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.

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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

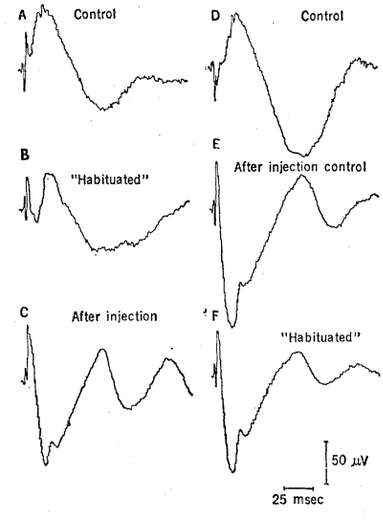

Fig. 1. Effects of barbiturate on medial geniculate habituation. (A) Control averaged evoked potential to stimuli at 1 stimulus per 10 seconds; (B) "habituated" potential after a 30-minute stimulation at 1 stimulus per second; (C) potential after injection with barbiturate, stimulation at 1 stimulus 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.

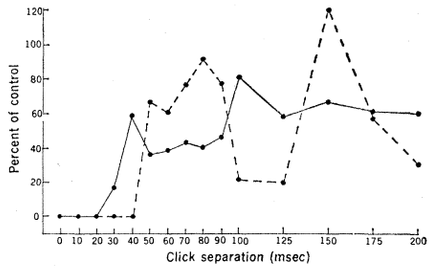

Fig. 2. Recovery amplitude curve for second of two paired clicks compared with control amplitude of single clicks. Broken line, with barbiturate (Nembutal); solid line, without barbiturate (awake). Each point is based on the peak amplitude of the average of 50 responses.

then injected with barbiturate (*10*), and a control was recorded which consisted of 50 responses averaged to stimuli given at the rate of 1 per 10 seconds. Each animal was then stimulated for 30 minutes at the rate of 1 per second, and 50 responses were averaged every 5 minutes.

The results showed a significant difference ($t = 8.37$, $P < .01$) between the unanesthetized (Fig. 1D) and the injected controls (Fig. 1E). This difference in amplitude and waveform was similar to that produced in the first experiment. This indicates that changes due to barbiturates can be obtained without intervening repetitive stimulation at rates known to produce habituation. There were also significant amplitude decrements (shown by the test of trend) during a 30-minute stimulation at 1 per second in animals given barbiturate (Fig. 1F).

All animals showed amplitude and waveform changes caused by barbiturates, but three animals showed marked waveform changes exhibiting cyclic spindling or reverberatory activity. This waveform consisted of gradually declining rhythmic activity with a period of approximately 100 msec. To determine the nature of this cyclic activity, the three animals were tested in a paired-click experiment (*12*), in which functions of recovery amplitude for the second of two paired clicks were determined both with and without barbiturate. To achieve this, 50 paired responses were averaged on the computer for each of a range of intervals between the two clicks. There are marked differences between recovery curves for anesthetized and unanesthetized animals (Fig. 2). The recovery curve obtained for the injected animal shows an initial depression in recovery followed by a facilitation, then another depression in recovery followed by a facilitation. The evoked potential to the second of a pair of clicks can be facilitated or depressed according to where in the phase of the activity induced by the first click the response to the second click arrives. The cyclic activity consists of alternate peaks of excitation and inhibition. Similar findings have been reported in the ventrobasal complex and the medial geniculate (*13*).

Recovery in the medial geniculate of unanesthetized animals is relatively slow (Fig. 2). Complete recovery from the effects of the first click often takes several seconds, a finding similar to that reported for the auditory cortex (*14*). Taken in conjunction with the evidence for a rate effect with repetitive stimulation (*1–3*) these data are in keeping with the proposition that auditory habituation is based on long-term synaptic inhibition. In fact, so called habituation decrements in the auditory pathway might be better interpreted as being due to a refractory process based on inhibition intrinsic to the particular auditory area.

In the medial geniculate this inhibition may be based on recurrent postsynaptic inhibition because a similar mechanism has been put forward to explain both barbiturate spindling in the ventrobasal complex (*15*) and depression of recovery in the lateral geniculate (*16*). It could also be argued that all these effects are due to tonic inhibitory activity arising in the reticular formation (*17*), and that barbiturates merely block this inhibition. This interpretation is unlikely because there is evidence (*13, 18*) that barbiturate spindling occurs in the isolated thalamus when all connections with the reticular formation have been severed, and amplitude decrements occur under barbiturates (Fig. 1F).

Changes in medial geniculate evoked potentials produced by barbiturates cannot be interpreted as abolishing habituation (*4*) or preventing habituation (*5*), because similar changes occur without repetitive stimulation. Furthermore, habituation of medial geniculate evoked potentials might be produced by inhibition intrinsic to this area (possibly recurrent postsynaptic inhibition). This interpretation would indicate that the decrements are more akin to a refractory phenomenon than to a true habituation process (*19*).

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Intracranial Self-Stimulation and the Rapid Decline of Frustrative Nonreward

Abstract. *Animals deprived of reward for a task previously rewarded behave differently, depending on whether the reward is food or positive brain stimulation. Unlike the relatively stable frustration effects obtained with conventional reward, frustration produced by withholding brain stimulation dissipates rapidly with time.*

Behavior reinforced with conventional rewards has been compared with that obtained by intracranial self-stimulation (ICS) (*1*). When behavior is controlled by central stimulation it has often been reported (*2*) that performance is impaired on simple learning tasks involving schedules of reinforcement and rates of extinction. However, some investigators (*3*) have found that some of the differences seem to disappear when procedural details are more closely controlled in order to make the comparisons more