Computerized EEG Mapping During Cognitive Activation with Verbal Task

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This study aimed at investigating patterns of EEG reactivity during cognitive activation with word fluency test. Thirty two healthy volunteers were investigated using brain mapping system during rest, with eyes closed and while performing the task. EEG maps showing the difference between the two conditions, as well as off-line statistical analysis were performed. There was involvement of the left hemisphere as shown by reactivity in the alpha band frequency. Changes in the beta activity showed a different pattern, i.e., they were more localized than changes in the alpha activity; and took place mainly in the frontotemporal areas. The results are in accordance with neuropsychological findings. The implications of these findings to brain-mind research in normal subjects and psychiatric patients are discussed.

(Egypt.J. Psychiat.,1994, 17: 9-16).

Introduction

The relationship between cerebral structure and function has been the subject of intensive research during the last three decades. Luria (1973) was able to show evidence for localization of different functions in neurologic patients. More evidence in normal subjects had accumulated using the newly developed neuroimaging techniques: regional cerebral blood flow (Ingvar and Lasse, 1963); positron emission tomography to measure regional cerebral blood flow (Gur *et al.*, 1987).

However, the situation of EEG studies of mental functions is more complicated. Since the beginning of electroencephalography, researchers have attempted to relate mental and cerebral activities. In the thirties, Berger showed the desynchronization of alpha rhythm during visual information processing. However, the challenge remains to find cerebral activation indices related to cognitive processes in a certain task.

Traditional (visual) methods of analyzing EEG data were not encouraging in detecting subtle changes during mental activity. It was until digital methods of computer analysis and imaging of EEG and event-related potentials (ERP) were introduced that revival of interest in this field took place. Some authors argue that EEG changes during mental activity are nonspecific and related to the difficulty of the task (Rumsey *et al.*, 1989) or to

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differences in stimulus characteristics, efferent activity and performance related (Gevins *et al.*, 1979). On the other hand, it is argued that when such factors are controlled, EEG topography can differentiate between different states of activation (Ojeman *et al.*, 1989; Lazarev, 1989) and also between psychopathologically different patient groups (Okasha and Raafat, 1988 & 1990; Gruzelier, et al., 1990). Recent studies have shown background EEG reactivity in auditory event-related potentials (Van Dijk, et al., 1991) as well as patterns of cortical activation during planning of voluntary movement; cognitive processes during reading and classification of words (Pfurtscheller and Kleimesch, 1988); and during a verbal recognition task (Dujardin *et al.*, 1993).

Subjects and Method

A) Subjects:

32 healthy volunteers (21 males and 11 females, aged 21-35 years) took part in the experiment. All subjects were right-handed, received no drugs and were interviewed for exclusion of past history of psychiatric illness.

B) Procedure:

1- EEG acquisition:

EEG was recorded using a set of 16 electrodes according to 10-20 system (F7, F8, F3, F4, C3, Cz, C4, T3, T4, T5, T6, P3, Pz, P4, 01, 02) with ipsilateral earlobes reference. Recording took place simultaneously on a conventional electroencephalographer and a hard disc of EEG mapping system (Brain-Atlas II). The signals were amplified with a 35 Hz high-frequency cut-off filter and 0.3 time constant, with sample rate of 128 Hz. The procedure took place in a sound-proof dark room with subjects relaxed in a comfortable chair after 10 minutes of adaptation to the experiment condition. EEG was recorded for 3 minutes with the eyes closed (state 1), as well as during verbal performance (state 2), with eyes still closed.

2- The verbal task:

Word fluency test was used for cognitive activation. Subjects were instructed to form complete meaningful sentences of not less than 3 words, all beginning with a given letter. The recording was started after spelling out the stimulus letter and interrupted when the subject completes the sentence, as indicated by a special signal. Only segments that corresponded to right answers were used for further analysis.

3- Analysis of data:

Eye inspection was used to exclude artefacts (mainly eye-movement). In spite of the fact that this is more time consuming than automatic exclusion of artefacts, this method is better and more accurate. Artefact-free 2 second-segments (40-60 sec) were subjected to Fast Fourier analysis followed by construction of EEG maps. Substraction maps (state 1 minus state 2) showing EEG background reactivity to cognitive activation, as well as maps representing results of Student t-test were also constructed. This was achieved through the Bank-mathematics program of Brain-Atlas II which allows the performance of multiple statistical procedures.

Binnie and MacGillivary (1992) warned against the dangers of clinical misuse of mapping. They state that for research purposes interest in graphic presentation of derived EEG features may be counter-productive if it promotes the generation of pictures above the rigorous application of statistical methods.

Thus, in our study a further off-line statistical analysis of EEG data was done using the BMDP II programs. The data were transformed into numerical values in the term of amplitude of spectrum, and these were subjected to matched-pairs

T-test (T), Sign test (S) and Wlcoxon signed ranged test (W) in order to compare the two testing conditions. Frequency bands used for analysis were alpha 1 (8-9.5Hz.), alpha 2 (10-11.5 Hz.), alpha 3 (12-13 Hz.) and beta (13.5-30 Hz.). Only fast components of the EEG were included. Van Dijk *et al.* (1991) showed that the background EEG changes in the higher frequencies (alpha and beta) are related to the task during an auditory event-related potentials (AERP) study, while changes in the slow components were interpreted as AERP dependent. Event-related desynchronization (ERD) was first quantified in the alpha and beta frequency bands as changes in these activities during planning of voluntary movement (Pfurtscheller and Arnibar 1979).

Results

Figure (1) shows a substraction map (state 1 minus state 2) in the alpha frequency band. We can notice that the maximal reaction took place in the posterior region of the left hemisphere. The peak of reactivity is seen at the frequency band 9-10.5 Hz., especially at 10 Hz.

Figure (2) shows a map representing the results of Student t-test showing the reaction to verbal activation in the beta frequency band (13-30). Here, another pattern of topographic distribution can be observed, i.e., there is involvement of fronto-temporal areas bilaterally.

Table (1) shows the results of matched-pairs T-test (T), Sign test (S) and Wlcoxon signed ranged test (W). Results are presented in terms of p value when all the tests are statistically significant, or when tendency to significance is present. In the alpha band, maximal reactivity is noticed in the alpha-2 band, which is congruent with results of mapping. Although there is involvement of both hemispheres, the level of signifi-

Table 1

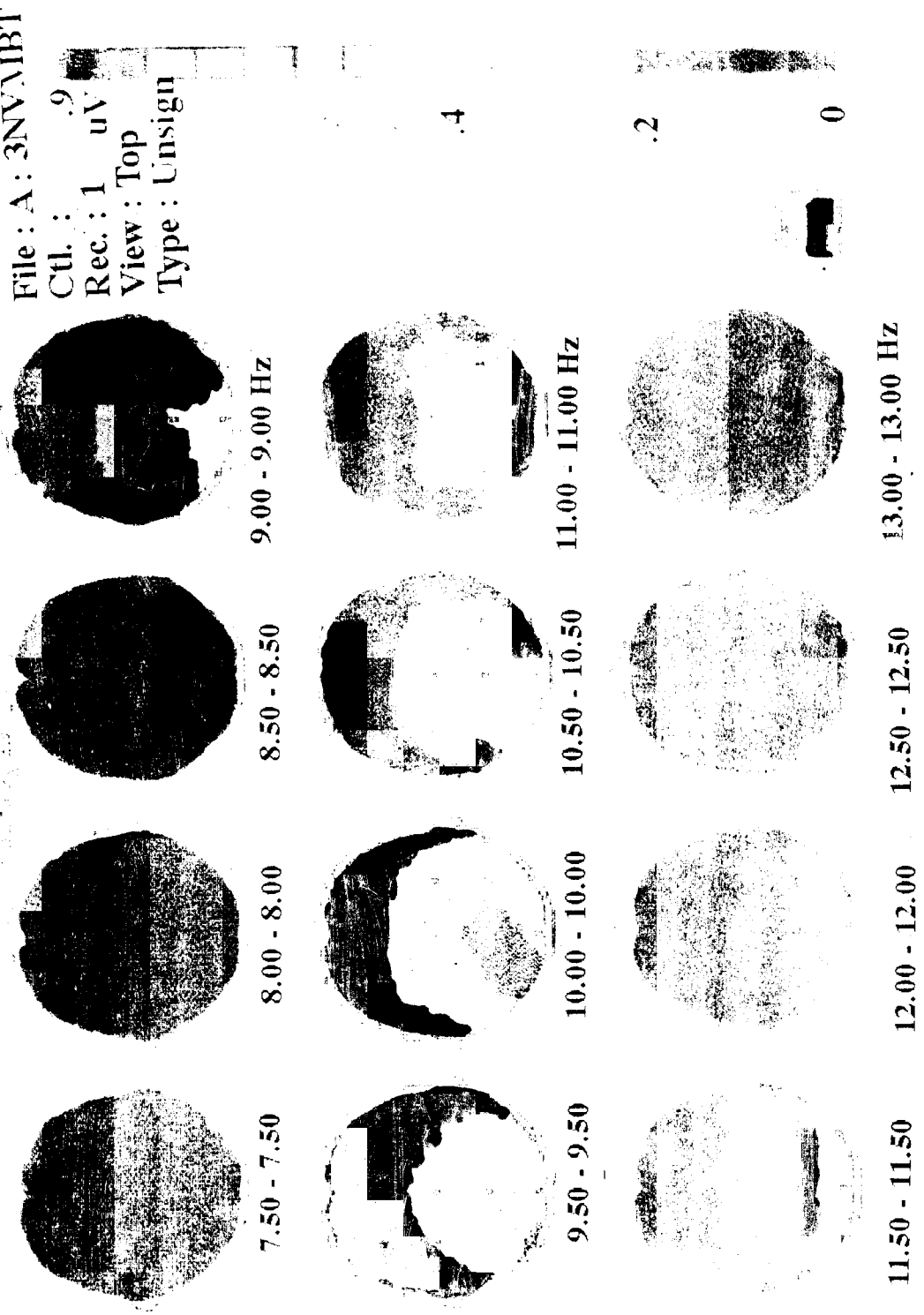
P Values [a] of T, S, W Tests [b]

Frequency Band *	F3	F4
alpha 2		
T	0.03	0.05
S	0.08	0.06
W	0.02	0.03
beta		
T	0.06	
S	0.05	
W	0.03	
	F7	**F8**
alpha 2		
T	0.05	
S	0.02	
W	0.07	
beta		
T	0.01	
S	0.05	
W	0.01	
	T3	**T4**
alpha 2		
T	0.001	0.002
S	0.003	0.01
W	0.001	0.000
alpha 3		
T	0.02	
S	0.02	
W	0.01	
beta		
T	0.000	0.003
S	0.000	0.003
W	0.000	0.000
	T5	**T6**
alpha 2		
T	0.004	0.03
S	0.003	0.02
W	0.003	0.01
alpha 3		
T	0.1	
S	0.1	
W	0.1	
beta		
T	0.002	0.001
S	0.003	0.000
W	0.000	0.000
	01	**02**
alpha 1		
T	0.04	
S	0.05	
W	0.03	
alpha 2		
T	0.003	0.1
S	0.003	0.1
W	0.000	0.01

a- When all the tests are statistically significant, or whe tendency to significance is present.

b- T=matched-pairs T-test , S= Sign test, W= Wlcoxo signed ranged test, to compare the two testing conditions.

* Frequency bands used for analysis were alpha 1 (8-9.5Hz.), alpha 2 (10-11.5 Hz.), alpha 3 (12-13 Hz.) an beta (13.5-30 Hz.).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.4
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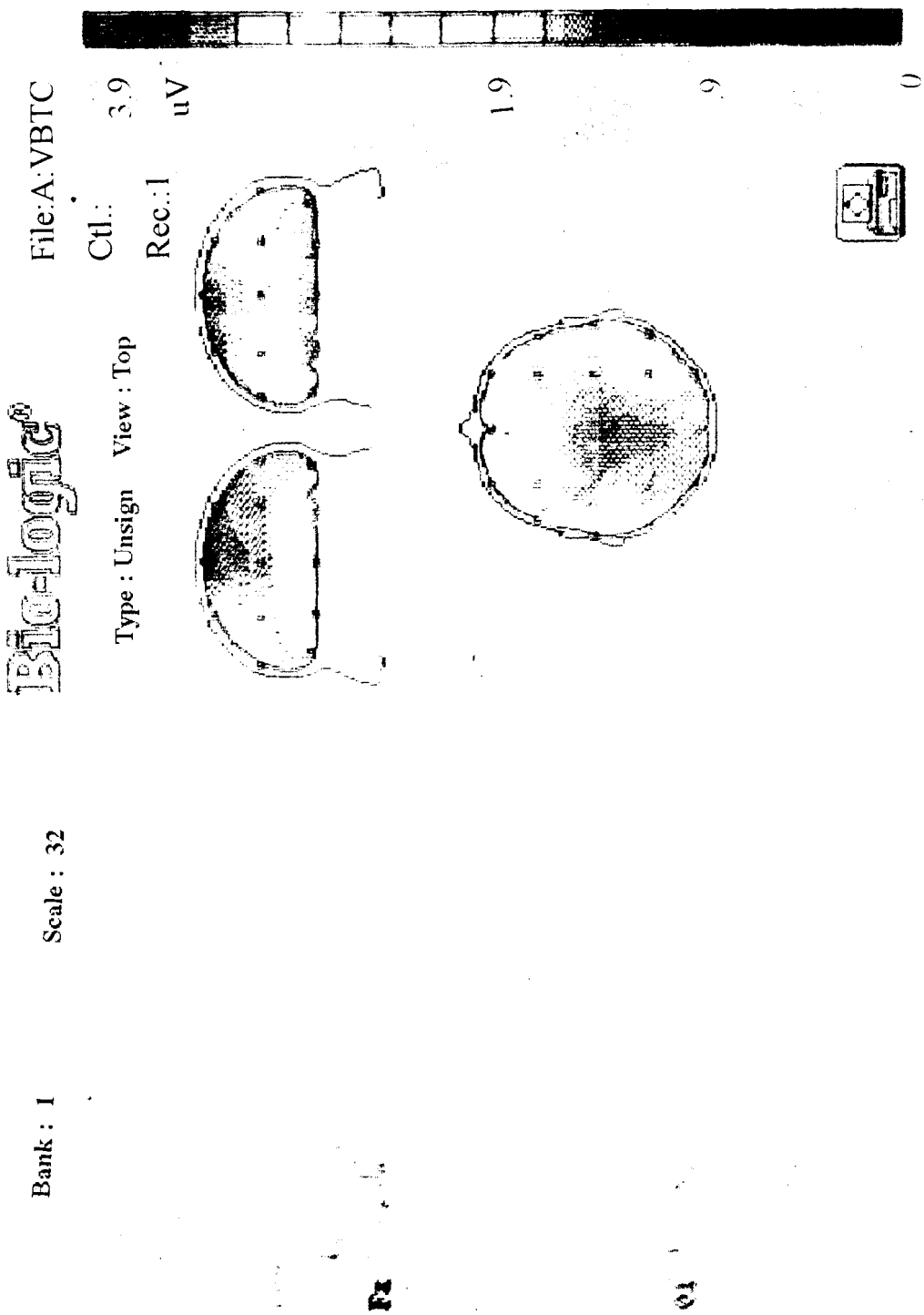
9.00 - 9.00 Hz
8.50 - 8.50
8.00 - 8.00
7.50 - 7.50
11.00 - 11.00 Hz
10.50 - 10.50
10.00 - 10.00
9.50 - 9.50
13.00 - 13.00 Hz
12.50 - 12.50
12.00 - 12.00
11.50 - 11.50

FIGURE I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Scale : 32
Type : Unsign View : Top
Ctl.: 3.9
Rec.:1 uV
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File:A:VBTC
T TEST,VERBAL &BB
INTERVAL: 20.00-30.00 Hz

FIGURE .2

cance is higher in the left hemisphere. The values of reactivity in the right fronto-temporal area did not reach significance. In the occipital region, no involvement of the right hemisphere was found. In the beta band, the significant results are in congruence with mapping, as marked involvement of language- related areas (fronto-temporal regions) is observed.

Discussion

The fact that EEG quantification by spectral analysis is a form of data reduction, which allows for a long record to be described in terms of few numerical values, makes it an aid to visual interpretation of EEG (Binnie and MacGillivary, 1993). When cognitive processes are involved only subtle changes in the EEG take place, being almost impossible to interpret on the basis of visual inspection. This makes quantified EEG and EEG mapping a useful tool for the investigation of mechanisms of mental activity. Event-related potentials are usually used for this purpose. However, Pfurtscheller and Arnibar (1979) coined the term event-related desynchronization (ERD) for changes in the EEG in reaction to cognitive activation. The technique used in this study is different from that of Pfurtscheller and Arnibar (1979) in the fact that the subject is involved in a task for a longer duration, which might be useful in detecting more stable patterns of reactivity.

The results of our study are in accordance with neuropsychological data on the specificity of the left hemisphere for verbal performance. This is evident from the results of mapping as well as statistical analysis. The reaction of the left hemisphere is more marked in the alpha frequency band (especially alpha-2). This might suggest that alpha activity is related to general activation. It also suggests that different components of alpha waves might have different origin in the brain. The pattern of reactivity in the beta band frequency was different from that in the alpha band. Cortical areas known to be language related are activated during the task (fronto-temporal areas). This suggests that beta activity is more related to task-related cognitive activation, while alpha activity is related to general activation. The bilateral involvement of fronto-temporal regions might be ascribed to the difficulty of the task, being highly semantic, a fact that would call for involvement for both hemispheres. This finding is against localizationists' views on brain functioning.

In general, the findings of this study shed some light on the usefulness of EEG- mapping when appropriate methods of activation are applied. The results can be replicated in normal subjects as well as in different psychiatric population which might contribute to understanding of cognitive processes and their disturbance in mental illness.

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La Carte Computeriseé EEG Durant L'Activation Cognitive Avec Le Devoir Vérbal

Cette étude vise à investiguer la réactivité du EEG durant l'activation cognitioe à l'aide du teste de fluencité des mots. 32 volontiers ont été investigués en utilisant le système de la carte du cerveau durant le repos, avee les yeux fermés pendant la performance la carte EEG a démontré La différence entre les deux conditions, ainsi que des analyses statisticales d'hors. ligue ont été performer. le y avait un involvement de l'hémisphère gauche tel que fut démontré par la réactivité dans la fréquencie de la bande alpha. Des changements dans l'activité du beta ont démontré des patternes différents, i.e., ils étaient plus concentrés que les changements de l'activité du alpha; et on eu liev principalement dans les donaines frontotemporals. Les resultats sont en accordance avce les découuerts neuropsy chologicals. Les implications de ces découvevts sur la rechevche de la vaison du cerveau dans les sujets normals et les patients psychiatriques sont discuteés.

التخطيط الطبوجرافى للمخ أثناء التنشيط المعرفى باستخدام اختبار لفظى

يهدف هذا البحث إلى دراسة أنماط التغير فى النشاط الكهربى للمخ خلال التنشيط المعرفى بواسطة اختبار الطلاقة اللفظية. وقد تم البحث على ٣٢ متطوعا من الأسوياء ، حيث أجرى لهم تخطيط طبوجرافى للنشاط الكهربى فى حالة الاسترخاء وأثناء أداء الاختبار. وتم عمل التحليل الإحصائى للفروق بين الحالتين باستخدام التخطيط وكذلك المؤشرات الكمية للنشاط الكهربى. وقد وجد أن هناك تنشيطا للجانب الأيسر من الدماغ بمؤشر موجات ألفا ، أما نشاط موجات بيتا فقد أظهر نمطا مختلفا للتفاعل حيث شمل التغير المناطق الجبهية-الصدغية فى الجانبين بشكل أساسى. وتتفق نتائج هذه الدراسة مع الدراسات العصبية النفسية، وقد نوقشت النتائج المتضمنة وأهميتها فى بحث علاقة المخ - العقل لدى الأسوياء وكذلك المرضى النفسيين.