Quantitative Electroencephalogram in Smoking and Smoking Deprivation

Abstract. *After being deprived of cigarettes for 24 hours, eight young males who were heavy smokers showed significant changes in the electroencephalogram analyzed electronically and by digital computer. Compared to their records before smoking deprivation, there was a significant increase in slow frequencies. Resumed smoking reversed these trends.*

We have studied effects of smoking withdrawal upon brain function as reflected in the electroencephalogram (EEG). Wechsler (*1*) and Hauser *et al.* (*2*) studied EEG changes in healthy adults during and after the act of smoking. Transient periods of EEG flattening and downward shifts in dominant alpha frequency were interpreted as being related to the act of smoking, rather than due to physiologic or metabolic effects of substances present in the cigarette. Lambiase and Serra (*3*) found that after one cigarette 80 percent of their subjects showed depression in voltage and an acceleration in frequency of the alpha rhythm. With frequency analysis, Brown demonstrated that the EEG resting records of heavy smokers were readily distinguishable from those of nonsmokers, in that heavy smokers showed less alpha and more high frequency rhythmic activity than did the nonsmokers (*4*). Although Brown initially asked nine of the heavy smokers to abstain from smoking for 12 hours prior to the experiment, she did not report any observed differences between the satiated state and the state of smoking deprivation.

In our experiment ten male subjects (ages 16 to 21) were selected as heavy smokers (one or more packs of cigarettes per day). Males were used to rule out EEG fluctuations associated with the ovarian cycle (*5*). Each subject acted as his own control, and an initial EEG record was taken to accustom the subject to laboratory procedures. The first experimental (base line) record was carried out on a subsequent day. The second experimental record followed a 24-hour period of deprivation from smoking, and the third EEG was recorded on the same day, after a 5-minute period during which two cigarettes were smoked. The EEG's were taken on a Grass Model 6 electroencephalograph with standard calibration, paper speed, and electrode settings, using both monopolar and bipolar leads. During the test, subjects were in a semireclining position, with eyes closed, but there was checking to avoid drowsiness. The right occipital to right ear lead was analyzed on a Gray Walter type electronic brain wave analyzer [Loeffel and Ulett Modification, (*6*)]. This analysis consisted of the measurement of pen deflection in 24 frequency bands (3 to 33 cycle/sec) for each 10-second epoch. The same EEG lead combination was recorded on tape and analyzed later with a digital computer (IBM-1710) using period analysis programs (*7*, *8*). With this analysis 20 different EEG characteristics (seven frequency bands, average frequency, and frequency variability for zero crossing and for the first derivative, as well as average absolute amplitude and average amplitude variability) were determined for every 10-second epoch. For the statistical analysis, EEG's of only eight of the ten subjects could be used because of artifacts and technical problems. From each recording, a minimum of six to a maximum of 30 EEG samples of 10-second length were used from the analog frequency analyzer measurements. For the period analysis evaluation on the digital computer, 30 samples of 10-second duration were used. Pulse and blood pressure readings were taken before and after each of the records. All subjects were questioned regarding subjective feelings during the period of deprivation.

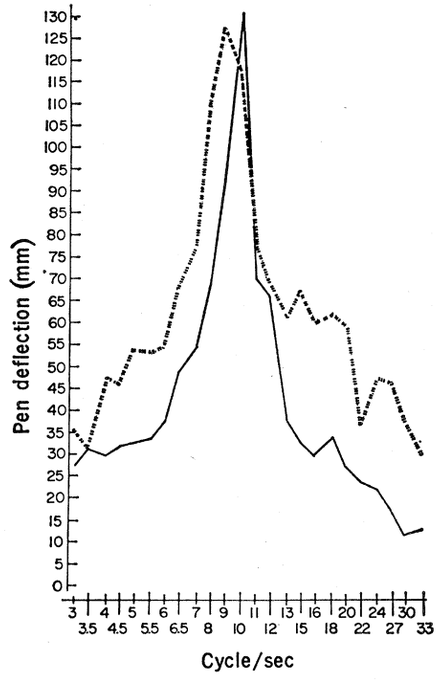

Fig. 1. Mean average graphs of the brain wave spectrum obtained by the analog frequency analyzer during the resting period and after 24 hours of smoking deprivation for eight of the ten subjects in whom the electronic analysis data was technically satisfactory for statistical analysis. Solid line, before deprivation; dotted line, after 24 hours of deprivation.

Mean average graphs (Fig. 1) of the brain wave spectrum obtained by the analog frequency analyzer showed that although there were differences among the resting EEG's of these subjects, the average distribution of EEG frequency showed a dominant alpha rhythm at 10.5 cycle/sec, as would be anticipated in the resting record of a normal healthy adult population. After 24 hours of smoking deprivation the peak alpha frequency for the group dropped 1 cycle/sec to 9.5 cycle/sec. Analyses of the electronic power spectrum showed an increase in all slow frequency bands (3 to 8 cycle/sec), as well as all fast frequency bands (13 to 33 cycle/sec).

Statistical analysis (analysis of variance) of the electronic frequency analyzer data indicated significant increases in the frequency bands of 3.5, 4, 4.5, 6, and 7 cycle/sec at the level of $P < .05$ and in the frequency bands of 5 and 5.5 cycle/sec at the level of $P < .01$. Although observed in the graphed data, the difference in the high frequency bands was not significant upon statistical analysis, due to individual variability.

The EEG recorded after the subjects smoked two cigarettes (in a period of 5 minutes) showed a reversal of the above changes, with a return of all frequencies toward the EEG before deprivation.

Statistical evaluation (analysis of variance) of the EEG data, obtained by the digital computer period analysis, also revealed a significant increase ($P < .05$) of the slow activity (1 to 3.5 cycle/sec frequency band in zero cross) during smoking withdrawal. The computer analysis data showed also a reversal to the base line, again more marked in the fast than in the slow frequency bands following the smoking of two cigarettes.

During deprivation there was a tendency for slower pulse and increased systolic blood pressure in most subjects, with a reversal after smoking two cigarettes. In general, the most commonly

reported behavioral change was some subjective dysphoria during the period of deprivation.

Most authors state that smoking is a habit, satisfying primarily a psychological need. The initial reasons for adopting this habit are many and varied, perhaps often related to a desire to conform to social patterns (*9*). Previous EEG studies, indicating differences between the EEG's of heavy smokers and nonsmokers, included speculation that such findings may represent basic differences in constitutional or personality types. Our results reveal physiological alterations, including a change in the pattern of electrical brain activity, associated with smoking withdrawal. This change was in the direction of what is usually classified as EEG abnormality, and accompanied by behavioral symptoms such as drowsiness, restlessness, and dysphoria. These alterations in body function reversed upon the resumption of cigarette smoking.

A significant increase of slow wave activity by smoking deprivation is a typical EEG sign of decreased vigilance. Such EEG findings may explain the behavioral alterations experienced by persons seeking to break the tobacco habit. These findings of EEG change and reversibility may have been so clearly demonstrated because our subjects were young and hence possessed greater neurophysiological sensitivity to centrally effective drugs (*10*). Our results support the contention that tobacco smoking is a complex psychosomatic problem, analogous to drug addiction.

JUDITH A. ULETT
TURAN M. ITIL

Missouri Institute of Psychiatry,
Department of Psychiatry,
University of Missouri, St. Louis

References and Notes

1. R. Wechsler, *Fed. Proc.* **17**, 169 (1962).
2. H. Hauser, B. E. Schwartz, G. Ross, R. G. Bickford, *Electroencephalogr. Clin. Neurophysiol.* **17**, 454 (1964).
3. M. Lambiase and C. Serra, *Acta Neurol. Naples* **12**, 475 (1957).
4. B. B. Brown, *Neuropsychologia* **6**, 381 (1968).
5. W. Lamb, G. A. Ulett, W. Masters, D. W. Robinson, *Amer. J. Psychiat.* **109**, 840 (1953).
6. R. G. Loeffel and G. A. Ulett, *Electroencephalogr. Clin. Neurophysiol.* **5**, 113 (1953).
7. N. R. Burch, W. J. Nettleton, J. Sweeney, R. J. Edwards, *ibid.* **11**, 827 (1959).
8. D. Shapiro and M. Fink, *Psychiat. Res. Foun. Missouri Publ.* **66-1**, 113 (1966).
9. Advisory Committee to the Surgeon General of the Public Health Service, "Smoking and Health," *Public Health Serv. Publ. No. 1103* (1964).
10. T. Itil, *Electroencephalographische Studien bei Psychosen und Psychotropen Medikamenten* (Ahmet Sait Matbaasi, Istanbul, 1964), p. 128.
11. We thank Dr. G. A. Ulett, B. LaConte, H. Klingenberg, and B. Hsu for their assistance. Supported by USPHS grant MH-11381 and in part by the Psychiatric Research Foundation of Missouri.

5 December 1968; revised 20 March 1969

Auditory Habituation and Barbiturate-Induced Neural Activity

Abstract. *The finding that barbiturates abolish habituation decrements in auditory evoked potentials has been interpreted as being caused by removal of the influence of the reticular formation. Similar changes in the medial geniculate are produced by barbiturates without any intervening habituation, suggesting that refractory processes have been confused with habituation.*

If a transient auditory stimulus is regularly repeated, the potentials evoked in the auditory pathway by this stimulus exhibit a progressive decrease in amplitude (habituation) which is largely a function of rate of stimulation (*1–3*). It has been suggested that habituation is due to the action of an intrinsic inhibitory mechanism, capable of exerting relatively long-lasting effects (*2*).

An alternative interpretation is that centrifugal influences arising in the reticular formation are responsible for habituation (*4*). Some evidence for this theory comes from studies of effects of barbiturates, which reportedly abolish decrements obtained at the cochlear nucleus (*4*) and prevent the occurrence of decrements at the medial geniculate (*5*). However, barbiturates do not abolish the decrement at the cochlear nucleus (*1*); thus, the medial geniculate study is the main evidence for this hypothesis. Al'tman (*5*) did not determine whether barbiturates produced changes in the medial geniculate responses that were independent of repetitive stimulation. These experiments were designed with this control condition so that the effects of barbiturates on evoked potentials recorded at the medial geniculate could be determined.

Bipolar stainless steel electrodes were permanently implanted in the medial geniculate of five cats at Horsley-Clark coordinates A5.0, L11.0, H0.0 (*6*). All placements were verified histologically after the experiments. Small earphones were mounted on the head of each animal to deliver auditory stimuli. The animals were tested in a sound-proofed box (*7*). Evoked responses were averaged on a fixed-purpose computer (*8*), and the averaged peak amplitude was determined from either X-Y plotter recordings or a printout of the memory.

The first experiment consisted of three stages. (i) Each cat was stimulated by a 105 db pulse burst (*9*) once every 10 seconds until 50 responses were averaged. This average was regarded as the unanesthetized control. (ii) Each cat was given a 30-minute stimulation with pulse bursts at the rate of 1 per second. Fifty responses were averaged every 5 minutes. (iii) Each animal was then injected with sodium pentobarbital (*10*). Stimulation continued throughout at 1 per second, and another 50 responses were averaged after all signs of reflexes had been abolished.

As shown by a test of trend (*11*), there was a marked decrease in evoked potential amplitude over 30 minutes stimulation (Fig. 1B) compared with the unanesthetized control (Fig. 1A). The barbiturate abolished this decrement (Fig. 1C), producing a significant increase in amplitude compared with the record taken after a 30-minute stimulation ($t = 3.18$, $P < .05$). There was a change in evoked potential waveform from that in unanesthetized controls.

In the second experiment another unanesthetized control consisting of the average of 50 responses to stimuli (*9*) delivered at the rate of 1 per 10 seconds was obtained. Each animal was

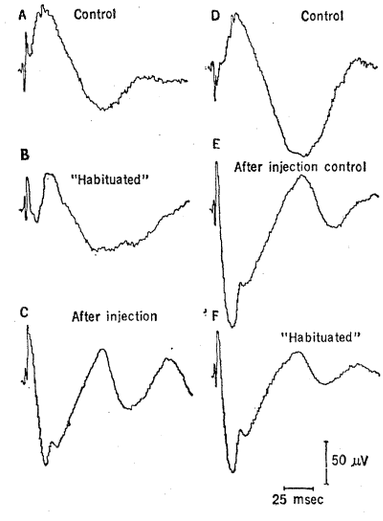

Fig. 1. Effects of barbiturate on medial geniculate habituation. (A) Control averaged evoked potential to stimuli at 1 stimulus per 10 seconds; (B) "habituated" potential after a 30-minute stimulation at 1 stimulus per second; (C) potential after injection with barbiturate, stimulation at 1 stimulus per second; (D) control averaged evoked potential to stimulation at 1 stimulus per 10 seconds; (E) control potential under barbiturate to stimulation at 1 stimulus per 10 seconds; (F) "habituated" potential under barbiturate after a 30-minute stimulation at 1 stimulus per second. Fifty responses were averaged for each record.