Effects of amphetamine on the monkey's visual threshold¹

JOHN B. THURMOND²
UNIVERSITY OF LOUISVILLE

Abstract

Five macaque monkeys were tested individually on brightness discriminations of near threshold stimuli under photopic and scotopic conditions. The drug amphetamine produced an increase in errors as a function of increasing dose, but did not affect performance differentially under the two lighting conditions.

Problem

Sensory thresholds give an index of maximum sensitivity that might be expected to reflect the effects of variables such as drug dosages, general sensory inputs, direct central nervous system stimulations, etc. For example, both general sensory inputs and electrical brain-stem stimulations appear to have facilitatory effects on sensitivity (Rossi & Zanchetti, 1957; Jasper et al, 1955). Isaac & Reed (1961) have interpreted these effects as resulting from increased arousal and mediation of the ascending reticular activating system (ARAS).

If this interpretation is correct, amphetamine administration should result in facilitatory behavioral effects analogous to those produced by sensory input and electrical stimulation since amphetamine has been reported to facilitate arousal and activate the ARAS (Bradley & Elkes, 1957). On the other hand, administration of amphetamine might result in poorer sensitivity, for example by reducing the sensory input to the visual system; indeed, there is some evidence that this might occur in both rats (Shulte et al, 1941) and monkeys (Davis, 1957). The present experiment was designed to measure the effects of amphetamine on the visual threshold of monkeys under both photopic and scotopic conditions. In addition, to permit generality of results, the animals were tested over several levels of masking noise.

Method

Five mature macaque monkeys, two males and three females, were tested in a chamber which was designed and constructed to provide controlled conditions for testing macaque monkeys on discrimination problems. All of the animals had been in the laboratory for more than 2 yr., and all had undergone extensive training on difficult brightness discriminations. The chamber was essentially a sound-attenuated, light-proof, temperature-controlled environment. The inside dimensions of the chamber measured 76 cm high, 48 cm wide, and 71 cm deep. Ambient light and noise sources and air exit vents were recessed in the ceiling.

Stimuli were presented at either of two transparent 7-cm square plexiglas stimulus-response panels located at one end of the chamber, 25 cm above the floor. Light

from a 4-watt fluorescent lamp was projected through a lens diffusing system to a translucent ground-glass screen directly behind the panels. The panels, spaced 5.7 cm apart, were hinged at the top, and S responded by pushing a panel, displacing its lower edge by 0.3 cm. If S's response was correct, a food reinforcement (a small amount of apple sauce) was automatically delivered directly below the S-R panels. A steel cover plate was lowered in front of the panels to protect them between trials. In addition, raising the cover plate provided a warning signal to indicate the onset of a trial.

Three levels of amphetamine and three levels of broad-band noise were used: 0.0, 0.1, or 0.2 mg/kg of d-amphetamine sulfate administered orally to S in fruit juice 30 min. before S was put in the test chamber, and 60, 75, or 90 db SPL (sound pressure level) noise. Thus, there were nine experimental drug-noise conditions. Also, since S was adapted for 30 min. inside the chamber prior to testing, the drug had an hour to take effect.

In order to study the effects of the drug and noise variables on rod function, S was adapted in the chamber for 30 min. in the dark, and then a blue filter (Kodak Wratten No. 49B) and a neutral density filter (density of 2.00) were interposed between the lamp and the lens system. The lamp was calibrated to give a value of 0.968 mlam at the S-R panels; the filters further reduced this value to 0.54×10^{-6} mlam, the light intensity of the stimulus used to study rod function.

For studying cone function, 0.45 mlam ambient illumination was maintained in the test chamber throughout the 30 min. adaptation period and the testing session (except for the 1-sec. periods of stimulus presentation and response). The stimulus lamp was calibrated to give a value of 1.076 mlam at the panels, and then a red filter (Kodak Wratten No. 26) was used to reduce this value to 1.96×10^{-3} mlam, the light intensity used to study cone function.

Under both photopic and scotopic conditions, light from the stimulus lamp, reduced to near-threshold values by means of the filters, was projected tachistoscopically onto one of the S-R panels for durations of 10, 20, 40, 100, 200, and 500 msec. Thus, a distribution of errors across this range of stimulus durations was obtained.

One-half of the trials throughout each session contained no stimulus presentation, and Ss were trained to respond by pushing one panel if the stimulus was presented and the alternate panel if the stimulus was not presented. The stimulus always appeared at the same panel for a specific S, when it was presented.

Each session consisted of 60 trials, one trial being presented every 30 sec. The six different durations occurred in random order throughout the session; restrictions were imposed, however, so that each duration occurred five times during a session and no more than four stimulus presentations (or nonpresentations) occurred consecutively. The stimulus, when presented, always followed the warning signal by 500 msec.

Each S was tested alternately under photopic and scotopic conditions over 108 consecutive days. Thus, each of the nine conditions of drug and noise for both photopic and scotopic conditions was replicated six times, so the results are based on a total of 32,400 responses. The performance measure recorded was the number of erroneous responses.

Results and Discussion

An analysis of variance indicated that only one major effect was significant; namely, an increase in errors with increases in the doses of amphetamine from 0.0 to 0.1 to 0.2 mg/kg ($p < .05$). The mean errors obtained under these three drug conditions were 31.7%, 34.5%, and 35.4% respectively.

The only significant interaction was that of Ss with light-level conditions ($p < .01$). The drug by light-level interaction was not significant ($p > .20$). These results indicate that cone and rod functions were similarly affected by the drug levels, but that the specific effects differed from S to S. Some Ss performed relatively better under scotopic conditions, whereas others did so under photopic conditions. Close examination revealed no sensible grouping of Ss that would help explain this interaction, and the interpretation suggested is that the interaction reflects individual differences in the degree of independence of rod and cone functions (cf. Wald, 1945).

The decrement in performance obtained with increasing dose levels of amphetamine could have resulted from the drug's affecting either the sensory input in the visual system or the motivation of the animals. That is to say, amphetamine could be acting to reduce the total responses of the visual system to light stimuli, or it could be acting to reduce S's attempts to make difficult discriminations. Other evidence, however, suggests that the motivational effects, if any, should be relatively unimportant with the task employed. For example, Miles (1959) found that performances of squirrel monkeys on brightness discrimination problems was not influenced by S's degree of hunger.

On the other hand, studies of the effects of amphetamine and level of illumination on the cage activity of the nocturnal rat and the diurnal monkey have indicated that the drug may reduce the effects of sensory input, presumably by its action on the visual system. That is to say, the rat is normally more active in the dark and less active in the light, and it has been found that amphetamine produces a relative increase in the rat's cage activity in light (Shulte et al, 1941)—a result that would be obtained also if the effective illumination to the eye were reduced.

The monkey, as contrasted with the rat, is normally more active in light than in dark, yet the monkey's cage activity has been found to be decreased in light when he is administered amphetamine (Davis, 1957)—again, a result that would be obtained also if the effective illumination to the eye were reduced.

Thus, it seems reasonable to hypothesize that amphetamine acts somehow to reduce the effects of illumination, probably by some sort of direct action on the visual system rather than by a more general action on the ARAS and the arousal level. The results of the present study are in agreement with this hypothesis.

References

- Bradley, P. B., & Elkes, J. The effect of some drugs on the electrical activity of the brain. *Brain*, 1957, 80, 77-117.
- Davis, G. Effects of central excitant and depressant drugs on locomotor activity. *Amer. J. Physiol.*, 1957, 188, 619-623.
- Isaac, W., & Reed, W. G. The effect of sensory stimulation on the activity of cats. *J. comp. physiol. Psychol.*, 1961, 54, 677-678.
- Jasper, H. H., Naquet, R., & King, E. E. Thalamocortical recruiting responses in sensory receiving areas in the cat. *EEG clin. Neurophysiol.*, 1955, 7, 99-114.
- Miles, R. Discrimination in the squirrel monkey as a function of deprivation and problem difficulty. *J. exp. Psychol.*, 1959, 57, 15-19.
- Moruzzi, G., & Magoun, H. W. Brain stem reticular formation and activation of the EEG. *EEG clin. Neurophysiol.*, 1949, 1, 455.
- Rossi, G. F., & Zanchetti, A. The brain stem reticular formation, anatomy and physiology. *Arch. Ital. Biol.*, 1957, 95, 199-435.
- Shulte, J. W., Reif, E. C., Bacher, J. H., Lawrence, W. S., & Tainter, M. L. Further study of central stimulation from sympathomimetic amines. *J. Pharmacol. exp. Ther.*, 1941, 71, 62-74.
- Wald, G. Human vision and the spectrum. *Science*, 1945, 101, 653.

Notes

1. This work is based on a dissertation submitted to the Emory University Graduate School in partial fulfillment of the requirements for the Ph.D. degree. The research was conducted at the Primate Laboratory of Emory University while the author was a PHS predoctoral Fellow and was supported by Grant MH-04539 from the National Institute of Mental Health. This paper was presented at the Kentucky Psychological Association meetings in November, 1964.
2. The author wishes to thank Dr. Walter Isaac, under whose direction this investigation was conducted.