A CORRELATIVE STUDY OF THE ELECTROENCEPHALOGRAPH IN VOLUNTEER, PHYSICALLY ILL AND MENTALLY ILL OLD PEOPLE

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by

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Introduction

Purpose:

The purpose of this study was to investigate various aspects of brain function in subjects of 65 years of age and over. In particular it was hoped to find

1. if the electroencephalogram (E.E.G.) shows any specific characteristic in old age.

2. the significance of an abnormal E.E.G. in old age.

3. the effects of acute physical illness on cerebral function as indicated by the E.E.G.

4. the value of the E.E.G. as a diagnostic tool in elderly patients suffering from various types of mental illness.

5. the relationship between the E.E.G. and the level of mental function as measured by a group of psychological tests.

Our hypotheses are (a) that old age is characterized by an increased amount of slow activity and a decrease in alpha frequency in the E.E.G., (b) that these findings are indicative of impaired cerebral function and will therefore be more evident in ill subjects and finally (c) that the degree of abnormality in the E.E.G. will be reflected in the level of psychological functioning.

Review of Literature:

One of the earliest studies of the E.E.G. in old age was reported in 1941 by Davis (9) who described a slowing of alpha frequency and an increase of slow activity as compared to the tracings of young adults. The same author believed that there is a reciprocal relationship between cerebral metabolic rate and the frequency of brain waves and similarly between blood oxygen tension and the alpha rate. This belief gained support from the important studies of Engel and Romano (11) who showed that the degree of slowing of the E.E.G. frequency is proportional to the level of consciousness and to the degree of metabolic

impairment of the brain. The question now arises whether the slowing seen in the senescent E.E.G. is a reflection of decreased cerebral metabolic rate; some workers (25,26) suggest that advanced age alone is not responsible for the slowing but implicate cerebral arteriosclerosis and senile neuronal changes. It is well established that the brain has the most exacting metabolic requirements of the body in that unlike other tissues, it is unable to incur any significant oxygen debt. Obrist and Bissell (34) in their studies of aged patients with cardiac and cerebral vascular disease found that these subjects have a slower alpha frequency and a greater incidence of slow activity than normal old people. Many other workers (26,32,33,46,56) have drawn attention to the increased amount of theta (4-7 c/s) and delta (½-3 c/s) activity in the electroencephalograms of elderly people. However there is some difference of opinion (31) as to whether this is characteristic of old age since theta activity is also commonly seen in children. Busse and his co-workers (4) in a study of 223 elderly community volunteers found that only 49% had normal electroencephalograms as compared to the standards used for young adults and over 20% showed diffuse slow activity. By comparison, Harvald (18) reviewed the E.E.G. records of 299 patients attending a general hospital and found that 29% showed diffuse abnormalities in the 60-69 years age group but this increased to 52% in the group over 80 years of age.

As a more specific aspect of slowing of E.E.G. frequency, many studies have focussed attention on the alpha rhythm. Friedlander (16) determined the alpha frequency of 814 patients and showed that over the full span of adult life there is a definite slowing with increasing age. Obrist (32,33) and Mengoli (30) previously reported similar findings but with much smaller groups of patients and Mundy-Castle et al (31) conclude that the most significant characteristics of the E.E.G. in normal old age are "the decreased frequency, amplitude and per cent time of alpha rhythm" and that "these (are) almost certainly related to an aging factor".

Another finding which has been reported as a characteristic of the senescent E.E.G. is an increased incidence of focal abnormalities, first reported in 1954 by Busse (5). These foci may present as slow activity (theta and delta frequency) or mixed spikes and sharp waves and are seen most frequently over the left temporal lobe of the brain. Such abnormalities have been found in 30 to 40% of all persons over the age of 65 years in both healthy community volunteers and institutionalized patients (2,6,14,18). Busse and Obrist (6) showed that these focal disturbances were not related to cerebral dominance nor did they correlate with clinical findings or psychological functioning. By following up their subjects over a period of three to four years they found that the foci remained stable and no clinical symptoms developed. On the other hand, Silverman, Busse and Barnes (46) found that the incidence of foci was proportional to the degree of social adaptation. It has been suggested (6,7,14,18) that the foci are due to an incipient degenerative process in the hippocampus which is probably vascular in origin, a view which gains support from the increased incidence found in patients with cerebrovascular disease. When the focal abnormality extends beyond the temporal lobe, particularly into the frontal area, then chronic brain disease is more likely to be present (38). The high incidence of focal disturbances observed by Busse in normal senescence has not been confirmed by some other workers (32,45) who found less than 3%. The discrepancy is possibly explained by differences in electrode placements; for example, Busse et al (6,46) recommend an electrode placed immediately above the zygoma as the best position for detecting focal abnormalities in the anterior temporal lobe.

Finally, some attention has been given to frequencies in the beta range (14 to 30 c/s) as a possible characteristic of the E.E.G. in elderly subjects. Mengoli's report (30) stressed a "tendency to fast activity" rather than slow activity from an examination of 105 records while Mundy-Castle et al (31) state that the "type of abnormality in senility -- appears paradoxically to be a tendency

towards paroxysmal fast activity rather than excessive slow". Beta waves were found to be the dominant frequency in 12% of cases studied by Obrist (32) although 13% showed delta (1 to 3 c/s) activity. Among community subjects, those with fast activity have a lower mean age than those with other E.E.G. changes without fast activity (4). In subjects past 80 years and those with mental deterioration, fast activity is relatively decreased or absent (2,31,46), a finding which suggests that the presence of fast activity may indicate a favourable prognosis, and its absence a feature of cortical atrophy. On the other hand, Silverman et al (46) observed only a few cases of fast wave abnormality in normal elderly persons and none in persons over 79 years of age.

In summary, four E.E.G. characteristics have been investigated and reported as being specific findings in elderly persons: an increased incidence of slow wave activity in the theta and delta ranges; a slowing of the alpha frequency; a high incidence of focal abnormalities and finally, an increase in the amount of fast activity in the beta range. Although none of these has been accepted as being a specific finding in old age, studies of various clinical groups have shown that one factor may be affected more than others in certain pathological conditions. For example, among elderly hospitalized psychiatric patients, about two-thirds show some E.E.G. abnormality (2,13,14,15,17,24,25,26,37,38,56) although the incidence of abnormal records varies in different diagnostic categories. Greenblatt (17) reported 22% abnormal in alcoholic psychosis, 23% in schizophrenia, 31% in behaviour and personality disorders, 51% in involutional psychosis and 54% in senile and arteriosclerotic psychoses. Other reports (22,24,27,31,56) have confirmed the higher incidence of abnormalities in organic psychoses and dementia. In an effort to correlate symptom complexes with E.E.G. findings, Liberson and Seguin (24) reported a greater incidence of abnormality associated with a "confusion-irritability" complex compared to those showing an "anxiety-delusions-agitation" complex of symptoms. Weiner and Sohuster (56) showed that severe dementia is associated with marked slowing of the E.E.G. and Luce and Rothschild (25) report

a correlation between E.E.G. abnormalities and patients showing disturbances in stream of talk, in memory and in orientation.

The common occurrence of elevated arterial blood pressure in elderly persons has prompted study of the effect of blood pressure on the E.E.G. Obrist, Busse and Henry (36), Harvald (18) and others (29,52) have shown that the incidence of normal electroencephalograms was highest in those with elevated blood pressure while hypotensive patients were most likely to show diffuse slow disturbances.

Attempts to correlate E.E.G. findings with scores on various psychological tests such as the Rorschach Psychodiagnostic Ink-Blot Test, the Wechsler-Bellevue and Wechsler Adult Intelligence Scale have produced several reports. Barnes et al (2), Busse et al (4) and Obrist and his co-workers (35) failed to find any differences in psychological test scores of old people and various E.E.G. groupings. McAdam and McClatchey (26) point out that well developed occipital alpha activity is more common in inactive, quiet or "passive" individuals while less well developed alpha rhythm tends to be found in restless or "active" persons.

In view of the many conflicting reports of E.E.G. studies in elderly people, both healthy subjects and those suffering from physical or mental illness, it was decided to study a sample of each of these three categories using E.E.G., physical and psychological methods of investigation.

Methodology

Subjects:

Three groups of subjects age 65 years and over were studied: community volunteers, patients in a general hospital suffering from an acute physical illness and patients admitted to the adjacent psychiatric hospital.

The volunteers were residents of a Senior Citizens' apartment building and were socially competent and independent in the community. It is realized

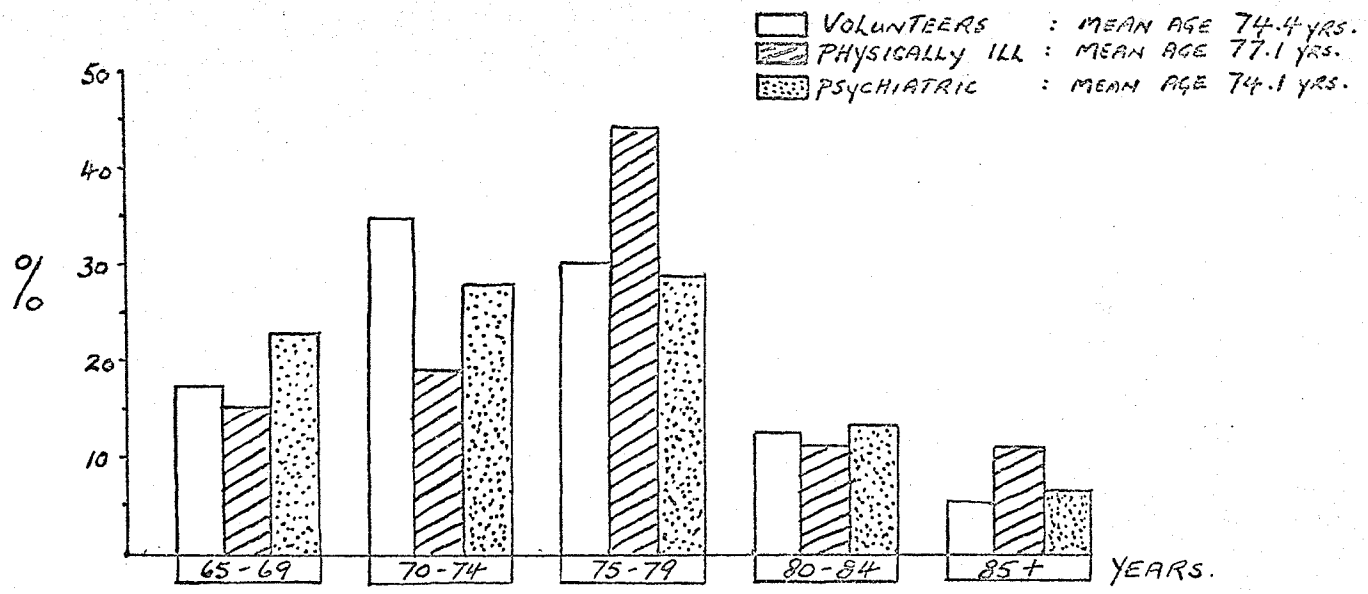
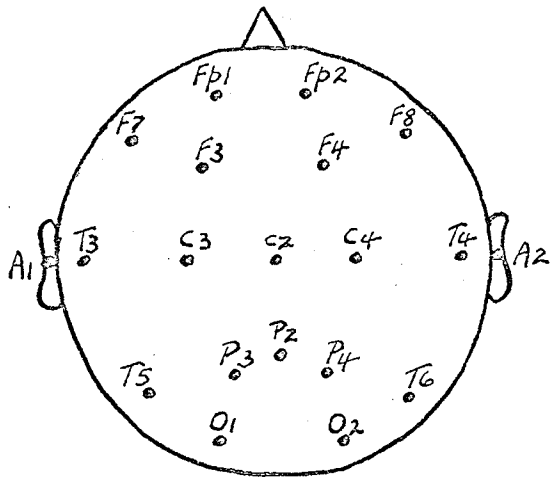


FIG. 1. AGE DISTRIBUTION OF VOLUNTEER, PHYSICALLY ILL AND PSYCHIATRIC GROUPS.



Fp. - PRE-FRONTAL.
F. - FRONTAL.
A. - EAR.
T. - TEMPORAL.
C. - CENTRAL.
P. - PARIETAL.
O. - OCCIPITAL.

FIG. 2. LOCATION AND DESIGNATION OF SCALP ELECTRODES. EVEN NUMBERS DENOTE THE RIGHT SIDE OF THE HEAD, ODD NUMBERS THE LEFT SIDE.

that such a group is not a representative cross-section of the elderly population but this factor was discounted since the purpose was to obtain physically and mentally healthy subjects and establish "norms" for comparison with the ill groups. A total of 41 (of 212 residents) volunteered but one was rejected because she was unable to travel to the hospital for investigations. Forty volunteers were studied, of whom 15 were males and 25 females, the mean age of the group being 74.4 years.

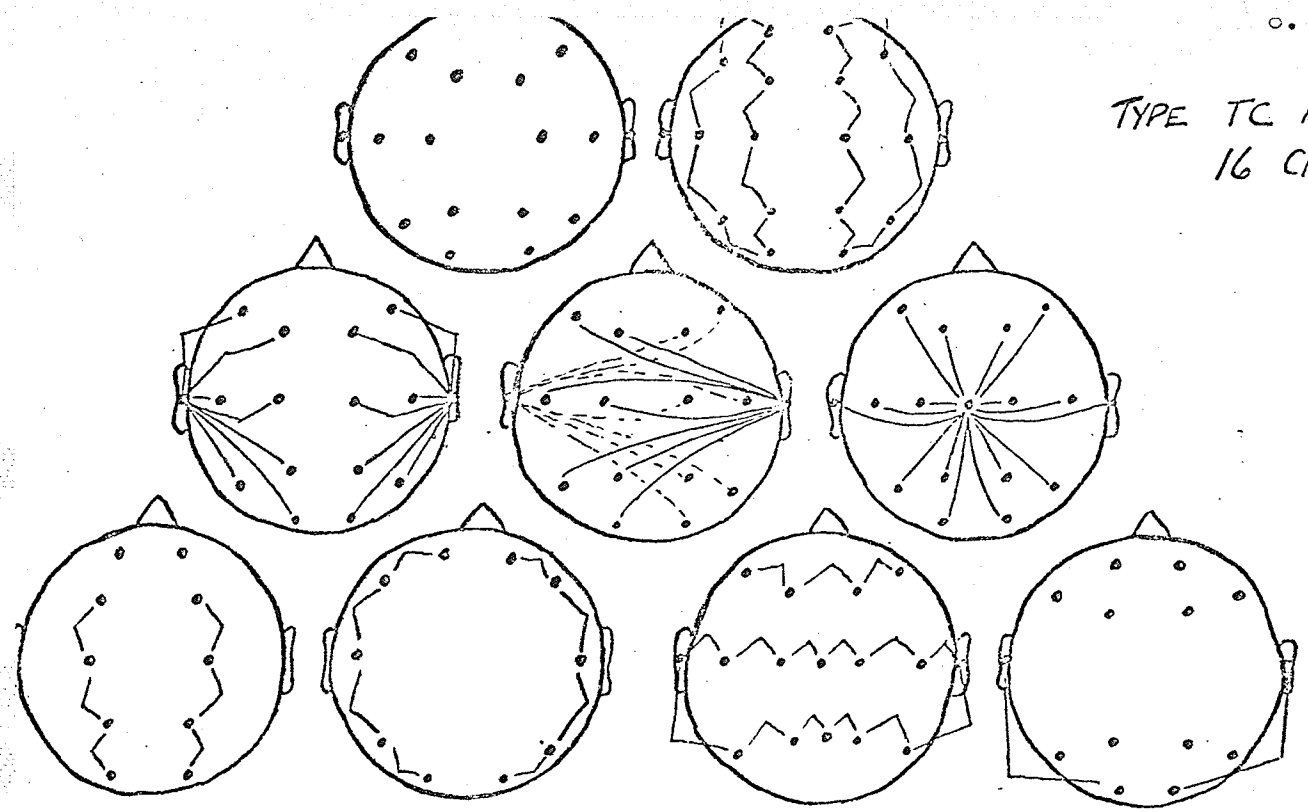
The physically ill group represented a random sample of all elderly patients admitted to the Winnipeg General Hospital during the period of the study. The admission list of the hospital was examined each day and the names of patients age 65 years and over were extracted. From these, one name was selected using tables of random numbers and in this way a total of 55 patients were chosen. Of this group 27 were studied (20 males and 7 females) with a mean age of 77.1 years and 28 were rejected as unsuitable for the following reasons:

- patient confined to bed 19
- severely impaired vision or hearing 4
- discharged from hospital 3
- language barrier 2

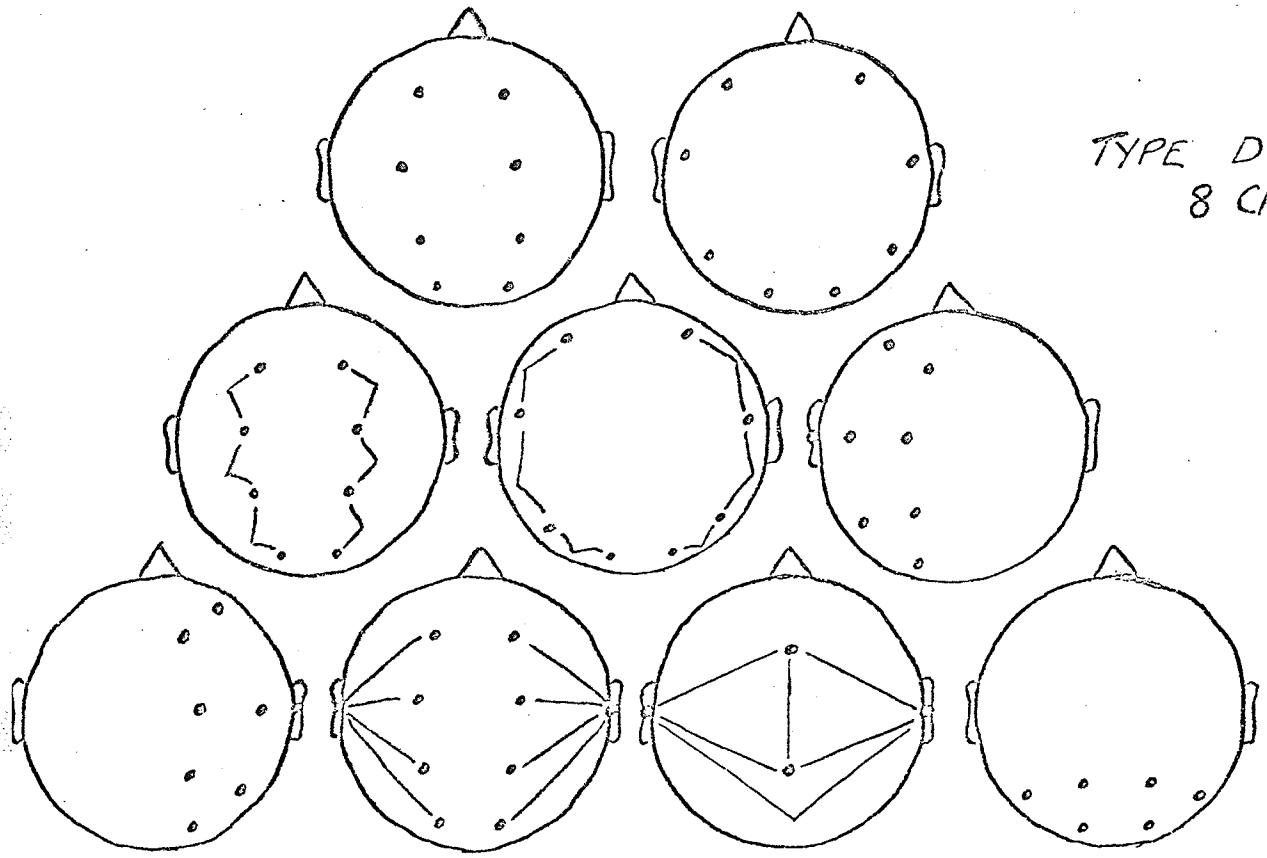
Those confined to bed were suffering from such conditions as fever, paralysis, coma, or were in traction for fractures.

The psychiatric group consisted of 50 consecutive admissions of patients 65 years and over to the Psychiatric Institute in Winnipeg. Three patients had to be rejected from the study because they refused to cooperate and one patient was transferred to a mental hospital shortly after admission. This left a total of 46 patients (30 males and 16 females) with a mean age of 74.1 years.

Figure 1 shows the age distribution of each of the three study groups arranged in 5 year periods. There were no statistically significant differences between the groups with regard to age. The mean educational level of each group



TYPE TC BECKMAN.
16 CHANNEL.



TYPE D3 OFFNER
8 CHANNEL.

FIG. 3. MONTAGE SELECTIONS USED WITH 16 CHANNEL (BECKMAN) AND 8 CHANNEL (OFFNER) EEG MACHINES.

in terms of school grade completed was 8.03 (Volunteers), 5.65 (Physically ill) and 7.52 grades (Psychiatric). The Volunteer and Psychiatric groups were not significantly different but both showed a significant difference ($p < 0.01$) from the Physically ill group.

Investigations

A full medical and psychiatric history was obtained from each patient in addition to a thorough physical examination, paying particular attention to the central nervous system. Equivocal findings were further investigated, e.g., electrocardiograph, x-ray of chest or skull. Laboratory investigations on all subjects included haemoglobin (Hgb.), erythrocyte sedimentation rate (E.S.R.) and urinalysis.

Electroencephalograms were taken in the waking state with standard placements of Ediswan silver-silver chloride scalp electrodes (Fig. 2) and using both monopolar (average) and bipolar runs on 16 channel (Beckman) and 8 channel (Offner) machines (Fig. 3). The electroencephalograms were classified according to alpha frequency, percentage of slow wave activity (theta and delta frequencies) and the presence or absence of focal abnormalities. It was decided that it would be unreliable to estimate the percentage of fast (beta) activity by manual means.

Alpha frequency was measured by counting the number of waves in samples of artefact free tracing from the occipital areas and although, by definition, alpha frequency ranges from 8 to 13 cycles/sec., the frequency of the dominant occipital rhythm was calculated even when this was less than 8 c/s (down to 7.5 c/s). Because of the common occurrence of movement and muscle artefact in the electroencephalograms of elderly persons, it was only possible to use samples of brief duration and the number of waves in two - three centimetre (1 sec.) samples were counted. Where alpha rhythm was well developed, several samples were counted and in this way the reliability of the two sample technique was

QUESTIONS.

HOW OLD ARE YOU.
WHAT YEAR WERE YOU BORN.
WHAT MONTH WERE YOU BORN.
WHAT DAY IS IT TODAY.
WHAT MONTH IS IT.
WHAT YEAR IS IT.
WHAT IS THIS PLACE.
WHERE IS THIS PLACE (LOCATED)
WHO IS PRIME MINISTER OF CANADA.
WHO WAS PRIME MINISTER BEFORE HIM.

SCORING:
9 OR 10 — NO IMPAIRMENT.
7 OR 8 — MILD DEMENTIA.
4, 5 & 6 — MODERATE DEMENTIA.
0 TO 3 — SEVERE DEMENTIA.

FIG. 4. DEMENTIA SCALE: QUESTIONS AND SCORING.

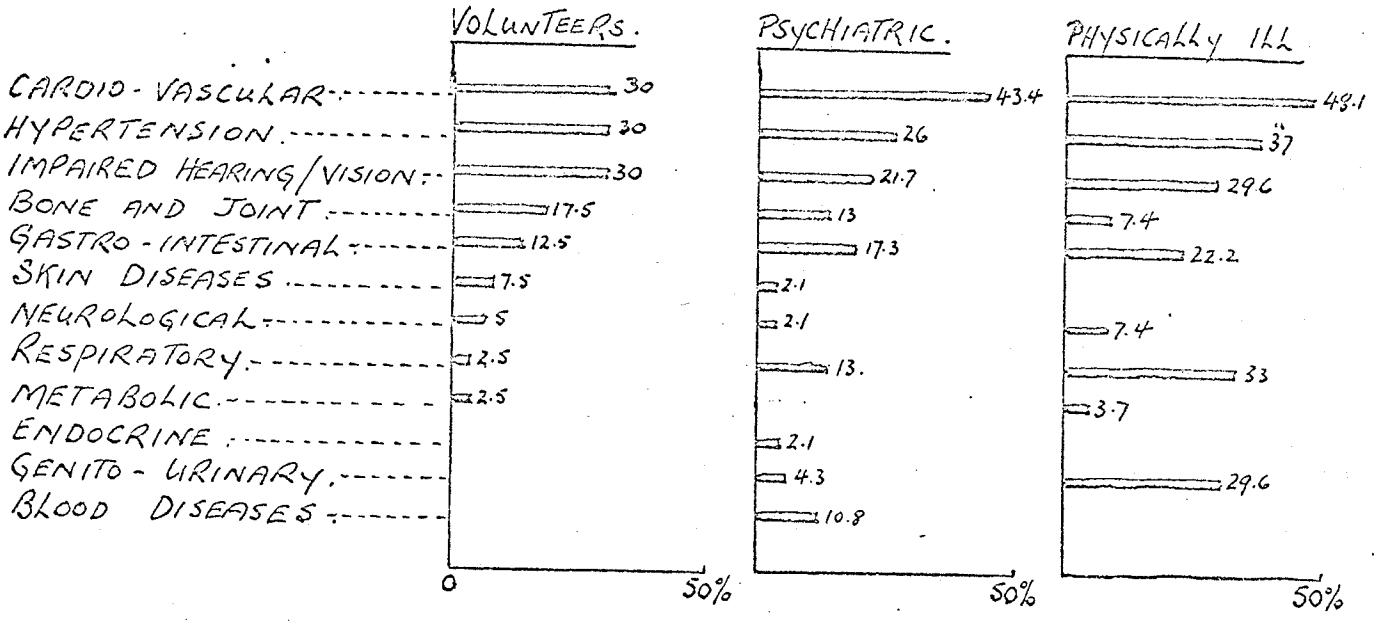


FIG. 5. INCIDENCE OF CHRONIC PHYSICAL ILLNESS IN VOLUNTEER, PSYCHIATRIC AND PHYSICALLY ILL GROUPS.

demonstrated to our satisfaction.

The percentage of slow activity was derived by counting all waves of 7 cycles/second or less in a 12 cm. (4 sec.) artefact free sample of tracing taken while the eyes are closed and calculating the percentage of the total time. For this calculation the scalp to ipsilateral ear montage was used (Fig. 3). As for alpha frequency, more than one sample of tracing was analyzed where possible and the results obtained were found to be very similar.

Where focal abnormality was present, the type and position were noted.

Two tests of psychological function were administered: first, a 10 point dementia scale (Fig. 4) as described by Kahn et al (23) but modified for Canadian citizens ("Prime Minister" substituted for "President"). According to Kahn (23) a score of 9 or 10 indicates no dementia; 7 or 8 mild dementia; 4, 5 or 6 moderate dementia and 0 to 3 severe dementia. The second psychological test consisted of a group of sub-tests of the Wechsler Intelligence Scale for Children. This scale was chosen in preference to the adult scale since it is a less difficult test extending downwards to a chronologic age of 5 years and therefore more likely to produce a measurable score in demented subjects. On the other hand it measures upwards to a chronologic age of 15 years which is adequate for non-impaired subjects. It should be emphasized here that the W.I.S.C. was not employed as an intelligence test but rather as a series of tasks designed to compare differences in group and individual functioning. It has the disadvantages that there are no 'norms' for this age group of subjects and also that some of the questions are not suitable for adults. However, it has the big advantage of measuring lower limits of mental functioning than the adult scale. The verbal sub-tests used were Information, Comprehension, Similarities and Digit Span and of the performance sub-tests, Picture Arrangement, Block Design and Coding were chosen. The tests were presented in the order given and occupied, on an average, about forty minutes of the subject's time. The

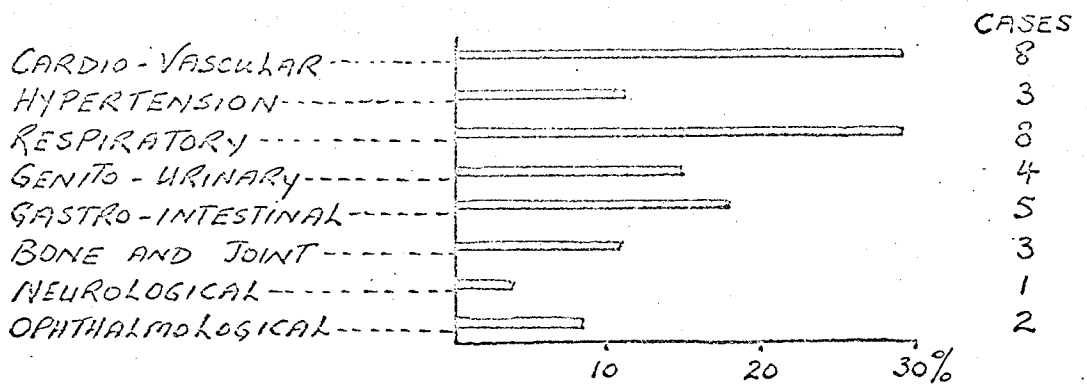


FIG. 6. PERCENTAGE DISTRIBUTION OF ACUTE ILLNESS IN PHYSICALLY ILL GROUP.

	MEAN HEMOGLOBIN GM.%	MEAN E.S.R. MM/HR.
VOLUNTEERS	13.06	29.72
PHYSICALLY ILL	13.22	42.54
PSYCHIATRIC	13.00	30.63

BLE 1. MEAN VALUES FOR HEMOGLOBIN AND ERYTHROCYTE SEDIMENTATION RATE IN VOLUNTEER, PHYSICALLY ILL AND PSYCHIATRIC GROUPS.

time taken for testing was considered important since elderly persons are more liable to become fatigued than younger subjects. These tests give some indication of memory function, concentration and attention span, common sense reasoning, ability to deal with the environment and to apply abstract reasoning. They are, therefore, the tests most likely to be affected in patients suffering from organic brain disease. The verbal tests are to some extent related to the cultural and educational background of the subject but the performance tests are relatively free of these influences and therefore may be a more valid indication of native ability. The mean raw score for each sub-test in the three study groups was calculated.

Results

Medical and Psychiatric Histories

A full medical and psychiatric history was obtained from the volunteers and the physically ill subjects but the mental status of the psychiatric patients frequently accounted for incomplete information being obtained. Among the volunteers, one had had treatment for depression but was not depressed at the time of the interview, two had family histories of mental illness (one of suicide and the other of depression) while three had family histories of epilepsy. Of the physically ill group, one suffered from paranoid schizophrenia and another had been treated for a reactive depression but was well at the time of the study. No patient in the physically ill group had a family history of mental illness or epilepsy.

Physical Data and Mental Status

The incidence of chronic physical illness in each of the study groups is shown in Figure 5. If we consider cardiovascular disease and hypertension together we find that this is by far the most common type of disability in the elderly. This is not surprising in view of the fact that diseases of the cardiovascular system constitute the commonest cause of death in the aged.

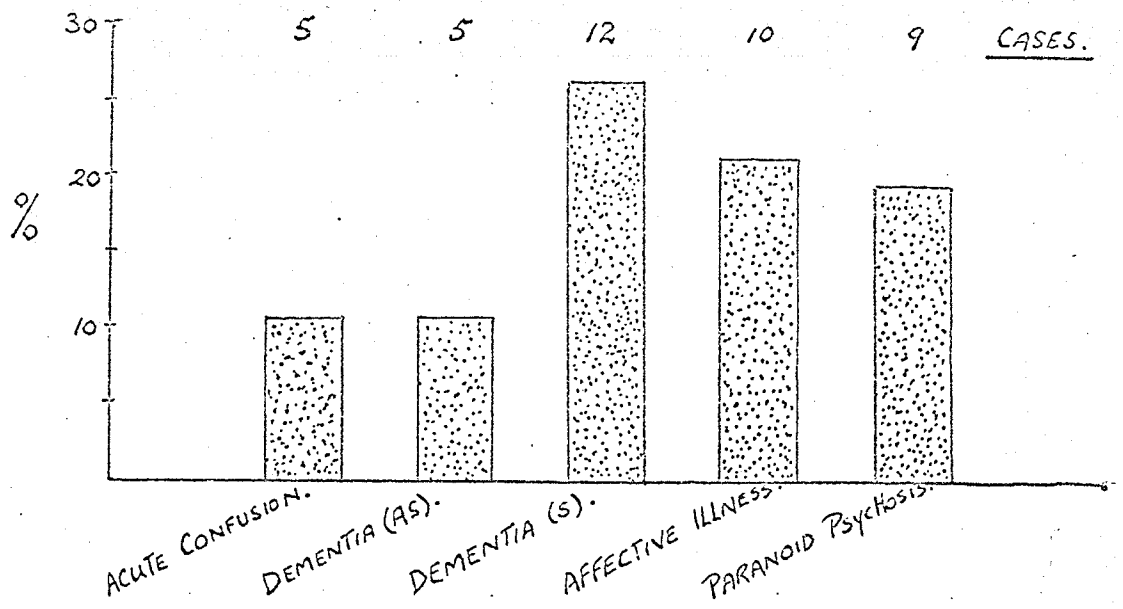
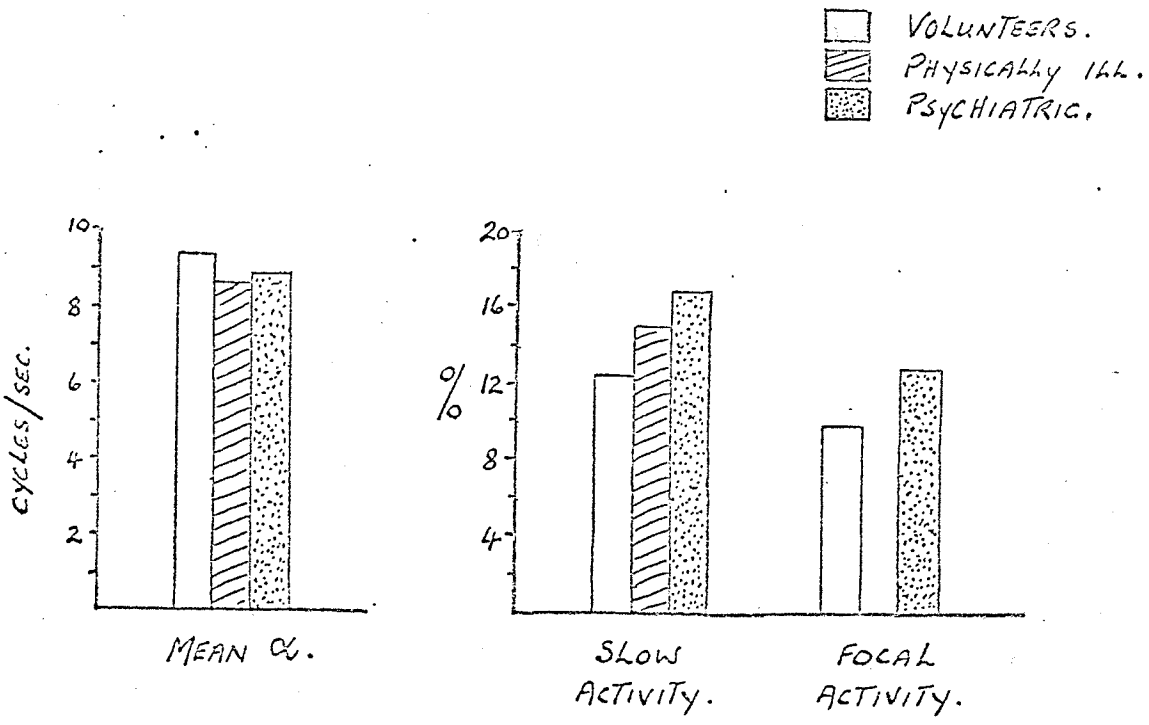


FIG. 7. PERCENTAGE DISTRIBUTION OF DIAGNOSTIC CATEGORIES IN PSYCHIATRIC GROUP.



G. 8. E.E.G. ANALYSIS: MEAN ALPHA VALUES; MEAN PERCENTAGE OF SLOW ACTIVITY; AND MEAN PERCENTAGE OF PATIENTS SHOWING FOCAL ACTIVITY IN EACH OF THE THREE STUDY GROUPS.

A patient was considered hypertensive if the systolic blood pressure exceeded 160 mm. and the diastolic pressure was 95 mm. of mercury or more, with the patient in a sitting position. Impaired vision or hearing and diseases of bones and joints showed a fairly high incidence and in the two ill groups, respiratory disease was also frequently present. All of these illnesses restrict the mobility and physical effort of the patient and may in turn contribute to mental illness in old people.

Cardiovascular and respiratory diseases were the most common acute illnesses in the physically ill group and along with hypertension accounted for more than half (55.8%) of all the acute illnesses. However, in view of the large number of patients rejected in this group, the figures shown (Fig. 6) do not present a true incidence of the various disease categories. This is especially so for neurological diseases where patients were often unsuitable subjects because of hemiplegia, aphasia or coma. The mean haemoglobin and mean erythrocyte sedimentation rates (E.S.R.) were calculated for each group but no statistically significant differences were found among the values shown by analysis of variance (Table 1). No clinically remarkable abnormalities were found in the urine examinations.

Assessment of current mental status revealed one patient among the volunteers who was mildly depressed and one among the physically ill who was schizophrenic. Otherwise there was no significant psychiatric illness in these two groups. The distribution of diagnostic categories in the psychiatric group is shown in Figure 7, arranged according to the classification proposed by Roth (35). Arteriosclerotic (AS) and senile (S) dementia composed 41.4% of the group and should probably be considered as one group since differentiation between the two on clinical grounds is often difficult and uncertain. However, since it was felt that the distinction might be important for purposes of E.E.G. comparison, patients with unequivocal historical or clinical evidence of cerebral

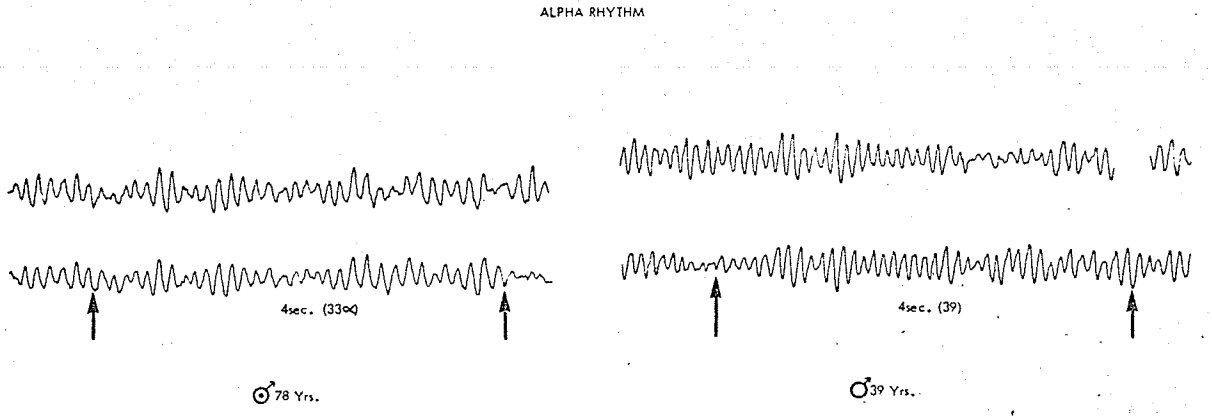


FIG. 9. ALPHA RHYTHMS OF 78 AND 39 YEAR OLD MALES.

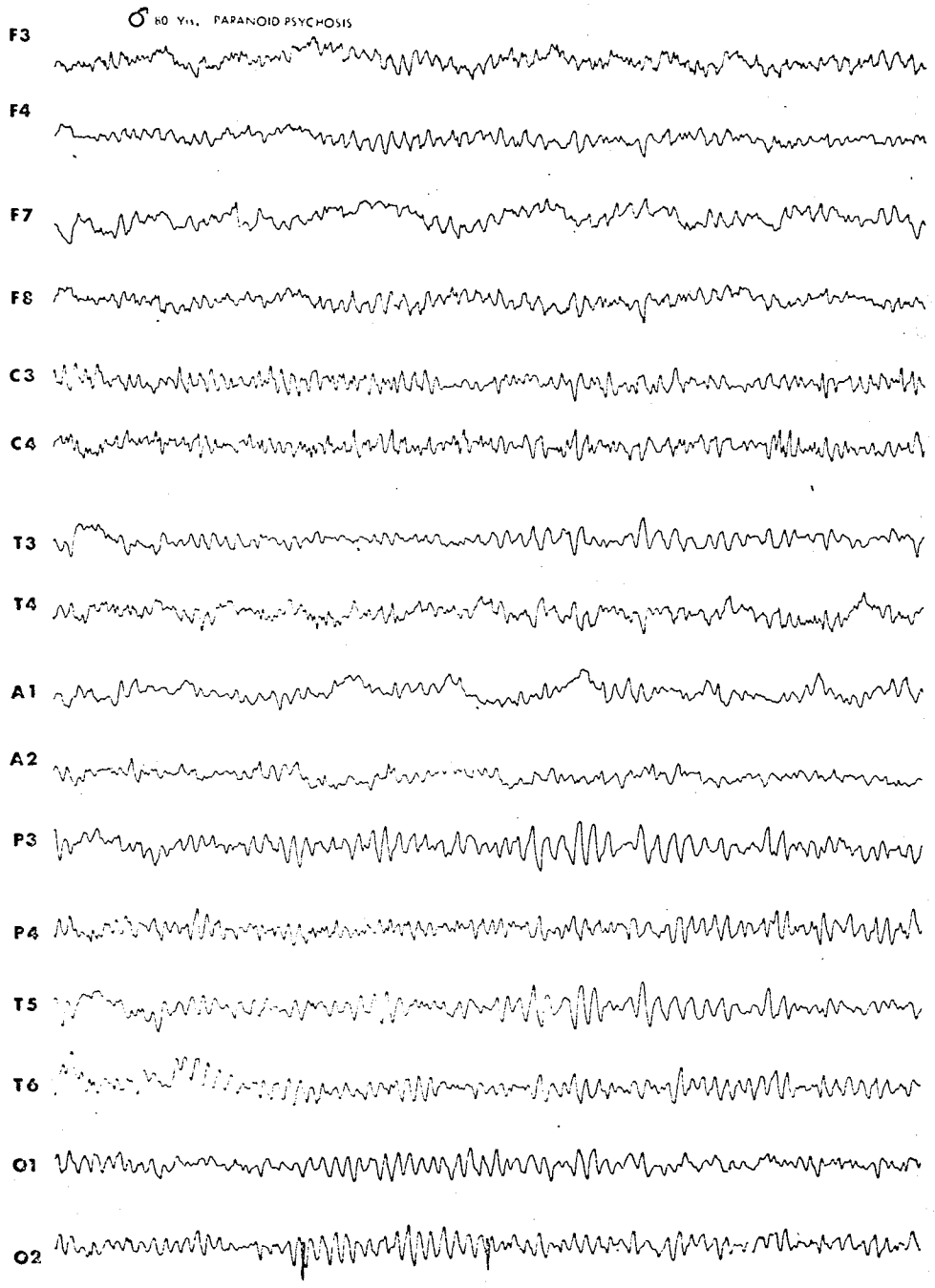


FIG. 10. LEFT TEMPORO-PARIETAL SLOW ACTIVITY.

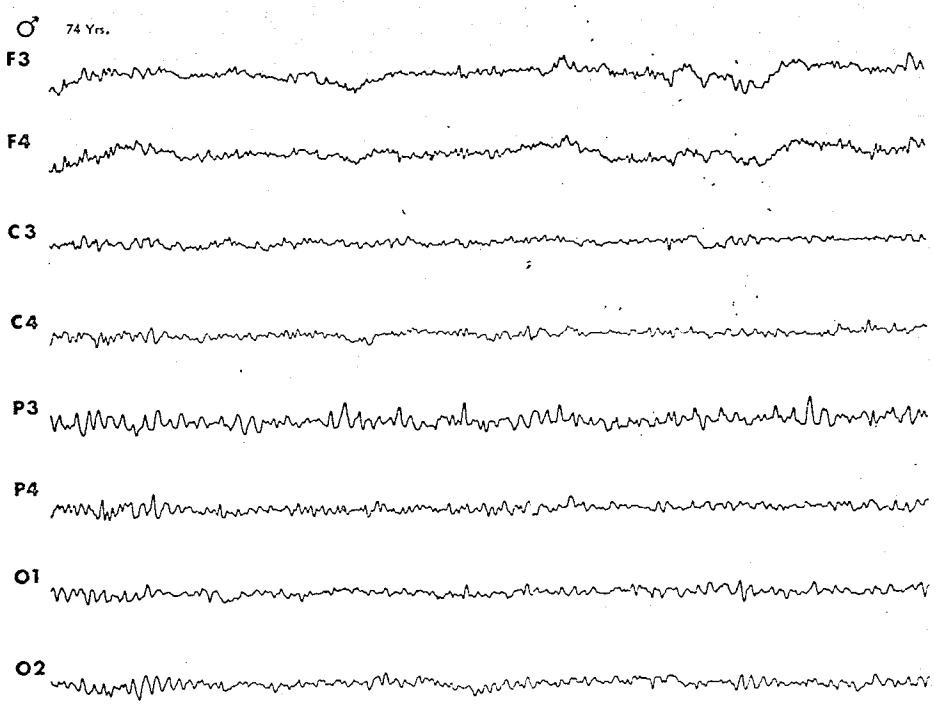


FIG. 11. LEFT PARIETAL SLOW ACTIVITY.

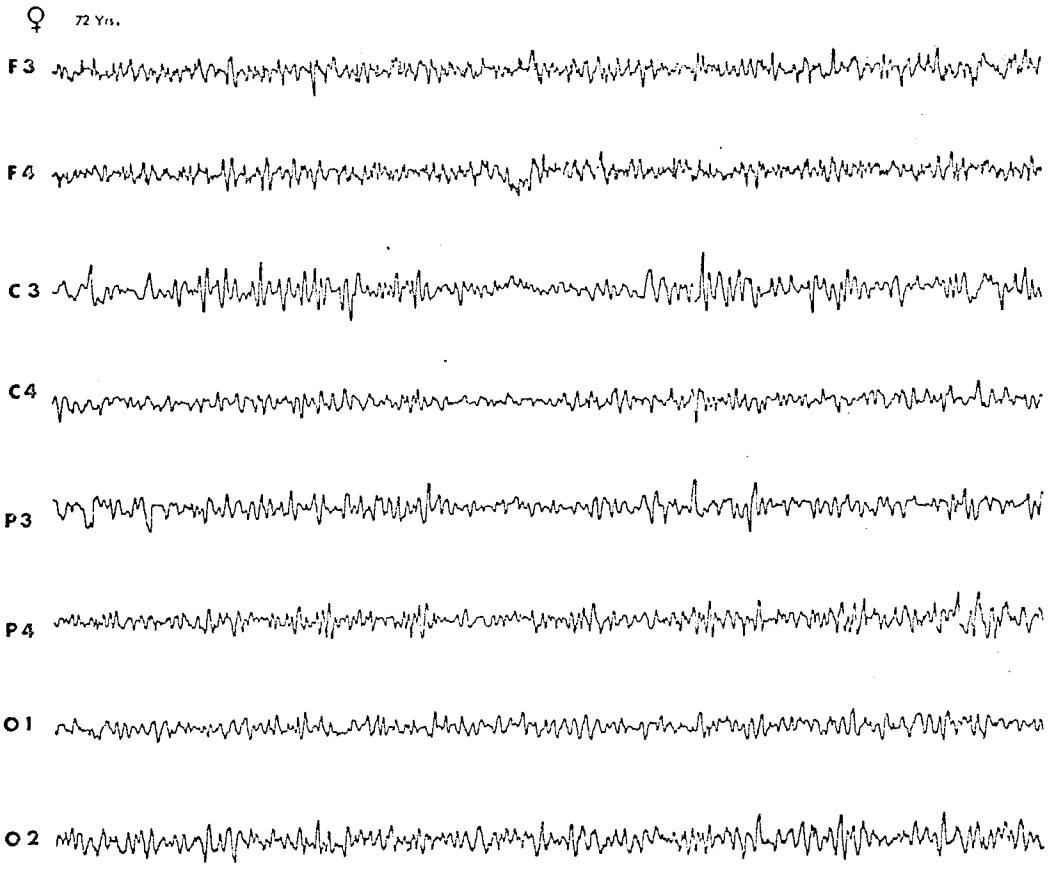


FIG. 12. LEFT CENTRAL - PARIETAL SPIKES AND SLOW WAVES.

arteriosclerosis were classified separately. Approximately 24% suffered from depression (affective illness) and about 22% from paranoid psychotic illnesses, the smallest group (12%) being acute confusional states.

Electroencephalographic Data

Mean values were calculated for the alpha frequency, percentage of slow activity and percentage of patients showing focal activity for each of the three groups. These values are shown in Figure 8. By analysis of variance (and subsequent "t" tests), a statistically significant difference ($p < 0.01$) was found between the mean alpha frequency of the volunteers (9.4 cycles/sec.) and that of both the other groups (physically ill 8.7 c/s; psychiatric 8.9 c/s), but no significant difference was found between the physically ill and psychiatric groups. Also, mean alpha frequency, mean percentage of slow activity and incidence of focal abnormality was calculated for the nine healthiest volunteers. These values were 9.9 c/s, 12.1% and 11% (1 case) respectively. Comparing the mean alpha frequency of the males with that of the females within each group failed to show any statistically significant difference.

Figure 9 illustrates the differences between the alpha rhythm of a 39 year old healthy male and a 78 year old healthy male volunteer. The latter is less stable, has a lower mean amplitude and a slower frequency (8.25 c/s compared to 9.75 c/s).

No significant differences were found between the percentages of slow activity (12.5%; 15.2%; 16.5%) or focal abnormalities (10%; 13%) of the groups, nor was the mean percentage of slow activity (12.1%) of the "nine best" volunteers significantly different from the values found in the other groups. The incidence of delta activity (½ to 3 c/s) was very low in the great majority of tracings and did not warrant calculation. Therefore, for all practical purposes, the values for percent of slow activity represent activity in the theta (4 - 7 c/s) range. In all instances, focal abnormalities occurred in the left hemisphere and consisted of runs of slow activity (Fig. 10; Fig. 11) or mixed spikes and

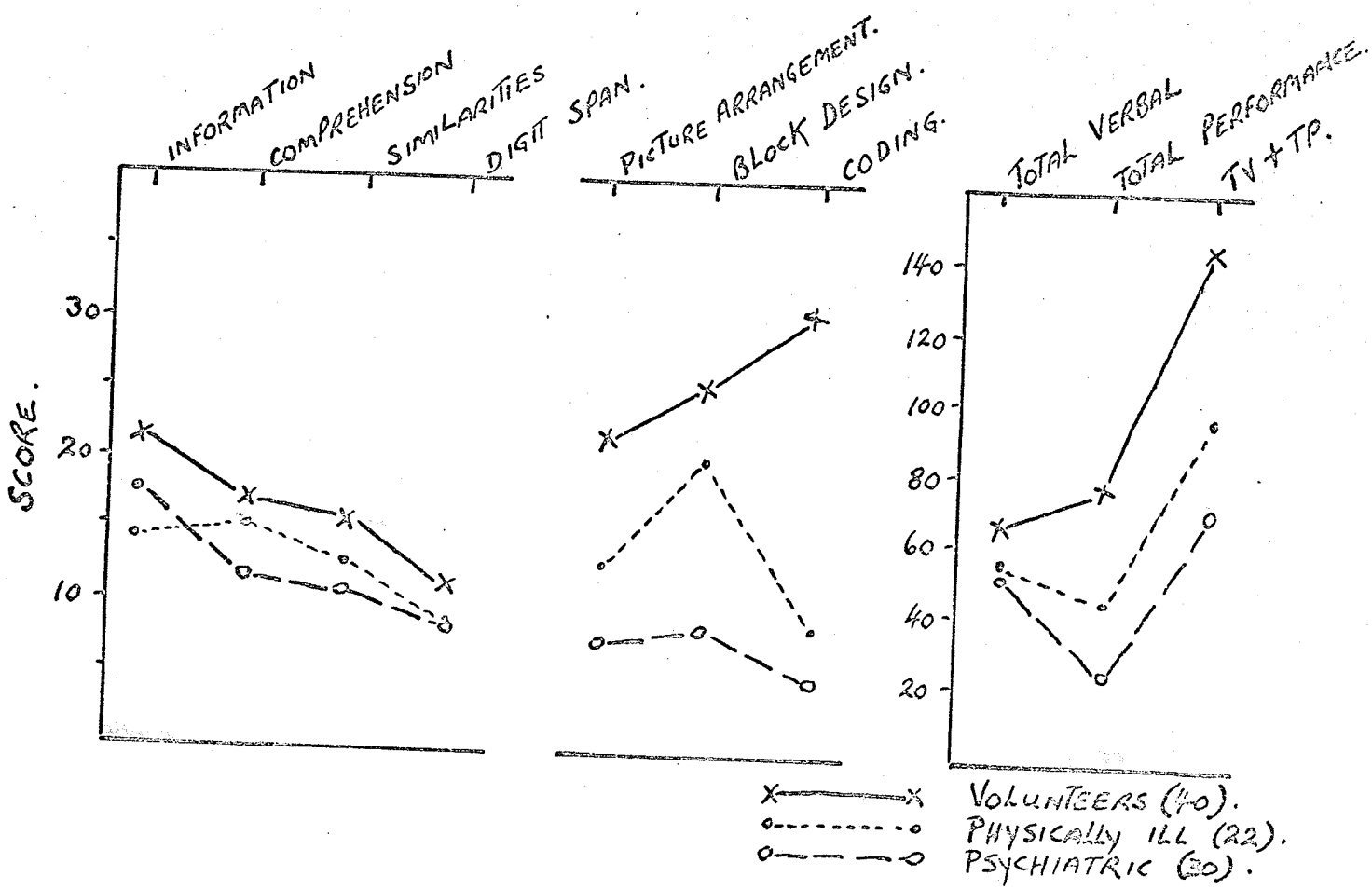


FIG. 13. MEAN WISC RAW SCORES OF VOLUNTEER, PHYSICALLY ILL AND PSYCHIATRIC GROUPS.

slow waves (Fig. 12), the temporal and parietal areas being the most common sites.

Since all patients in the ill groups had been in hospital for one day prior to having an E.E.G., the possible effect of medication had to be considered. The drugs most likely to affect the E.E.G. are sedatives, anti-depressant drugs and the major ataractics, therefore the mean alpha rate and mean percent slow activity was calculated for patients who had received any of these drugs. The values obtained were compared to the mean values for patients who had not received any medication likely to affect the E.E.G., as shown below.

- Physically ill: - no medication: 8.7 c/s; 14.0%
  - with medication: 8.8 c/s; 18.3%
- Psychiatric: - no medication: 8.9 c/s; 13.7%
  - with medication: 8.9 c/s; 17.1%

No statistically significant differences were found between the mean alpha frequencies in each group and it would appear that the initial few doses of medication have no effect on alpha frequency. In the physically ill group, no significant difference was found between the mean percent of slow activity of patients receiving medication and those not receiving medication. However, in the psychiatric group those patients who had no medication showed significantly less ($p<0.05$) slow activity than those with medication, (usually a major ataractic). However, it was decided to discount the possible influence of medication since the effect on the E.E.G. varies greatly between individuals.

Psychological Data

When we compare the mean scores on the Dementia scale of the physically ill and psychiatric groups (8.5 and 6.3 respectively) we find a statistically significant difference ($p<0.01$). Similarly, plotting the means on each sub-test of the W.I.S.C. (Fig. 13), we find the volunteers score significantly higher on each test ($p<0.001$) than the other two groups while the physically ill score higher ($p<0.01$) than the psychiatric group, (with the exception of 'information').

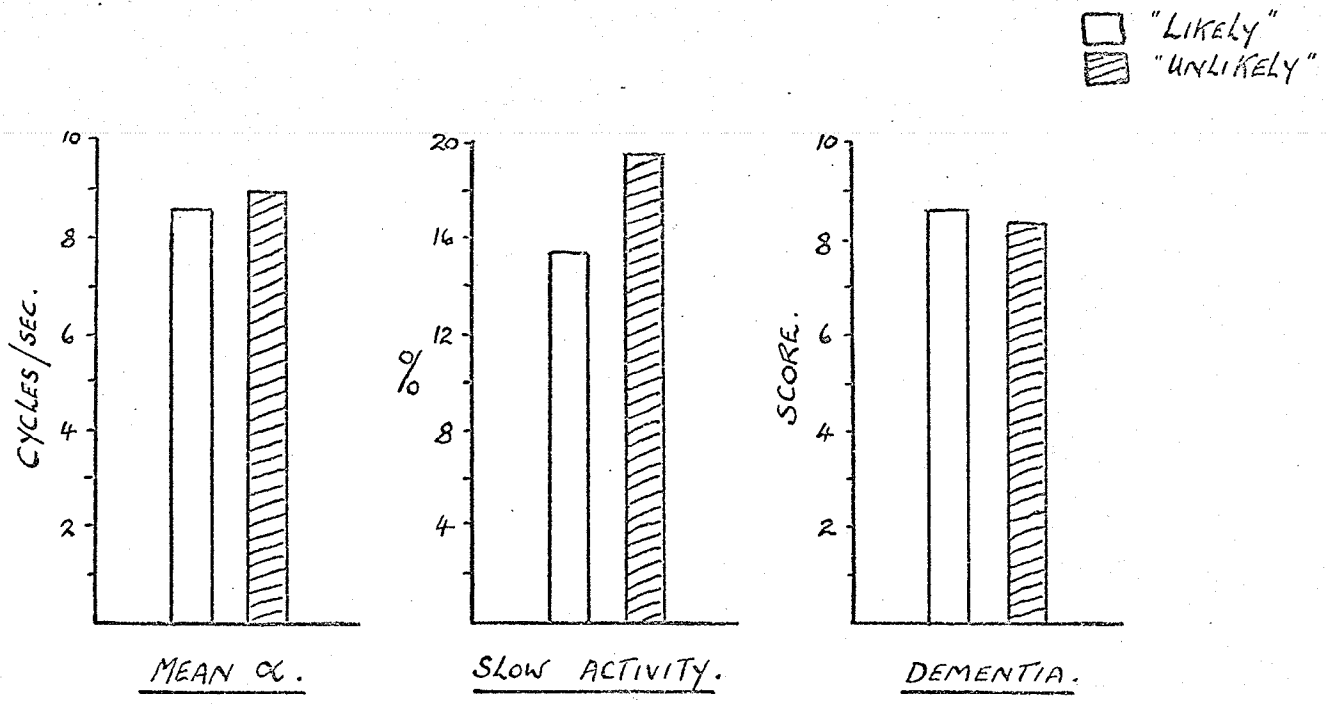


FIG. 14. COMPARATIVE EEG ANALYSIS AND DEMENTIA SCORE; PATIENTS "LIKELY" AND "UNLIKELY" TO HAVE CEREBRAL DISTURBANCE FROM THEIR PHYSICAL ILLNESS.

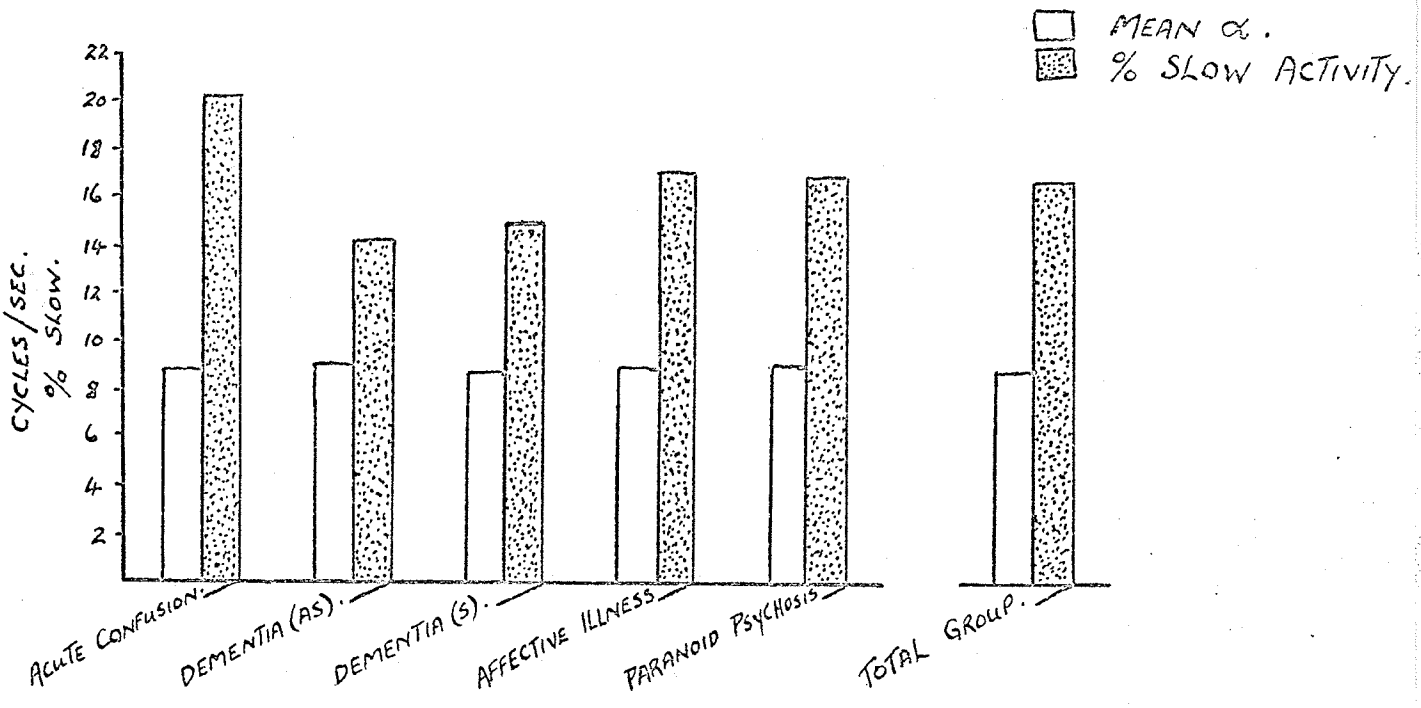


FIG. 15. EEG ANALYSIS OF PSYCHIATRIC SUB-GROUPS AND TOTAL GROUP.

It is interesting that all groups showed a relatively good score on 'block design' and 'information' and a poor score in 'Digit Span', 'picture arrangement' and 'coding' in comparison to the other sub-tests. The volunteers were the exception in that they did very well in 'coding', but this was the last test administered and one must consider the possibility of fatigue in the ill groups.

Relationships between E.E.G. and Psychological Data

In order to discover some E.E.G. characteristic which is peculiar to elderly subjects and to their physical and mental status, several analyses relating the E.E.G. data to physical and psychological functioning were carried out.

Patients in the physically ill group were sub-divided into those "likely" to suffer cerebral disturbance as a result of their acute physical illness and those "unlikely" to have such a disturbance. The "likely" group (12 patients) included those with cardiac and respiratory distress or marked anaemia and it is seen (Fig. 14) that they have a mean alpha frequency of 8.6 c/s compared to 8.8 c/s in the "unlikely" group, which consisted of patients with conditions such as fractures, eye diseases, enlarged prostates and renal calculi. The percentages of slow activity are 15.4% and 19.5% respectively and the dementia scores 8.6 and 8.3 respectively. None of the differences between the two groups is statistically significant, but the results suggest that reduced alpha frequency may be more indicative of disturbed cerebral metabolism than is an increased amount of slow activity.

When the E.E.G. data was examined for each of the psychiatric diagnostic categories (Fig. 15), no significant differences in the alpha frequencies or percentage of slow activity in the various groups were found. The acutely confused patients show the greatest proportion of slow activity, but, since there were only 5 such patients, it is probably because of the small number that this finding was not significant. The relatively high amount of slow activity in the affective and paranoid groups compared to the senile groups

makes one wonder if affective and paranoid illnesses in elderly people may be related to organic cerebral disease.

In order to establish possible relationships between the E.E.G. and psychological test findings, the data was analyzed on the University of Manitoba I.B.M. 360 Computer. Analysis of covariance was carried out to examine the individual relationships between alpha frequency and each of the following:

- Percent slow activity
- Age
- Information
- Comprehension
- Similarities
- Digit Span
- Total Verbal Score
- Picture Arrangement
- Block Design
- Coding
- Total Performance Score
- Dementia score

In the same way, analyses of covariance were carried out to examine the relationships between percent slow activity and all of the same set of variables. All of these analyses were carried out within each group of subjects and also for all groups combined.

Multiple regression analyses were carried out within each group of subjects with alpha rate and percent slow activity being the dependent values, each of these being related to all seven sub-tests, and all seven sub-tests plus dementia score in the hospitalized groups. In the same way multiple regression analysis was also applied combining the physical and psychiatric groups and combining all three groups. For these combined groups, age was included as an additional variable in separate analyses. The dementia scale was also examined as a dependent variable for the physically ill and psychiatric groups individually and combined, using the W.I.S.C. sub-tests as independent

Group.	Regression.		Correlation Coefficient.	T Value	D.F.
	A.	B.			
Volunteers.	47.459	-3.7078	-0.508853**	-3.40	33
Physically ill.	55.244	-4.3867	-0.390157	-1.99	22
Psychiatric.	54.554	-4.2971	-0.504685**	-3.41	34
Combined.	55.026	-4.4142	-0.498544***	-5.55	93

** $p < 0.01$
*** $p < 0.001$

TABLE 2. Regression Analyses of Percent Slow Activity and Alpha Frequency Values for Individual and Combined Groups.

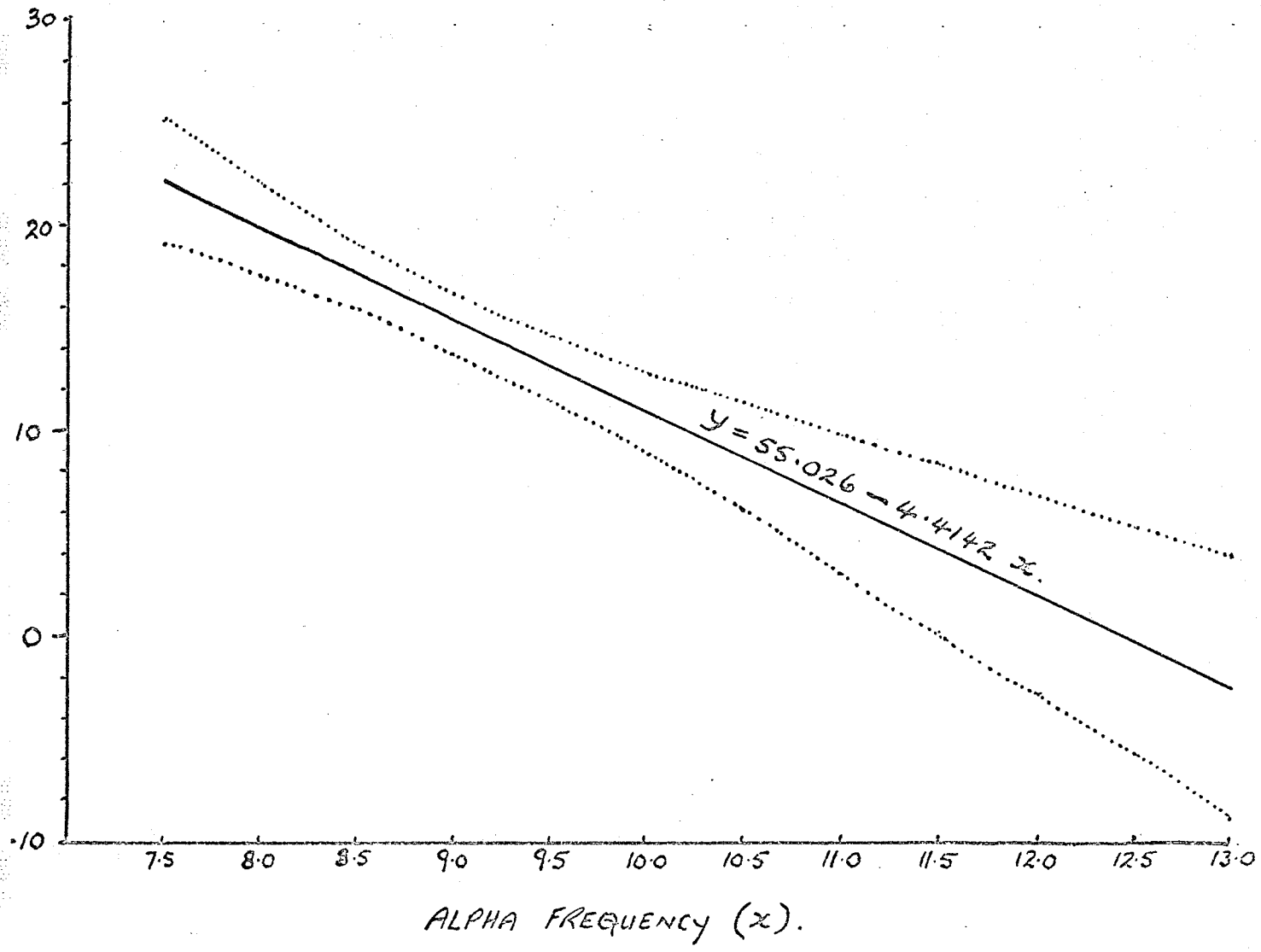


Fig. 16. RELATIONSHIP BETWEEN ALPHA FREQUENCY AND PERCENT SLOW ACTIVITY (ALL SUBJECTS) SHOWING 95% CONFIDENCE LIMITS.

variables, and also with the combined groups using Total Verbal and Total Performance Scores, in a separate analysis, as independent variables.

It was found that there were relationships between age and alpha frequency, age and percent slow activity and between alpha rate and percent slow activity. For alpha rate and percent slow activity the regression coefficients for the three groups were not significantly different (Table 2) and Figure 16 shows the relationship for all groups combined, the regression equation being:

. % Slow Activity = 55.026 - 4.414 Alpha rate ($r = -0.498$; $p < 0.001$).

The other regression equations are:

. Age = 96.916 - 2.430 Alpha rate ($r = -0.343$; $p < 0.001$)

. Age = 72.043 + 0.170 % Slow Activity ($r = 0.236$; $p < 0.05$)

Calculation of partial correlation coefficients for alpha frequency and percent slow activity (0.441), age and percent slow activity (0.304) and age and alpha frequency (0.409) showed that these three variables are significant and independent of each other. This suggests that changes in alpha frequency and an increase of slow activity with increasing age are the result of separate mechanisms.

Few relationships were found between E.E.G. data and W.I.S.C. sub-tests, and of the sixteen analyses of covariance performed, the only significant relationship was between alpha rate and Coding ($p < 0.05$). In the multiple regression analysis of the physically ill and psychiatric groups combined, a significant relationship was found between the alpha rate and age plus W.I.S.C. sub-tests (Similarities and Block Design) ($p < 0.05$). The same relationship was found when all three groups were combined and in addition alpha rate was significantly related to W.I.S.C. sub-tests alone (Similarities, Block Design and Coding) ($p < 0.01$).

The dementia score also showed some significant correlations with the E.E.G. and other psychological tests. Analysis of covariance showed significant relationships between the dementia score and percent slow activity ($p < 0.01$);

dementia score and age ($p<0.05$) and dementia score and alpha rate ($p<0.1$). The latter correlation was close to the 5% level of significance. Multiple regression analysis revealed significant relationships only for the combined physically ill and psychiatric groups. These were dementia score and total verbal plus total performance scores ($p<0.01$), dementia score and age plus W.I.S.C. sub-test scores (Comprehension and Block Design) ($p<0.05$); dementia score and W.I.S.C. sub-test scores (Comprehension and Block Design) ($p<0.05$).

Discussion

It is felt that the limited size of the study population makes it necessary to use caution before drawing any firm conclusions, however the results of this study have revealed some positive relationships among the variables studied. Alpha frequency shows a significant relationship ($p<0.01$) with age and we agree with Davis (9) and others (16,30,32,33) that there is a slowing of alpha frequency with increasing age. Possible reasons for this slowing involves problems of the origin and significance of the alpha rhythm. It is possible that the characteristics of the alpha rhythm are inborn and hereditary (55) although it is not seen in early childhood, making its appearance about the age of 3 or 4 years and becoming dominant by 11 years. Walter (55) suggests that the appearance of alpha rhythm in early childhood may be associated with the development of imaginative thinking. Adrian and Yamagiwa (1) and Walsh (54) believe that alpha rhythm is produced by 2 generators, one in each parieto-occipital region and that these generators are 'beating' at approximately the same rate. This theory is supported by the fact that a unilateral sub-cortical lesion may abolish the arousal reaction in one hemisphere only. Eccles (10) attributes alpha rhythm to reverberating chains of neurones in the cortex.

The reason for slowing of the alpha generators as a feature of aging is far from clear although several possibilities have been proposed. Hermann and Quarton (19) demonstrated a close relationship between alpha frequency and

the blood level of thyroid hormone. They propose that alpha frequency is a 'Physiological clock' established and regulated by the level of thyroid function. Slowing, therefore, might be related to a lowering of metabolic rate. Recently some interesting work by Saunders and Zubek (44) has shown that slowing of alpha frequency is a feature of both perceptual and sensory deprivation, being more marked in the former and taking as long as 7 days to return to the normal frequency. This slowing associated with kinaesthetic deprivation can be counteracted to some degree by allowing the subject to exercise at regular times during the study period. The possibility arises that slowing of alpha rhythm with age may be related to diminished kinaesthetic input and the relative immobility of elderly persons. In this regard, Surwillo (51) has shown that E.E.G. reactivity declines with age and in particular that the attenuation latency period of the alpha rhythm following a visual stimulus increases with age.

Whether the slowing of alpha rhythm in elderly persons can be attributed to a lowering of metabolic rate, diminished sensory input to the brain, or a result of less physical activity is debatable. Certainly our most active group (Volunteers) showed a higher mean alpha frequency than the less active ill groups and when we compare the mean value of the "nine best" volunteers (9.9 c/s), the difference is still greater. These "nine best" subjects (3 male and 6 female) had no complaints about their health, were found to be normal on physical examination and scored above the mean for the group on the psychological tests. Presumably the E.E.G.'s of this sub-group is more likely to reflect the effects of age alone and we note that the mean alpha frequency compares closely to the 10 c/s commonly found in young adults. The significant slowing of alpha in the ill groups may be related to impaired cerebral metabolism, reflecting a state of physiological stress in a marginally functioning organ. On the other hand there was no significant difference between the mean alpha frequencies of thise "likely" and "unlikely" to have disturbed cerebral metabolism in the physically ill group.

Finally there is the possibility that the slower alpha rhythm of the

elderly is related to an increased amount of visual imagery possibly to compensate for less physical and interpersonal activity. In 1943 at the Burden Neurological Institute in England (55), individuals were classified into 3 groups according to alpha characteristics. About two thirds of a random sample of the normal population show alpha activity when the eyes are closed, but this activity responds to (is blocked by) visual stimulation on opening the eyes. These are referred to as the 'R' type. The other third of the sample is evenly divided between 'P' and 'M' types, the former being those whose alpha rhythm persists in spite of visual stimulation. The 'P' types consisted of people who use little visual imagery but rely more on auditory, tactile, or kinaesthetic perceptions. The 'M' types, on the other hand, show very little alpha rhythm even with the eyes closed and characteristically use a great deal of visual imagery. It is interesting that the proportion of 'M' types is higher in science students than in Arts students. One wonders if there might be a move towards the 'M' type (and increased visual imagery) with increasing age but further investigation is needed to test this hypothesis.

The percentage of slow activity was also found to correlate with age but only at the 5% level of significance. The correlation with the dementia score was more significant ($p<0.01$) which is in keeping with the work of Engel & Romano (11) that there is an increasing amount of slow activity associated with a decreasing level of awareness. This is further borne out by the high incidence of slow activity in the acute confusional group. On the other hand, no significant differences were found between the mean values of the 3 groups of subjects or between the "nine best" volunteers (12.1%) and the other groups. It is possible that the alpha frequency is a more delicate indicator of impaired cerebral function and shows the initial changes on the E.E.G. while the percentage of slow activity is a more crude measure indicative of more severe impairment. If this is so, then the large amount of slow activity seen in the affective and

paranoid conditions suggests that these illnesses may be emotional and behavioural disturbances secondary to impaired cerebral metabolism. In this regard, it would be interesting to study serial E.E.G. records of elderly people suffering from acute physical illnesses or affective and paranoid illnesses and note any changes in the percentage of slow activity as the patient's health improves. There is, therefore, the possibility that slow activity may be related to mood as well as organic cerebral changes.

Theta activity (4 - 7 c/s) was so named because it is believed to arise from the thalamus. It is a marked feature of the E.E.G. records of young children, being the dominant rhythm between 2 and 5 years of age. It does not respond to visual stimulation but appears to be much more closely related to the mood of the subject, and can be evoked by both frustration and pleasure (55). Walter (55) suggests that the more exuberant display of emotions characteristic of children (and the relative dominance of theta activity) may be due to later development of cortico-thalamic connections. Hill (20, 21) has shown that theta activity is rare in good tempered adults but is prominent in aggressive psychopaths and may be related to immaturity of the mechanism linking cortex, thalamus and hypothalamus. In a further study of delinquent children, 85% of the E.E.G. records were classified as abnormal but no relationship was found between amount of theta and 'badness'. However, careful analysis showed that children with most 'promise' (most cooperative with parents and authorities) showed significantly more delta (½ - 3 c/s) activity than those who were difficult to handle. It is interesting that visual stimulation at a frequency within the theta range produces feelings of annoyance and frustration even in normal subjects. However if the subjects are encouraged to suppress the unpleasant feelings, the theta activity diminishes (55).

The relationship between theta activity and mood suggested by the above work, provides the possibility that the increased amount of theta in old age may be associated with the many frustrations and difficulties of this age group. For instance, retirement with accompanying reduction in income, loss of social

status and prestige as a provider; increased leisure time with reduced physical stamina and often chronic physical disability; loneliness from disruption of family due to marriage of children or death of spouse. All of these may account for annoyances, frustration and depression in the aged.

The occurrence of focal disturbances on the E.E.G. seem to be non-specific findings in old age since they appear in both the volunteer and mentally ill groups with no significant difference. One of the 'nine best' volunteers showed left parieto-temporal slow activity but had no history or clinical evidence of cerebral disease. This is in keeping with the findings of Busse and Obrist (6). In some cases the focal abnormality was the only abnormality in the E.E.G. record and no significant differences were found between the mean alpha frequencies or mean percentages of slow activity of those subjects with focal disturbances and those without focal disturbances. It was noted that mentally ill patients who had a left parietal abnormality tended to have a slower alpha frequency and greater amount of slow activity than patients whose abnormality was confined to the left temporal area. However the incidence of focal abnormalities and the total number of subjects studied is too small to allow any conclusion to be drawn from this observation. Our findings agree with those of other workers (2,6,14,18) in that focal abnormalities occur mainly in the left cerebral hemisphere. No instance of a right sided abnormality occurred in this study. It has been suggested (6,7,14,18) that these are due to vascular changes, a view which gains support from the clinical observation that cerebro-vascular accidents occur more often in the left cerebral hemisphere. Because of the anatomical position of the temporal lobes, it is often difficult to record abnormal discharges from the routine scalp electrode, a difficulty aggravated by the common occurrence of movement and muscle artefact in elderly persons. In a more cooperative group of subjects, one can detect more temporal lobe pathology by using sphenoidal needle electrodes inserted beneath the zygoma to a depth of approximately 4 cm. Busse and his co-workers, (6,46) emphasize

the importance of electrode placement and suggest a position immediately above the arch of the zygoma in order to detect anterior temporal pathology.

Psychological test results show significant differences between the mean scores of each of the three study groups with volunteers showing the best scores and the mentally ill the poorest scores. A significant difference also exists between the mean dementia scores of the physically ill and psychiatric groups. In spite of these findings, analysis of covariance failed to demonstrate any relationship between E.E.G. data and any single psychological test, although in the physically ill group the percent of slow activity and the dementia scores are significantly related ($p<0.01$). The poor scores of the mentally ill no doubt reflects the effects of psychosis (thought disorder, hallucinations, emotional disturbance) in addition to purely organic cerebral changes, although apparently these interfere less with 'information' than with the other tests. The ill groups showed that Coding was the poorest score of the performance group of sub-tests and we note a significant relationship between alpha frequency and Coding ($p<0.05$). One must bear in mind that Coding is a visuomotor test involving a speed factor and therefore may correlate closely with neurophysiological mechanisms. Attempts to establish a significant formula relating groups of psychological tests to E.E.G. data met with little success, although, combining all 3 groups of patients we find that alpha frequency is significantly related to total sub-test scores ($p<0.01$). The ease with which elderly persons tire or become impatient, intolerant or frustrated, makes the use of brief tests imperative if valid results are to be obtained. The simple dementia scale used in this study was found to be useful and easily administered and it correlates with the total W.I.S.C. scores (all values combined) at the 1% level of significance.

Although we failed to find any significant difference between the mean values for percentage slow activity in the three study groups, Surwillo (48, 49, 50) has shown that there is a strong correlation between response time and the mean frequency (period) of the E.E.G. Similarly, he found a significant

correlation between response time (to make a decision) and age. He pointed out that subjects with slow brain waves require more time to decide between two alternatives than subjects with fast brain waves. Surwillo (40) claimed that "the brain-wave cycle is the basic unit of time in terms of which a response is programmed by the central nervous system". Similarly, Walter (55) pointed out that variation in the period of the E.E.G. is a characteristic of the highly intelligent while dull subjects show a more constant value.

Our findings in this study suggest avenues for further investigation:

1. the need for serial E.E.G. studies in elderly people to determine early signs of abnormality as well as follow the progress of abnormal records and their relationship to clinical status.

2. the significant difference in alpha frequency between volunteers and acutely ill old people suggests that this may be an early E.E.G. indication of impaired cerebral function. Serial E.E.G. records on this group of patients might determine whether this is a reversible change or if it persists as a feature of permanent cerebral damage.

3. the similarity between E.E.G. records of demented patients and those suffering from affective and paranoid illnesses makes the E.E.G. of little value in distinguishing between these illnesses in the elderly. Again the reversibility of these E.E.G. findings in the affective and paranoid groups could be investigated by taking serial records throughout the course of treatment.

4. The restlessness and poor cooperation often found in elderly people produces a great deal of artefact on E.E.G. records and often it is difficult to obtain an artefact free sample of tracing for the purpose of frequency analysis. A further study of sleeping records in elderly subjects compared to young adults might be informative. If an E.E.G. character is to be discovered which is specific to old age, it is likely that electronic frequency analysis will be required rather than the more laborious and less reliable manual analysis.

5. Further study is required of the focal abnormalities found in senile E.E.G. records, with regard to both their form and anatomical location. It is noted that abnormalities extending into the parietal area were more likely to be associated with other abnormalities in the record (slow alpha frequency; increased slow activity) while those confined to the temporal lobe frequently occurred on an otherwise normal E.E.G. An insufficient number of cases in the present study precluded any attempt to correlate the form of the focal abnormality with the clinical status. One might hypthesize a difference in mental status between subjects showing spikes and sharp wave complexes from those showing runs of theta activity.

6. In the light of Surwillo's work, the response time to various stimuli in elderly people may be correlated with E.E.G. findings and with different diagnostic categories.

With reference to our hypotheses, we may conclude from our study that there is a significant slowing of alpha frequency and increase in slow wave activity in the E.E.G. with increasing age. These features are more prominent (but not significantly so) when elderly patients become physically or mentally ill and we confirm that the degree of slowing is significantly related to the level of awareness as measured by a dementia scale. These changes in the E.E.G. of elderly subjects, along with the finding of focal abnormalities, makes it necessary to interpret the senile E.E.G. with caution since there seems to be no relationship between E.E.G. findings and the clinical state. Similarly, there is little relationship between the E.E.G. and psychological test results although we found a significant relationship between the alpha frequency and Coding which is a visuomotor test. On the other hand, the percentage of slow activity is significantly related to the dementia score used in this study. These results are contrary to the findings of other workers (2,4,35). It would seem that the neurophysiological mechanisms producing alpha slowing and general slowing of the E.E.G. are independent. Our findings suggest

that if an elderly person becomes ill he will show a slowing of alpha frequency whereas if he becomes demented there will be an increase in the percentage of slow activity. The E.E.G. variables investigated in this study are of no value in distinguishing between diagnostic categories of psychiatric illness and, with the exception of delirium, are of little help in differentiating organic cerebral impairment from the so-called functional illnesses of elderly people.

Summary

Purpose

The purpose of this study was to investigate various aspects of brain function in subjects of 65 years of age and over. In particular it was hoped to find:

1. if the electroencephalogram (E.E.G.) shows any specific characteristic in old age.

2. the significance of an abnormal E.E.G. in old age.

3. the effect of acute physical illness on cerebral function as indicated by the E.E.G.

4. the value of the E.E.G. as a diagnostic tool in elderly patients suffering from various types of mental illness.

5. the relationship between the E.E.G. and the level of intelligence (or dementia) as measured by a group of psychological tests.

Methodology

Three groups of subjects age 65 years and over were studied: community volunteers, patients in a general hospital suffering from an acute physical illness and patients admitted to a psychiatric hospital. The final total of 113 suitable subjects consisted of 40 volunteers, 27 physically ill and 46 mentally ill patients with mean ages of 74.4, 77.1 and 74.1 years respectively. Following medical and psychiatric histories, each subject was given a physical examination with laboratory investigations (Hgb., E.S.R., Urinalysis), particular attention being paid to the central nervous system. The level of mental function was obtained by the administration of two psychological tests: a 10 point Dementia scale and a group of sub-tests from the Wechsler Intelligence Scale for Children. Electroencephalograms consisted of both monopolar (average) and bipolar montages and were analyzed manually for mean alpha frequency, percentage of slow activity and the presence or absence of focal abnormalities.

Essential Findings

1. The mentally ill patients showed the highest incidence of chronic physical illnesses.

2. The mean alpha frequency of the volunteers (9.4 c/s) was significantly higher ($p<0.01$) than that of the physically ill (8.7 c/s) and the mentally ill (8.9 c/s) but there was no significant difference between the two ill groups or the various diagnostic categories in the psychiatric group. The nine healthiest subjects in the volunteer group had a mean alpha frequency (9.9 c/s) similar to that commonly found in young adults.

3. All focal abnormalities on the E.E.G. were seen on the left side of the brain and mainly in the temporal or parietal areas. There was no significant difference in the incidence of focal abnormalities between groups. There was a suggestion that parietal lobe foci were more likely to be associated with other E.E.G. abnormalities than purely temporal foci.

4. The mean percentage of slow activity did not differ significantly among the groups and was of no value in distinguishing "functional" from "organic" illness in old people. There was a tendency for the percentage of slow activity to increase as mental function deteriorates (as measured by the Dementia score) and the highest incidence was found in acutely confused patients.

5. The volunteers show the best performance on the psychological tests, to be followed by the physically ill who in turn score better than the mentally ill. All subjects show their lowest scores on Digit Span and Coding (compared to the norms for a 15 year old person) which suggests that these are functions lost with aging. There is a significant difference ($p<0.01$) between the mean scores for each group of subjects.

6. Using analysis of covariance significant relationships were found between alpha frequency and percent slow activity ($p< 0.001$); alpha frequency and Coding ($p<0.05$); age and dementia score ($p<0.05$), alpha frequency and

percent slow activity ($p<0.001$); alpha frequency and the total sub-test scores ($p<0.05$). Partial correlation coefficients showed that alpha slowing and increased percentage of slow activity were both independently related to increase in age.

7. Possible reasons for the alpha slowing and the general slowing of senile E.E.G.'s are mentioned and include lowering of metabolic rate; decreased sensory input and physical activity; changes in mood in response to environmental stresses; increased use of visual imagery.

8. It is suggested that the neurophysiological mechanisms producing slowing of alpha frequency and general slowing of the E.E.G. are different. If an elderly person becomes ill, this will be reflected in a slowing of alpha rate while dementia is associated with a general slowing of the E.E.G.

9. Further investigations are indicated as a result of this study. These include serial E.E.G. studies in elderly people; classification of focal E.E.G. abnormalities according to form and anatomical position and their possible relationship to mental status; serial E.E.G. studies in acutely ill seniles to investigate reversibility of changes in the records; a similar study of the affective and paranoid illnesses of old people; comparison of sleeping records in young and old adults in order to avoid the movement artefact so commonly seen in the records of the elderly; finally, investigation of a possible relationship between response time to stimuli and E.E.G. findings or diagnostic categories of psychiatric illness.

ABSTRACT OF THESIS

A CORRELATIVE STUDY OF THE ELECTROENCEPHALOGRAPH IN VOLUNTEER, PHYSICALLY ILL AND MENTALLY ILL OLD PEOPLE

by

ROBERT G. BANKIER

December, 1967.

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