encouraged us to approximate the two sets of data, for left-right and right-left, with curves of the same slope but different intercept. Such curves, determined by least squares procedures, are shown in Fig. 1.

That left-right pairs were more easily discriminated from simultaneous pairs than were right-left pairs is another manifestation of the visual order illusion found in the experiments in which forced-choice was not used. With interstimulus interval held constant, a left-right sequence seems more clearly sequential (that is, nonsimultaneous) than does a right-left sequence. The horizontal distance between the curves in Fig. 1 provides an estimate of the time differential between left-right and right-left pairs. To equalize the apparent sequential character of left-right and right-left pairs, the interstimulus interval for the right-left pair would have to be about 10 msec greater than that for the left-right pair.

A possible explanation for the illusion may be found in Lashley's suggestion that the brain imposes a temporal order on simultaneous visual information (*9*): "Even with tachistoscopic exposures, the after-discharge permits a temporal survey, and with visual fixation, shifts of attention provide an effective scanning." The first part of Lashley's proposal, the idea of a brief poststimulus iconic or visual image, has gained common acceptance (*10*). The existence of a scanning mechanism which reads out from this store, the second part of Lashley's proposal, remains controversial. Heron (*6*) tried to account for various findings from studies of word recognition by postulating a readout mechanism that jumps from a rest position, near fixation, to the leftmost end of a stimulus array and then scans rightward. Others (*11*) have disputed the existence of such a scan.

A left-to-right scanning mechanism of the sort proposed by Heron could account for the prepotency of left-right perception of visual sequences. In scanning the temporary iconic store, information from the left portion of the field would be read out slightly before information from the right portion. Consequently, a sequence that was actually right-left, with a very short interval between the two stimuli, would appear left-right. If such a scanning mechanism jumped from its rest position to the locus of the leftmost stimulus (*6, 12*), then the lateral separation of the curves in Fig. 1, about 10 msec, could be used as a first approximation to the time required for the scan to go from rest to the leftmost stimulus position. Since we have not yet determined the locus of the rest position, we cannot yet translate this estimate of 10 msec into a measure of the speed of the proposed scan. Parametric variation of the location of targets may provide a more direct test of the scanning hypothesis, along with a quantitative description of the scan operation.

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References and Notes

1. I. Hirsh and C. Sherrick [*J. Exp. Psychol.* **62**, 423 (1961)] reported that about 20 msec is the smallest time difference discriminable by the human visual system. However, because they used no temporal differences between 0 and 20 msec, their estimate must be regarded as a rough one at best. Others subsequently reported temporal discriminations of 1 or 2 msec for the visual system; the performance of our subjects is consistent with these later estimates [D. N. Robinson, *Science* **156**, 1263 (1967); G. von Békésy, *Proc. Nat. Acad. Sci. U.S.A.* **64**, 142 (1969)].
2. Observations were made with moderate background illumination. The illusion could not be observed when background illumination was reduced. This was because the luminance of the cathode-ray tube phosphor (P31) after presentation of the first letter did not decay to below visual threshold before the second letter was presented; the resulting temporal overlap made judgments of order difficult. For the first and third experiments the targets and mask had a luminance of approximately 21 cd/m²; the background luminance was 7 cd/m². For the second experiment the corresponding values were 2.0 and 1.0 cd/m².
3. At the outset we considered whether we were dealing with a variety of apparent motion. We rejected this possibility because the temporal characteristics of our stimuli were more than an order of magnitude different from those that produce good apparent motion [F. J. Sgro, *J. Exp. Psychol.* **66**, 281 (1963)]. Indeed, our conditions did not produce apparent motion. Moreover, we have not been able to find in the literature on apparent or real (continuous) motion the kind of directional asymmetry that one would expect if our phenomenon were actually related to motion perception.
4. This experiment also eliminates as an explanation for the illusion a possible latency difference between temporal and nasal hemiretinas. A similar explanation for the illusion might be a gradient of latency running across the entire retina, the right hemiretina responding faster than the left. This hypothesis can be ruled out by several studies that show latency increases with distance from the fovea, for both left and right hemiretinas [M. Lichtenstein and C. T. White, *J. Opt. Soc. Amer.* **51**, 1033 (1961); J. D. Rains, *Vision Res.* **3**, 239 (1963); R. Rutschmann, *Science* **152**, 1099 (1966); W. H. Payne, *Vision Res.* **6**, 729 (1966); *Science* **155**, 481 (1967)].
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13. Supported by grant NS-10094 from the National Institute of Neurological Diseases and Stroke and grant EY-00321 from the National Eye Institute.

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Tobacco and Evoked Potential

Abstract. *Significant changes were found in two indices of the averaged visual evoked potentials in nine smokers after 12 and 36 hours of abstinence and after resumption of smoking. There was a decrease of the amplitude envelope accompanying withdrawal and an increase with resumption of smoking. These changes are consistent with the contention that tobacco increases arousal. Amplitude changes were found in a specific component of the evoked potential occurring between 100 and 125 milliseconds after the onset of the flash. The latter changes suggest the possibility that smoking selectively enhances the perception of weak stimuli.*

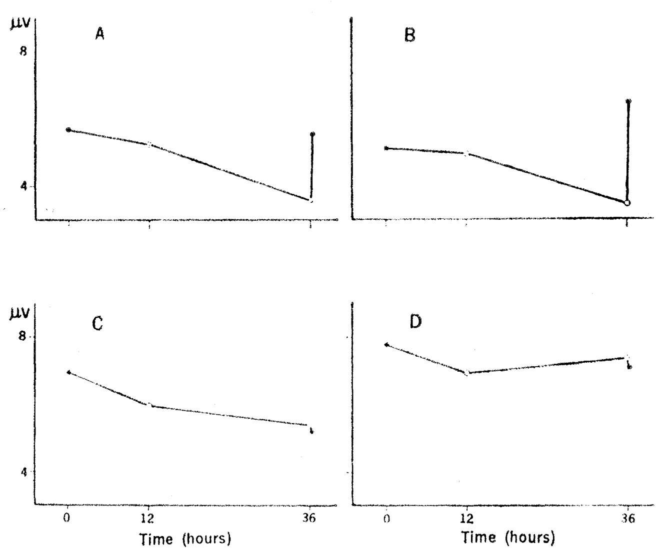
We have studied the neurophysiological effects of smoking withdrawal and resumption as reflected in the average visual evoked potential (AVEP). Electroencephalographic (EEG) changes commonly associated with lowered arousal have been reported during smoking withdrawal. These changes were reversed on resumption of smoking (*1*).

Numerous studies of smoking and nicotine administration (in doses comparable to those obtained from smoking) show a predominant arousal effect (*2, 3*). Improvement of learning with nicotine, possibly associated with increased vigilance, has been reported (*4*). Association of the amplitude of the AVEP with arousal and vigilance has been reported (*5*). It was predicted that the smoking-satiated state would be associated with higher amplitudes than the abstinent state, notwithstanding a report of an opposite trend (*6*) and another study that failed to reveal any significant AVEP differences (*3*). Another prediction was made, based on the subjective observations by one of us (R.A.H.) of greater impairment of awareness to weak than to strong stimuli during smoking withdrawal. It was postulated (i) that smoking withdrawal causes decrease of a certain component of the AVEP to dimmer flashes and causes less decrease or increase of this component with brighter flashes and (ii) that these changes are reversed by smoking resumption. The component, the positive-negative complex formed by events IV and V at 100 and 125 msec (*7*), has been related to subjective responsiveness to weak and strong stimuli and also to behavior in normal subjects and the diagnosis and therapeutic response of mental patients (*8*).

Subjects were six men and three women, ages 23 to 50. All habitually used between three-fourths and three packs of cigarettes per day, except for one inhaling pipe smoker who used ten pipefuls per day. After three baseline testings obtained without interfering with the usual smoking pattern of the subjects (intertest interval 3 to 7 days) each subject was tested after 12 and 36 hours of complete abstinence. Immediately after the test at 36 hours, the subjects smoked one cigarette (except the pipe smoker who smoked one pipeful) whereupon they were tested again. The test battery took about 20 minutes and always consisted of tests in the same order: a four-intensity vertex AVEP test as in (*7*), taking 8.8 minutes; subjective ratings by each subject of exploration, activity, excitability, aggression, rage, withdrawal, and fear on behavior scales used to objectively rate cat behavior in (*9*); a 40-item short version of the mood adjective checklist (MACL) of Nowlis (*10*); the kinesthetic figural after-effects (KFA) (*11*), a measure of the effect of stimulation on proprioceptive subjective width estimation.

The AVEP test was done with the subject seated comfortably in a totally darkened and sound-attenuated room (IAC 404A). The opened eyes were positioned 15 cm from the center of an opening (30 by 30 cm) in the front side of a chamber (50 by 50 by 50 cm). This was lined with foil to reflect flashes produced by hot cathode lamps (Iconix) located inside the front wall. Signal from the vertex referred to left mastoid was amplified (passband 1 to 70 hz, −3 db) and then separately averaged by a PDP-12 computer (Digital Equipment) for each of four intensities of the flash (9, 34, 138, and 420 lux). The computer also controlled the random presentation of the 120 flashes of 15-msec duration of each intensity (480 total flashes). Calibration, before and after each test, was obtained by averaging the 2.33-μv pulse generated by a photocell-triggered device that was substituted for the subject.

The amplitude envelope of the AVEP showed a consistent pattern of changes for the four intensities. Eight of the nine subjects showed the pattern of decrease in the mean amplitude envelope for the four intensities after 12 and 36 hours of abstinence, and of increase after smoking (*P* was .02, one-



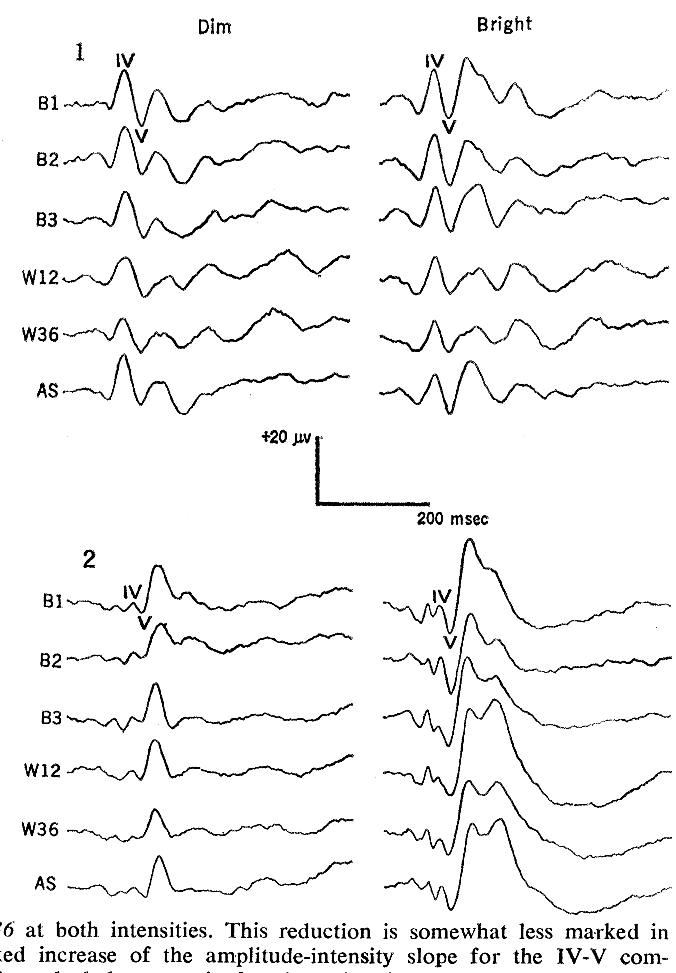


Fig. 1 (left). Changes in amplitude of IV-V complex of the AVEP to four intensities of flashes with smoking withdrawal and resumption. Data from AVEP to 120 15-msec flashes at each of four intensities (9, 34, 138, and 420 lux). Magnitude of decrease at 36 hours of mean amplitude in eight subjects from mean of three baseline tests diminished stepwise with intensity and is significant for the two lower intensities; decrease in amplitude-intensity slope after smoking was significant.
Fig. 2 (right). Effects of smoking withdrawal and resumption on AVEP. Curves are averaged responses to 120 15-msec flashes at 9 lux (dim) and 420 lux (bright) during baseline condition (*B1, B2, B3*), at 12 and 36 hours of smoking withdrawal (*W12* and *W36*), and after smoking (*AS*). Subject 1, a 43-year-old male, showed reduction of amplitude envelope at *W36* at both intensities. This reduction is somewhat less marked in subject 2, a 45-year-old female. However, she showed more marked increase of the amplitude-intensity slope for the IV-V complex during withdrawal than did subject 1. Both subjects showed marked decreases in four-intensity linear regression slope after smoking. These changes in slope are reflected in intensity-related shifts in amplitude of the IV-V complex, which can be seen in the two-intensity data shown.

tailed, sign test). The mean change of amplitude from the mean of the three baseline values was -2.40 ± 1.40 μv after 12 hours and -3.86 ± 2.50 μv after 36 hours of abstinence. These were highly significant decreases (respectively, P was .0039 and .0054, one-tailed, Wilcoxon matched-pairs signed-ranks test). The prompt return to the baseline level immediately after one cigarette or one pipeful was similarly significant (P was .0054, one-tailed, Wilcoxon test). Examined separately, the mean amplitude envelopes of the AVEP for all four intensities of the flash also showed significant drop from the mean baseline at 12 and 36 hours of abstinence, and increase after smoking (P was .0038 to .0329, one-tailed, Wilcoxon test).

Peak events (events) of the AVEP were identified according to an algorithm (*7*). Briefly, events VI and III are first identified as the most positive and negative peaks within the latency ranges of 125 to 250 msec and 65 to 105 msec, respectively. Then event IV is the most positive peak, after III and before VI, of 75 to 140 msec latency and event V is the most negative peak, after IV and before VI, of 90 to 165 msec latency. The effects on the mean amplitude of the IV-V complex in the eight subjects for whom both events could be so identified are shown in Fig. 1. The drop in the IV-V amplitude response at 36 hours was inversely proportional to flash intensity and was significant only for the dimmest and next to dimmest flashes (respectively, P was .0087 and .0344, one-tailed, Wilcoxon test). After smoking, the increases at these two lowest intensities approached the 5 percent level of significance (respectively, P was .1038 and .0643, one-tailed, Wilcoxon test); the small decreases for the two brighter flashes after smoking were insignificant ($P > .3372$, one-tailed, Wilcoxon test). The slope of the linear regression line of IV-V amplitude with log intensity is another measure which reflects the above relationships. The slope showed a mean decrease or "reduction effect" (*11*) after smoking (-1.89 ± 1.31); decrease occurred in every case, a significant finding ($P = .004$, one-tailed, sign test). The possibility of attributing these slope changes to systematic reduction effects of retesting alone is minimal in view of previous findings that showed some significant "augmentation effects" (*11*), but no reduction effects under short-term retesting conditions (*12*). The increase of slope after 36 hours of abstinence ($+ 0.93 \pm 1.76$) was not significant (P was .1038, one-tailed, Wilcoxon test).

The AVEP curves in Fig. 2 are illustrative. Both subjects show decrease of amplitude envelope and waveform changes at both intensities during withdrawal and prompt return to baseline amplitude and waveform after smoking. Changes in relative size of the IV-V complex are seen between the two intensities shown in Fig. 2. These reflect the increase of the four-intensity, amplitude-intensity, linear regression slope during withdrawal as well as decrease after smoking. They are marked in subject 2. Subject 1, incidentally, also showed increase of the P-300 wave (*13*) during abstinence, but this component showed no systematic changes for the subject group.

There were no significant changes of latencies for peak events IV and V, the 12 scales of the MACL, the 7 subjective behavior scales, or the KFA. That the behavior and mood rating scales and the KFA failed to detect differences after smoking could possibly be attributed to a wearing off of the effects by the time these tests were administered (after the 8.8-minute AVEP test). However, this appears unlikely, considering that these tests also failed to detect differences between the abstinent and baseline conditions. Therefore, the data seem to suggest that the AVEP is a more sensitive measure of the effects of tobacco on the brain than these other instruments.

The difference between the AVEP in tobacco-deprived and satiated conditions obtained by means of two different indices suggest that this substance alters the manner in which the brains of the smokers process sensory stimuli. The changes in the amplitude envelope are convergent with EEG and subjective data indicating a general alerting effect. In addition, the data regarding the IV-V complex suggest a differential effect that favors responsiveness to weak over strong stimuli. The latter is of special interest in relation to the theory of a perception-personality dimension of "augmentation-reduction" developed by Petrie (*14*), which has been supported by studies of the AVEP (*8, 9, 11*). In the context of that theory these data might suggest that smoking selectively enhances perception of weak stimuli among smokers. Further studies of the AVEP might help delineate a specific perception-related psychobiological factor that makes tobacco especially attractive and addicting to persons who become smokers.

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Irradiated Food

A petition has been filed with the German authorities to request permission to irradiate fresh ocean fish destined for human consumption. The purpose of irradiation is to prolong the storage life of iced fish and the petition foresees irradiation on board ship with a dose of 100 krad. There is ample experimental evidence that this dose, applied soon after catch, will