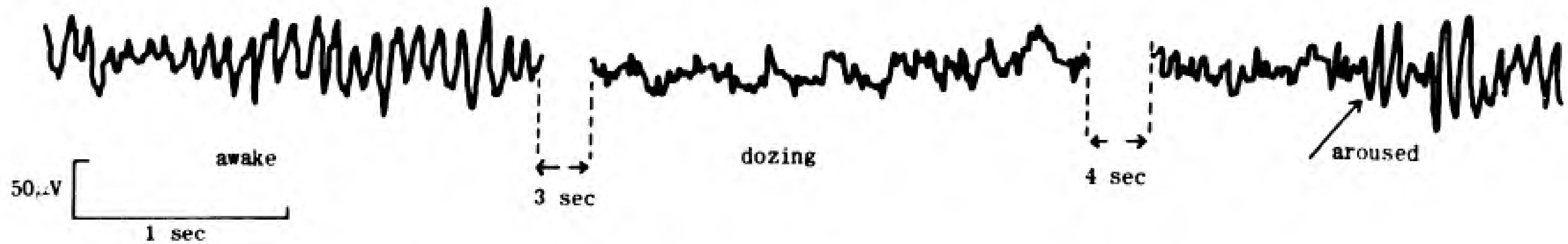


Fig. 5 Another type of reaction during isolation in the closed box.

(a) awake, imagining construction of a garage

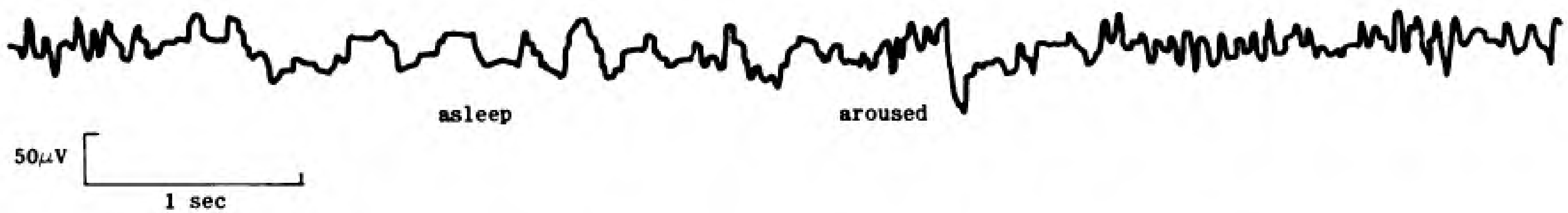
(b) 10 min later, dozing off. Sleep spindles evident at σ.

Records from above down: left and right parietal EEG, ECG, occipital EEG and 1 sec time-marker



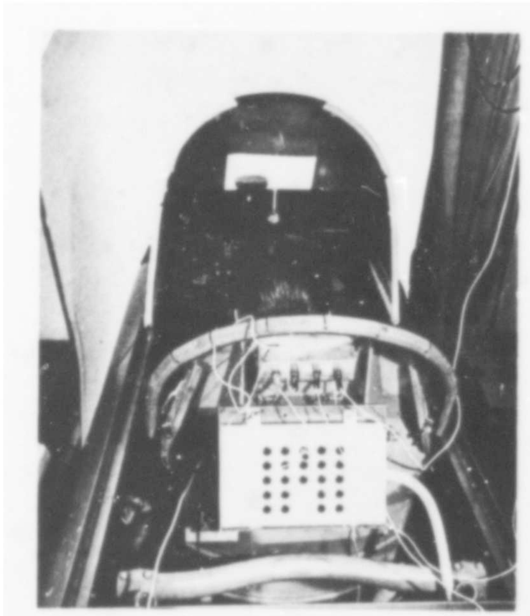
Subject A. 22. 5.'59

Fig. 6(a) One period of dozing. Tenth minute of record: EEG occiput-ear lead

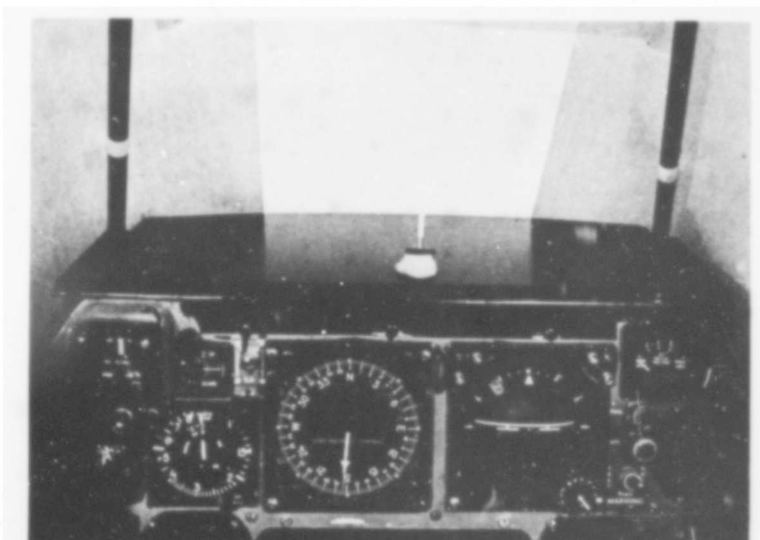


Subject A. 27. 5.'59

Fig. 6(b) During 1 hour of isolation in the cylinder. Record: as for Figure 6(a)

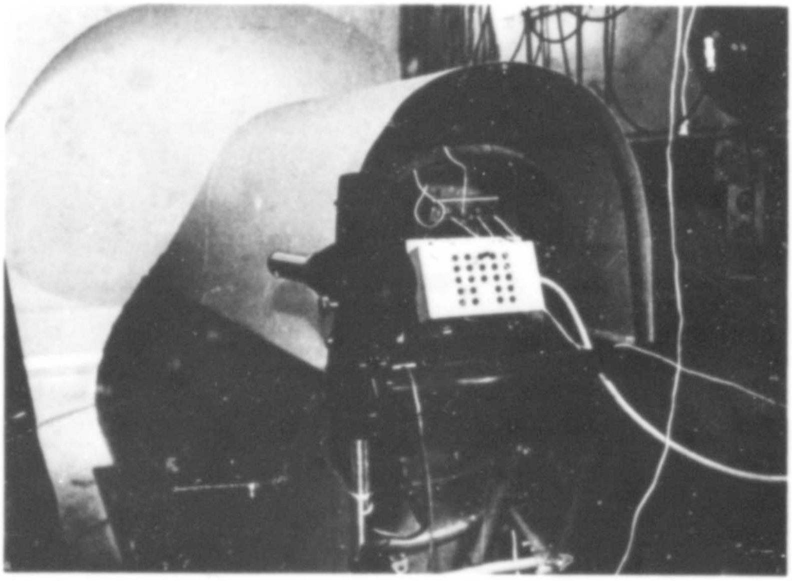


(a) Subject in the seat, hood removed. Note the instrumentation panel behind the seat



(b) The instrument panel. Note the limited aperture in the windscreen and the uniform illumination of the visual field

Fig.7 The cockpit simulator



(c) The cockpit with the hood in place. During experiments the rear of the cockpit is in darkness

Fig. 7 The cockpit simulator

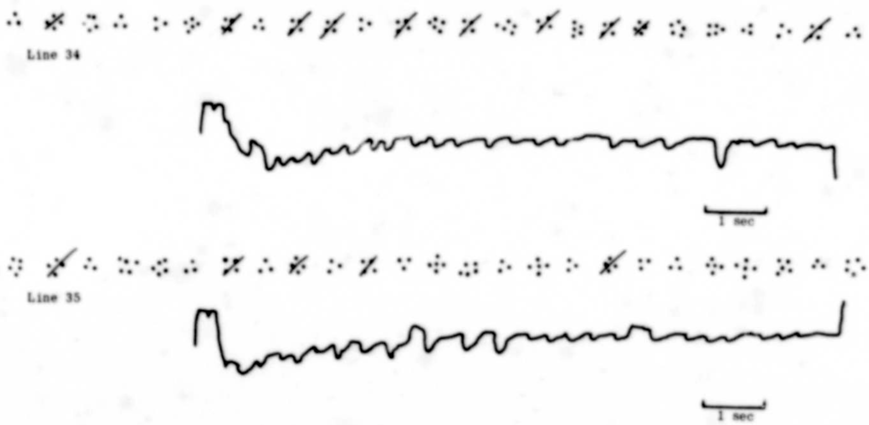
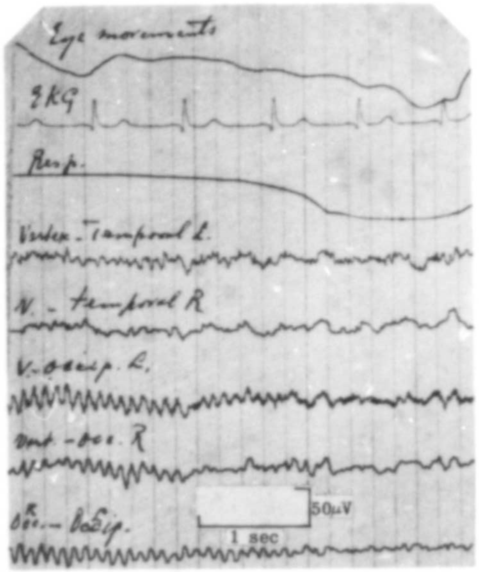
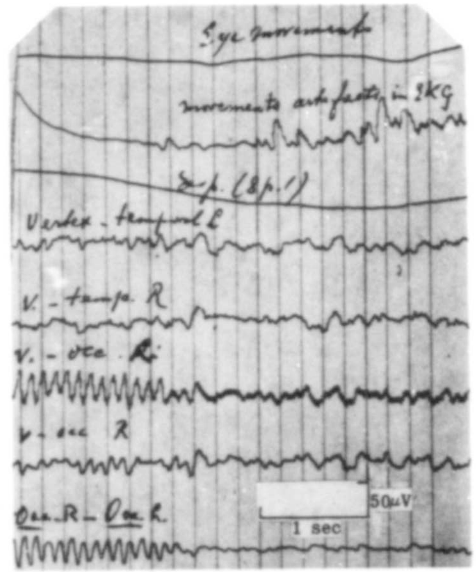


Fig. 8 Bourdon-Wiersma Stipple test and simultaneous record of eye movements on channel 1 of the EEG.

The subject must "cross out" all groups of four dots in each of 50 lines of 25 characters. Lines 34 and 35 are here illustrated. Each took 10.3 sec to complete, although 34 contains 10 fours and 35 only 5 fours. The record illustrates the essential scanning eye-movements. The hand movements for crossing the fours do not apparently consume extra time



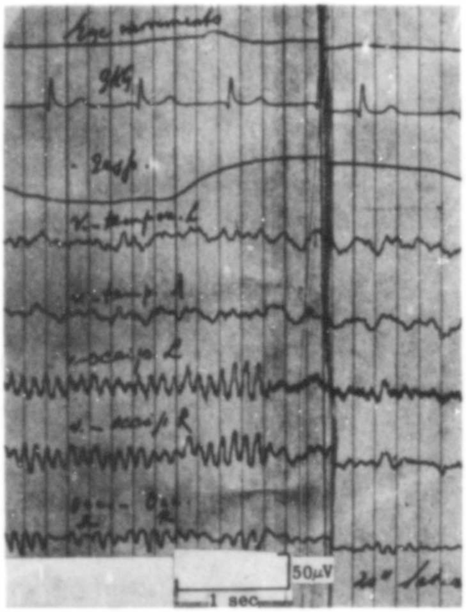
(a) 3rd minute: regular 10 c/s alpha, followed by low, fast, transition. Corresponds with "A" in Figure 9(d)



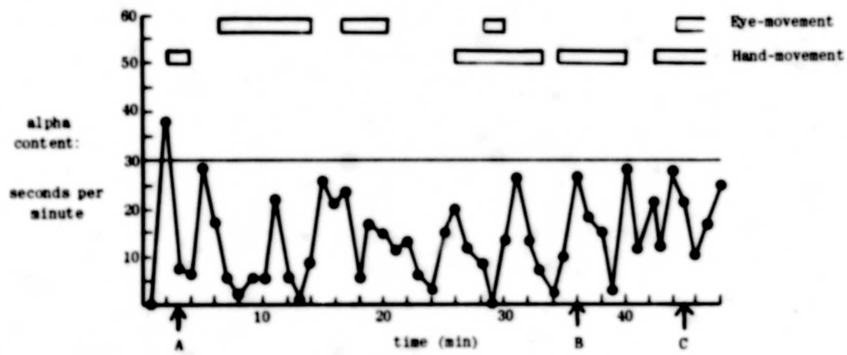
(b) 36th minute: third and fifth EEG channels show alpha; other leads irregular low, slow waves; bilateral asymmetry. Corresponds with "B" in Figure 9(d)

Fig. 9 Subject S.S. age 23 years 24.2.65, 1 hr total isolation in cockpit simulator with non-patterned white light and background noise. Subject seated, wearing harness, oxygen mask and electrodes

Recording channels from above, down: eye-movements, ECG, respiration, EEG vertex-temporal left, vertex-temporal right, vertex-occipital left, vertex-occipital right, and occipito-occipital



(c) 45th minute: normal alpha in occipital regions, followed 20 sec later (indicated by vertical line) by low, slow waves; temporal leads show continuous irregular slow waves; temporal independence. Corresponds with "C" in Figure 9(d)



(d) Analysis of experimental period of isolation illustrated in Figures 9(a), (b) and (c). Fluctuations in alpha content during isolation between 0 and 38 sec/minute. (Before and after isolation there was a continuous high level of α)

Respiration rate: before, 13-19: during, 8-13: after, 15
Pulse rate: before, 75-94: during, 67-84: after, 90

Fig. 9 (concluded)

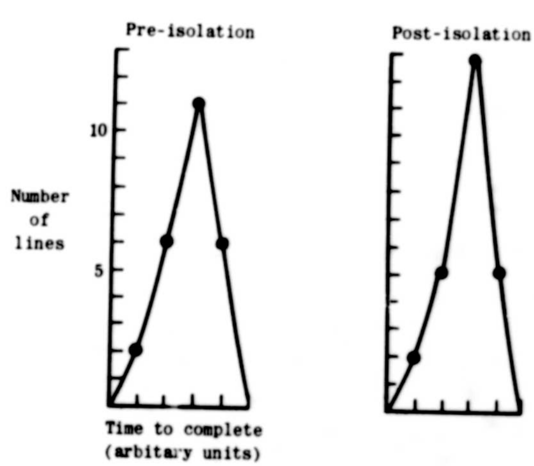
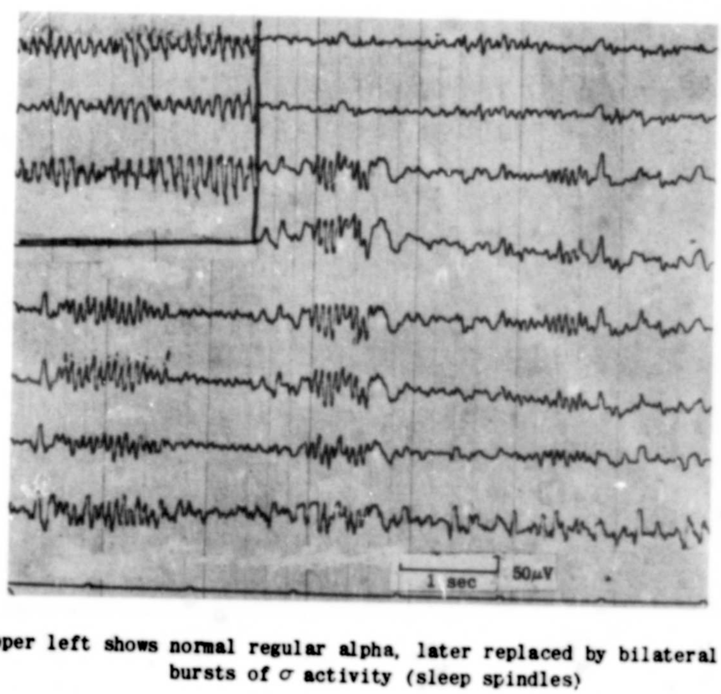
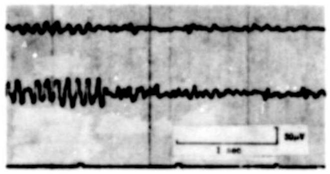


Fig. 10 Analysis of Stipple test (Bourdon-Wiersma). Subject S.S. age 23 years, 24.2.65. Above average performance as judged by distribution of time to complete lines. No change between pre- and post-isolation performance

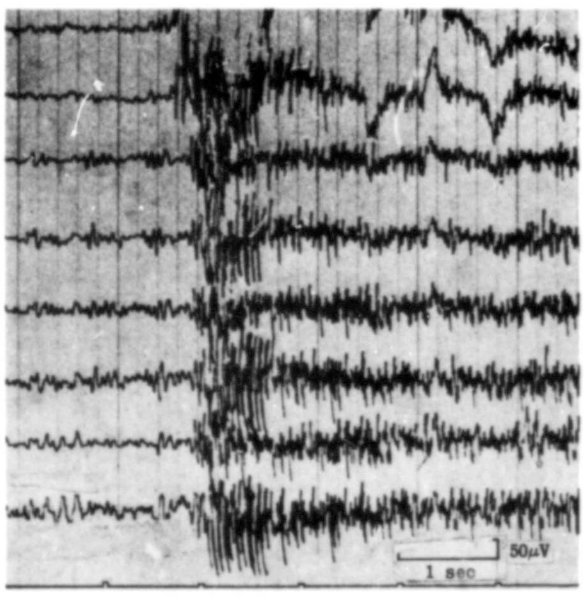


(a) Insert upper left shows normal regular alpha, later replaced by bilateral symmetrical bursts of σ activity (sleep spindles)

Fig. 11 Records obtained from subject L, pilot age 31 years, at routine examination 5.8.59. Subject not fasted

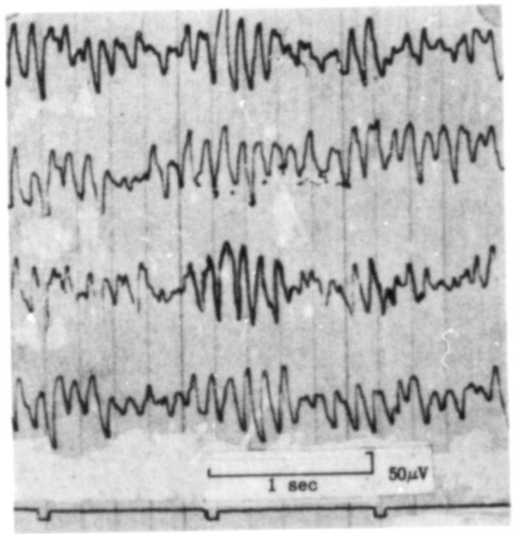


(b) Later in same record: periods of flattening - transition from "awake" to "asleep"

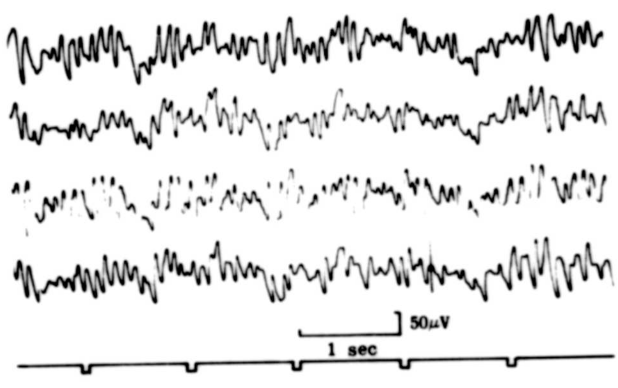


(c) At end of recording session. Subject asleep - sleep spindles; aroused; followed by 17 sec of generalised jerking

Fig. 11 (concluded)

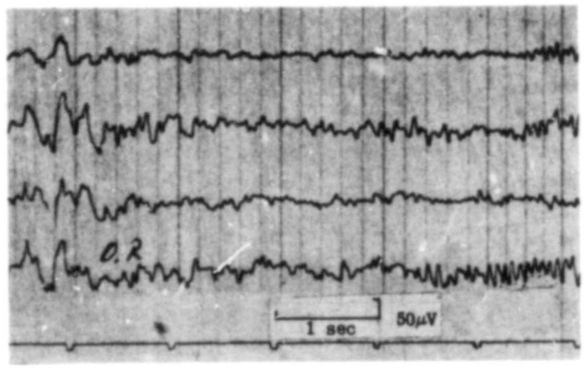


(a) Beginning of recording session. Alpha of 9 c/s. Regular

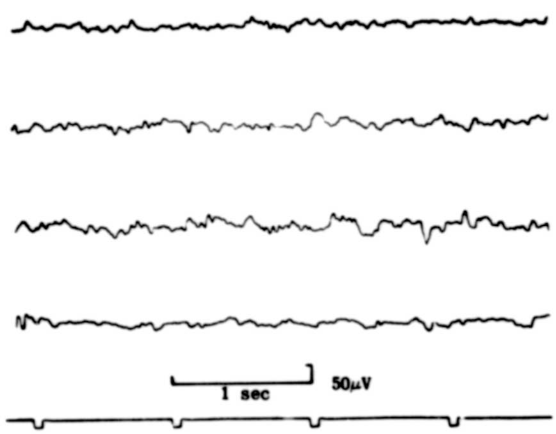


(b) Sleep spindle stage; subject did not react to loud instruction to open eyes

Fig. 12 Records of subject L; 4.10.61 (more than 2 years after records of Figure 11). Routine circumstances; i.e. quiet room, comfortable bed in corner; dim light; low noise level but for occasional aircraft noise. Fasting. Fluctuations of level of consciousness much more marked than in 1959. Channels (from above, down) L parietal, R parietal, L occipital, R occipital

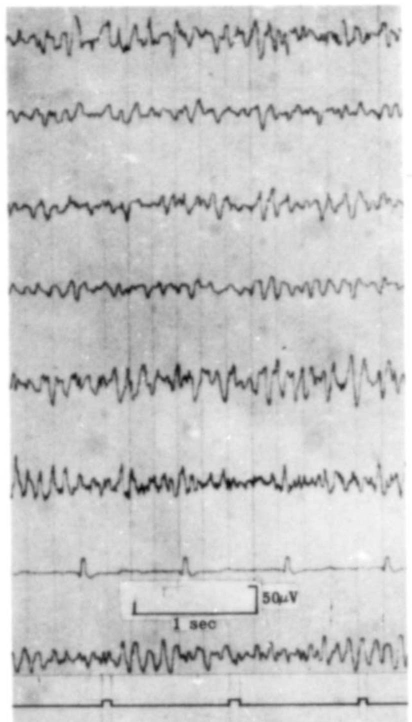


(c) Low, slow waves and sleep spindles

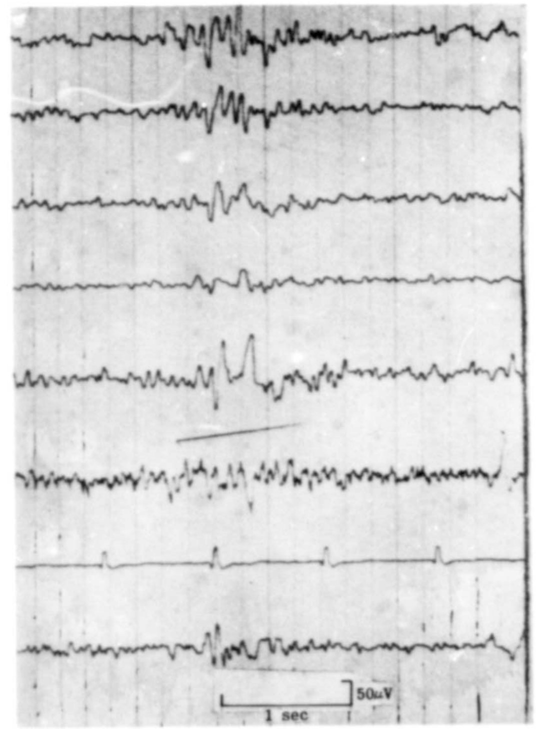


(d) All channels flat and irregular. Deeper sleep

Fig. 12 (concluded)

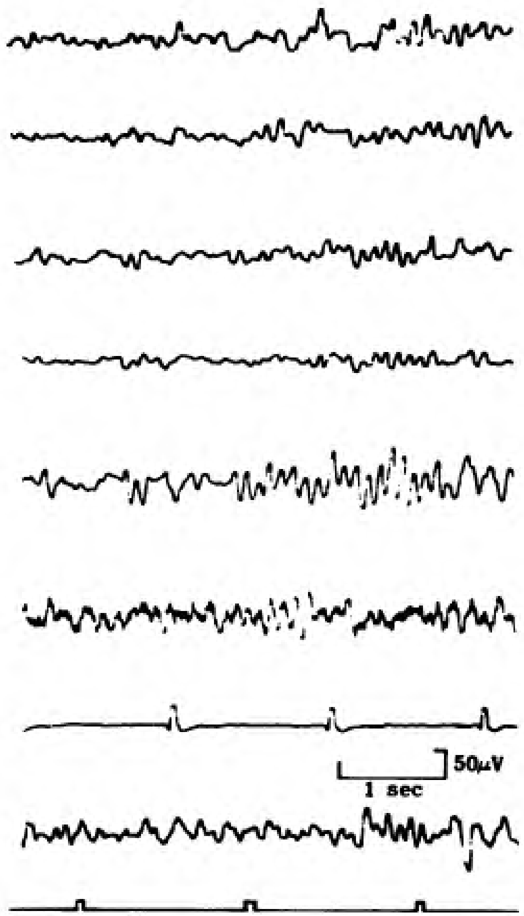


(a) Beginning of isolation; awake; well developed regular alpha

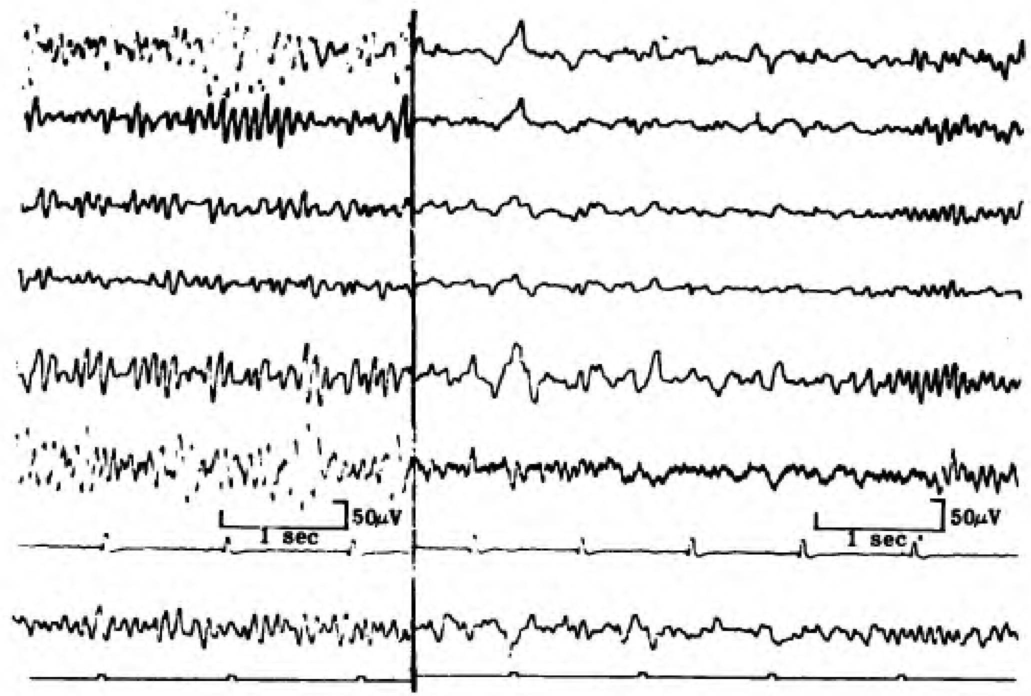


(b) 10th minute of isolation; high voltage bursts

Fig. 13 Further records of subject L: 13. 11. 61: complete isolation in total darkness and silence in cylinder.
Channels (from above, down) L frontal; R frontal; L temporal; R temporal; L parietal; R parietal; ECG; R occipital

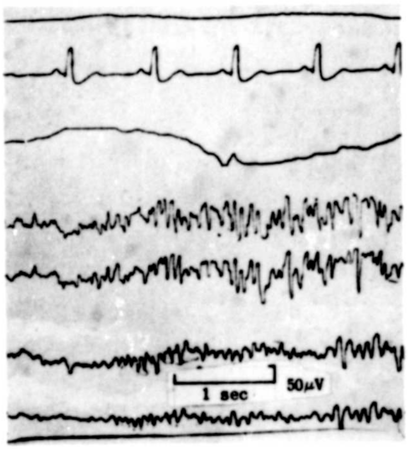


(c) 20th minute of isolation; moderate flattening and sleep spindles

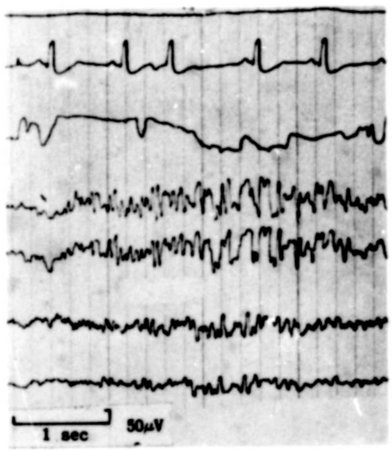


(d) Left: 31st minute; somewhat irregular alpha
Right: 33rd minute; asleep again. Bilateral asymmetry, high slow waves followed by sleep spindles

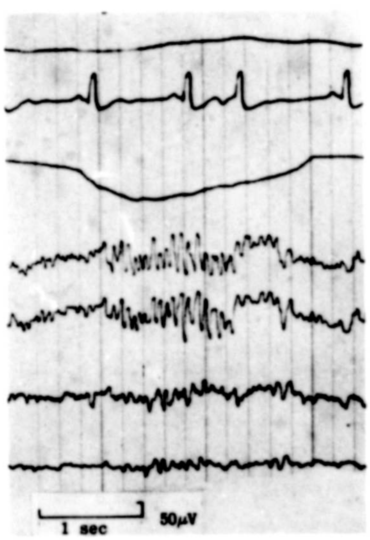
Fig. 13 (concluded)



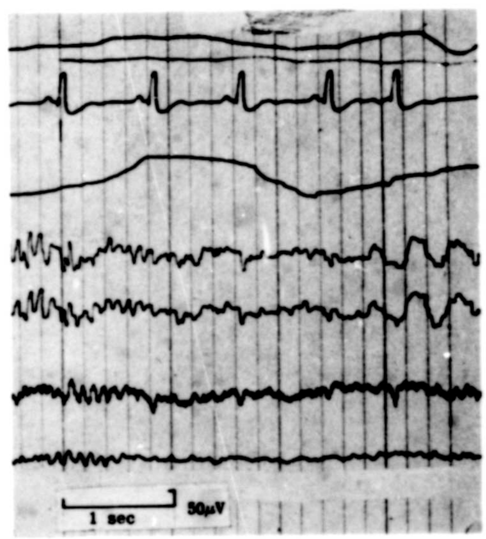
(a) 9th minute of isolation; sleep spindles and sharp waves



(b) 11th minute of isolation; cardiac extrasystoles; high slow waves and sleep spindles



(c) 24th minute of isolation; cardiac extrasystoles, sleep spindles



(d) 31st minute of isolation; temporal leads – slow, high waves; occipital leads – bilateral asymmetry

Fig. 14 Further records of subject L: 3.9.65: in cockpit simulator with non-patterned light and continuous noise; isolated for 1 hour.
Channels (from above, down) eye movements; ECG; respiration; L temporal; R temporal; L occipital; R occipital

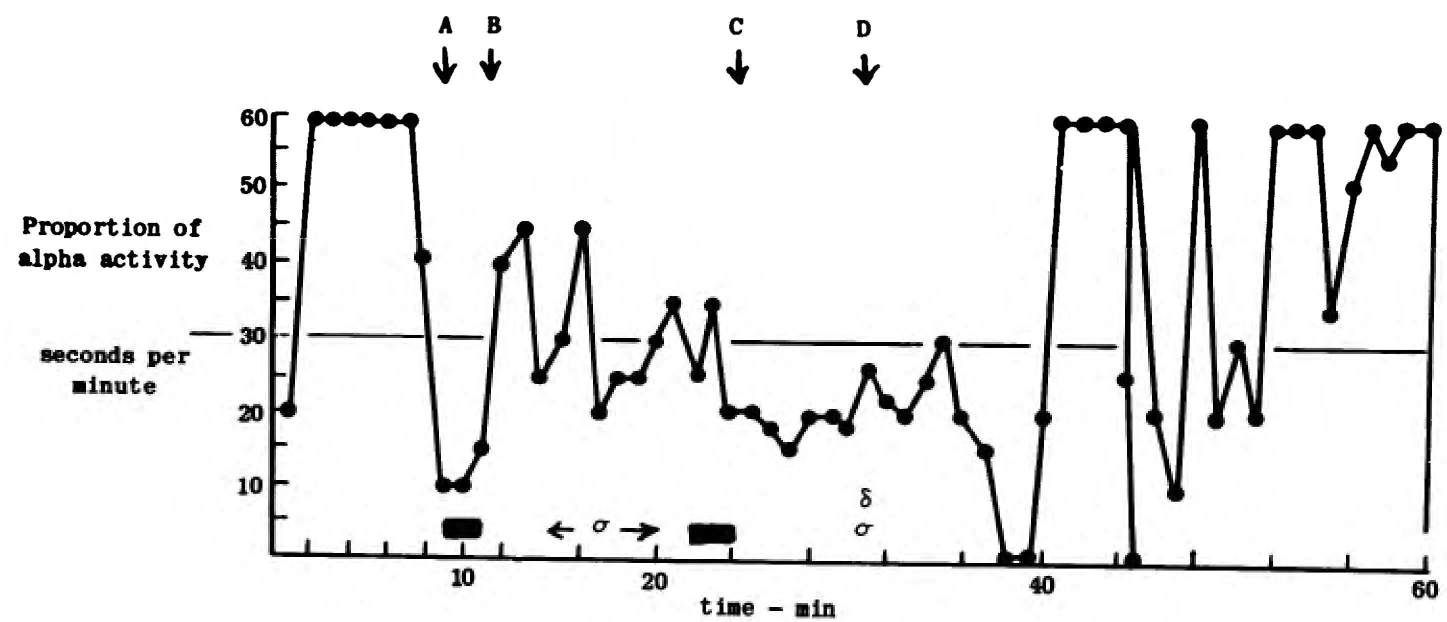
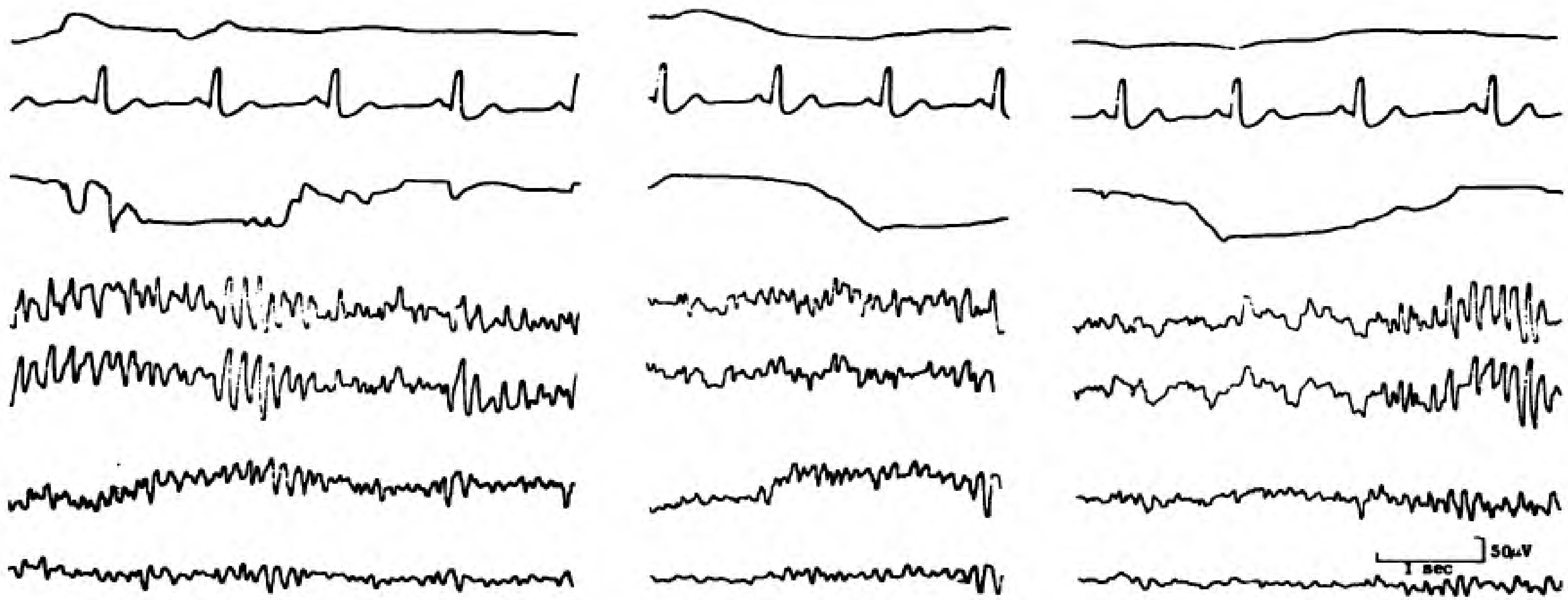


Fig. 15 Subject L: 3.9.65: cockpit isolation, 1 hour. Alpha-content analysis. Letters and arrows above indicate correspondence with Figures 14(a), (b), (c) and (d). Black bars at base indicate eye movement activity. Sigma and delta activity indicated by appropriate letter



(a) First minute: awake

(b) 11th minute: slow, irregular, sleep spindles

(c) 30th minute: high slow waves, then awakening

Fig. 16 Subject L: 3.9.65: period immediately following that illustrated in Figures 15 and 16. In cockpit but total darkness and silence for thirty minutes. Channel identity as Figure 14

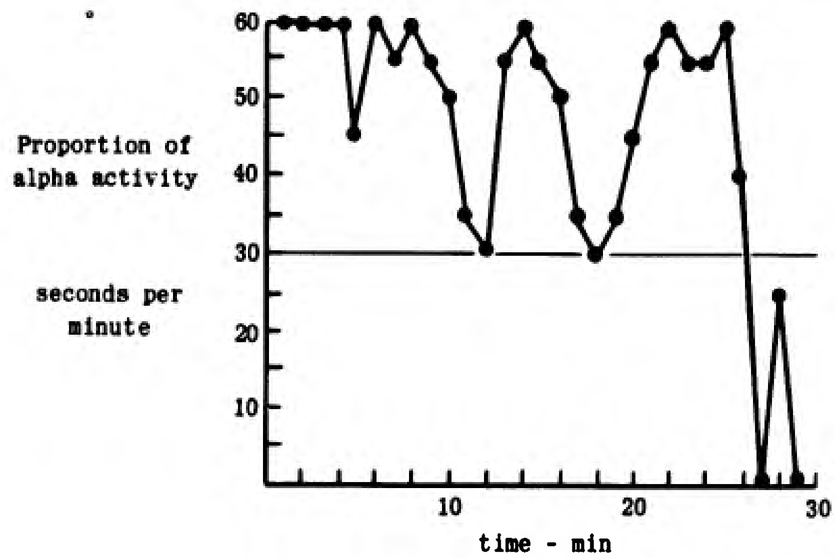


Fig. 17 Subject L: 3.9.65: cockpit isolation in total darkness and silence 30 min immediately following, without warning, period in light and noise. Fluctuations in alpha below 30 sec/min (50%) in last 3 minutes only. Bourdon-Wiersma Stipple test showed no significant change

ELECTROENCEPHALOGRAPHS OF AVIATORS IN RELATION TO AIRCRAFT ACCIDENTS AND ATTRITION FROM FLIGHT TRAINING

by

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Pensacola, Florida, USA

SUMMARY*

Baseline electroencephalographs (EEG's) have been taken on somewhat more than 7500 Student Naval Aviators over a five-year period. To date, 352 of these aviators have been involved in 578 aircraft accidents while in control of the aircraft and a much larger number have been eliminated from flight training for reasons which fall into eight major and several minor categories. Comparison of EEG's among these groups reveals several correlations which appear to be related to cerebral physiology:

(1) The overall accident group shows a somewhat greater percentage of EEG abnormality than the control group.

(2) The group involved in fatal accidents shows a markedly higher incidence of EEG abnormality than the control group.

(3) The incidence of EEG abnormality among aviators involved in multiple accidents (from 2 to 6 each) shows an incidence of deviation from normal similar to that of the fatal accident group.

(4) Certain categories of student aviators who were eliminated from training show an equal, and others a lesser, incidence of abnormality to that of the fatal and multiple accident group.

(5) There are other correlations which appear to relate cerebral physiology to success or lack of success in flight training.

There are some indications that the EEG types which go with success in training do not in all cases correlate well with uneventful subsequent flying careers. These and other implications of the data are discussed in relation to selection and prediction of success in training and survival as aviators.

* The full paper was not available at the time of going to press

SOMMAIRE

Des électro-encéphalogrammes de référence ont été effectués, au cours de cinq années, sur plus de 7500 candidats à l'aéronavale. Parmi ces aviateurs, 352 ont été, à ce jour, impliques dans 578 accidents aériens alors qu'ils étaient aux commandes de leur avion, et un nombre bien supérieur a dû être éliminé en cours d'entraînement pour des raisons que l'on peut olasser en 8 catégories principales et plusieurs catégories secondaires. En comparant les électro-encéphalogrammes de ces divers groupes, on découvre plusieurs corrélations qui semblent être su domaine de la physiologie cérébrale:

(1) La totalité du groupe impliqué dans des accidents aériens révèle un pourcentage d'anomalies électro-encéphalographiques légèrement supérieur à celui du groupe témoin.

(2) Au groupe d'aviateurs victimes d'accidents mortels correspond une incidence d'anomalies nettement supérieure à celle du groupe temoin.

(3) L'incidence des anomalies électro-encéphalographiques chez les aviateurs impliqués dans des accidents répétes (de 5 à 6 chacun) est semblable à celle du groupe des victimes d'accidents mortels.

(4) Certaines catégories de candidats pilotes éliminés en cours d'entraînement présentent une incidence d'anomalies égale à celle du groupe victime d'accidents soit mortels soit répétés, ou, dans certains cas, une incidence moindre.

(5) On a relevé d'autres corrélations qui semblent établir l'existence d'un rapport entre la physiologie du cerveau et le succés ou l'échec dans l'entraînement au vol.

Certains resultats portent a conclure que les types d'electro-encéphalogrammes correspondant à un entraînement réussi ne garantissent pas toujours une carrière ultérieure sans incidents. Cette observation, ainsi que d'autres implications se dégageant des résultats obtenus, seront étudiées par l'auteur sous l'angle de la sélection des pilotes et de la prédiction de leur succés à l'entraînement et dans leur carrière.

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