EFFECTS OF *d*-AMPHETAMINE ON OBSERVING BEHAVIOR IN THE SQUIRREL MONKEY¹

FOGLE C. CLARK

UNIVERSITY OF NORTH CAROLINA AT CHAPEL HILL

Four squirrel monkeys were trained to press a lever, which produced stimuli indicating availability or non-availability of reinforcement for pushing a key. Food reinforcements were available for the key response at random intervals with an average rate of 1 per min. When food was available, a single lever response produced a red light behind the key. Reinforcement availabilities and red keylights remained until terminated by a reinforced key response. When reinforcement was not available, each lever response produced a 0.5-sec green light on the key. Except after lever responses, the key remained dark. Under this procedure, lever responses functioned as observing behavior in that they produced discriminative stimuli correlated with the availability or non-availability of reinforcement for key responses. The procedure generated a high rate of responding on the lever, short latencies of the key response after onset of red lights and few responses to the key in the absence of red lights. Intramuscular *d*-amphetamine, in doses from 0.125 to 1.0 mg/kg, abolished both observing behavior and key responding for periods that increased as a function of dose. However, both observing and key rates were increased at the smallest dose in two subjects whose performances included responding to the key in the absence of red lights. Results are discussed in relation to previous findings regarding effects of amphetamines on operant behavior and on observing and monitoring performance.

Mackworth's (1948) original experiments on human monitoring performance showed that *dl*-amphetamine reduced decrements in the probability of signal detection that occurred as a function of elapsed time within sessions. Where there was no decrement there was no effect of amphetamine. This was confirmed by Jane Mackworth (1965). Similar effects of amphetamine on human tracking performance have been obtained (Payne, Hauty, and Moore 1957). Such findings have supported the use of amphetamine to maintain "attention" during prolonged vigils.

The role of observing or stimulus-producing behavior (Wyckoff, 1952) in the maintenance of monitoring performance has been the sub-

ject of considerable experimentation and has yielded an important behavioral interpretation of "attention" (Holland, 1958). The literature relating observing behavior to monitoring performance was reviewed by De Lorge, Hess, and Clark (1967). The effects of drugs on stimulus-producing behavior have also been investigated in several experiments. Cook and Kelleher (1962) studied the effects of several phenothiazines on stimulus-producing responses in pigeons. Weiner and Ross (1962) examined the effects of *d*-amphetamine upon both observing and detection behavior in humans. Using variable-interval schedules of signal availability they found that, although amphetamine increased observing response rates, it had no effect on detections.

Experiments in operant behavioral pharmacology have amply demonstrated that the behavioral effects of drugs are powerfully modulated by the conditions under which behavior is generated and maintained. Where different behavior patterns have been produced, as by different schedules of reinforcement, different drug effects have been obtained. In the case of the amphetamines, many effects on operant behavior appear to be related to the rate of responding generated by

¹Preparation of this paper was supported by Research Scientist Development Award 5 K02 MH35062 and Grant 1 R03 MH14401 from the National Institute of Mental Health. Experiments were conducted at Evansville (Indiana) State Hospital with the support of Grant NGR-15-002-001 from the National Aeronautics and Space Administration and Grant MH-05863 from the National Institute of Mental Health. The assistance of J. Hess and L. D. Hull in the conduct of experiments is gratefully acknowledged. *d*-amphetamine was kindly supplied by Smith Kline and French Laboratories, Philadelphia, Pa. Reprints may be obtained from the author, Department of Psychology, University of North Carolina, Chapel Hill, N.C. 27514.

a schedule (Dews, 1958a, 1958b; Dews and Morse, 1961; Clark and Steele, 1966; McMillan, 1968, 1969; Kelleher and Morse, 1968). Amphetamines increase the frequency of responses occurring at a low rate and decrease the frequency of those occurring at a high rate. Both effects depend on the dose as well as the pre-drug rate of responding.

Drugs have been studied in human monitoring and animal observing-response experiments under different schedule conditions. Animal experiments on observing behavior have typically employed both intermittent schedules of stimulus production and intermittent reinforcement of instrumental responses in the presence of "signals" (discriminative stimuli). In human monitoring experiments signals have most often been presented at variable intervals and the consequences of detection responses have usually been delivered according to a continuous reinforcement schedule. The present experiment was performed to examine the effects of *d*-amphetamine on both observing and detection behavior in squirrel monkeys under schedule conditions analogous to a human monitoring task.

METHOD

Subjects, Apparatus, and Basic Procedure

Four adult male squirrel monkeys, maintained at 80 to 85% of their free-feeding weights, were trained to depress a pushbutton to obtain liquid food. Animals were trained to depress the button with one paw, and then given 10 or more daily sessions of continuous reinforcement with the pushbutton key alternately lighted red or green, the colors being reversed after each reinforcement. The number of reinforcements per session was gradually increased to 250. After continuous reinforcement, a discrimination was established by reinforcing responses on the red pushbutton and extinguishing responses during alternate presentations of the green pushbutton light. During discrimination training, each response on the red pushbutton produced food. After each reinforcement, the pushbutton key was lighted green until no responses occurred for 20 sec. Each 20-sec pause in the green stimulus changed the keylight from green to red. During both continuous reinforcement and discrimination training the lever was removed from the cage. After a discrimination was well

established with red as the reinforced stimulus (S^D) and green as the non-reinforced stimulus (S^Δ), the lever was introduced into the chamber. Lever responding was established by conditioned reinforcement, the subject being presented with a green pushbutton light, and the lever being connected to change the green light to red. Responses on the red pushbutton continued to produce food, after which the green stimulus was presented again. Under this procedure the lever response was conditioned in all four monkeys within 15 min of the first session. Details of this preliminary training sequence are presented in De Lorge *et al.* (1967).

Once the lever response was conditioned, its function was changed to that of an observing or stimulus-producing response. Depression of the lever switch produced either a red (S^D) or green (S^Δ) light on the pushbutton. The button remained dark except after lever responses. Responses on the red pushbutton continued to operate the feeder and terminate the red light. Responses to the green pushbutton had no scheduled consequences. Red lights remained on the button until terminated by a reinforced response. Green lights remained for only 0.5 sec, after which the display could be relighted by another lever response. Reinforcement (red light) availabilities were scheduled to occur randomly with an average frequency of one per minute. Once scheduled, reinforcements remained available until delivered. This could occur in two ways: the monkey could first depress the lever, producing a red pushbutton keylight, and then depress the key; or, the subject could simply press the dark key without a lever response. Thus, reinforcement was not contingent on observing or stimulus-producing behavior. After preliminary training, however, responses on the dark key occurred infrequently.

Under this procedure, red-light availabilities corresponded to random-interval reinforcement availabilities on the pushbutton key. Lever responses functioned as observing responses in that they produced either a red stimulus (S^D), indicating reinforcement availability, or a brief green stimulus (S^Δ) indicating non-availability of reinforcement. In the language of monitoring experiments, red lights were randomly occurring "signals" and responses on the key were "detections". "Extra" responses to the dark or the green key were

"false detections". Signals were intransient, that is, they were terminated only by detection (key) responses.

Details of the apparatus and preliminary training procedures have been reported previously (De Lorge *et al.*, 1967). Briefly, experimental cages were 27.3 cm high, 29.8 cm long and 24.8 cm wide (modified Scientific Prototype Model A-103). Each cage was housed in a ventilated compartment. Subjects could be viewed through a wide-angle lens. Water was continuously available. During experimental sessions cages were illuminated by two 3-w lamps and white noise was continuously presented. The pushbutton response key (Grason-Stadler, Model E8670A) was centered on one cage wall 7.3 cm below the lid and could be illuminated by an in-line digital display (Industrial Electronics Engineers, Inc. Series 10,000). Red keylights were produced by two GE47 bulbs behind Wratten filters (No. 29) and green lights by similar bulbs behind filters (No. 74). The observing lever was a switchcraft lever switch centered 7 cm below the pushbutton and outfitted with a machined aluminum rod projecting 4.5 cm into the chamber. A dipper feeder (modified Ralph Gerbrands Model B) was directly below the lever with the recessed food aperture partially masked by clear plastic so that monkeys could obtain food only with a paw.

Both observing (lever) responses and detection (key) responses produced audible relay clicks. At the onset of 3-sec reinforcement cycles the feeder solenoid sounded and the dipper was inserted into the food aperture. During the feeder cycle the aperture was illuminated through the plastic mask and the house and keylights were off. The 3-sec reinforcement cycle duration was selected experimentally to permit both ingestion and grooming to be completed during the feeder cycle. Reinforcement was the delivery of approximately 0.3 cc of semi-liquid food (special monkey diet SK&F, micropulverized, Nutritional Biochemical Corp.). Food was prepared by blending 200 g diet with 30 cc water, 30 cc cottonseed oil, and 4.2 cc vitamin supplement. Subjects were fed a constant ration of the same diet in the home cage 1 hr after daily experimental sessions. The home cage ration was an amount determined experimentally to maintain the individual subject's weight at 80 to 85% of free-feeding weight.

Random-interval (RI) schedules of signal and reinforcement availability were generated by two probability gates in series (modified model PP-1, BRS Electronics). Clock pulses fed into the probability units at a rate of 1 per sec had a constant probability of producing output pulses. Each output pulse enabled the reinforcement and signal availability circuit. A random distribution of times between successive outputs of the probability units was obtained by frequency modulation of their internal clocks. Statistical properties of RI schedules and a related method of scheduling have been described previously (Clark and Hull, 1965). In RI schedules (Farmer, 1963) the probability (P) of a signal (or reinforcement) becoming available in a small time interval (T) is constant and independent of the number of intervals since the last availability. The mean interval between availabilities is T/P . In this experiment, T was 1 sec and T/P was 1 min.

Before beginning this experiment all four subjects had received over 100 sessions of preliminary training. These sessions were divided among feeder training, conditioning of the key response, discrimination training, conditioning of the lever response, and observing response training. Details have been reported in De Lorge, *et al.* (1967). After preliminary training, all subjects received 33 further daily 2-hr sessions under the RI 1-min schedule of signal availability before drug administration.

Drug Procedure

For four weeks, subjects were adapted to occasional injections of i.m. saline before daily 2-hr observing sessions. During this period, several trial doses of *d*-amphetamine were administered to establish effective doses. Thereafter, *d*-amphetamine sulfate was dissolved in saline and administered intramuscularly in doses of 0.125, 0.25, 0.50, and 1.0 mg/kg. *d*-amphetamine was administered to all subjects in ascending order of doses, injections being given 10 min before daily sessions and occurring not oftener than once per week, a minimum of five days intervening between drug days. All doses were injected in a volume of 1 cc/kg. A like volume of saline was administered 10 min before the experimental session on each day preceding drug days. The 1.0 mg/kg dose was not administered to animals whose observing and detection behavior

was abolished for 2 hr at 0.50 mg/kg. Drug or saline administrations were deferred or repeated whenever any procedural failure occurred or whenever an individual's observing rate on the preceding day deviated by more than 10% from the mean of its previous three sessions.

RESULTS

The rate of the observing (lever) response as a function of the dose of *d*-amphetamine is given in Fig. 1 for each subject. The points plotted against zero dose are means of four 2-hr sessions after saline injection for each subject. The ranges of these four saline sessions have been omitted to avoid cluttering the figure. In all cases, however, daily mean rates under saline were within $\pm 10\%$ of the plotted means. It is apparent in Fig. 1 that amphetamine, in doses of 0.25 mg/kg or more, progressively decreased the mean observing rate in all subjects. At 0.50 mg/kg, all animals had low rates and two subjects (M2 and M4) were not run under 1.0 mg/kg because their response rates were nearly zero at 0.50 mg/kg. At the smallest dose, 0.125 mg/kg, different effects were obtained in different animals. The observing rate decreased in Monkey M3, was unchanged in M8, and increased in M2 and M4.

The rate of the key (detection) response as a function of *d*-amphetamine dosage is given in Fig. 2. These data are for the same sessions as in Fig. 1. Since the average rate of S^D (signals or red lights) was one per minute, a sustained observing rate, together with an absence of "extra" responses to the dark or green keys, would lead to a control key rate of one response per minute. It is seen that the mean rate under saline (zero dose) exceeded this for two subjects in Fig. 2. These two monkeys, M2 and M4, reliably emitted "extra" key responses throughout the experiment. Figure 2 shows that key rates, like observing rates, decreased with increasing doses of *d*-amphetamine at or above 0.25 mg/kg. Also, the effect of 0.125 mg/kg upon the rate of the reinforced response was similar to the effect of this small dose on the observing rate. Two animals (M2 and M4) displayed increased key response rates at the small dose; one monkey's key rate was unchanged (M8); and one subject's rate decreased (M3). Thus, for all subjects, the

Fig. 1. Rate of the observing (lever) response as a function of *d*-amphetamine dosage for each of four monkeys. Points at zero dose are means of four saline sessions for each animal. Other points are mean rates for one 2-hr session at each dose.

Fig. 2. Key (detection) response rates for each subject as a function of *d*-amphetamine dosage. Data are plotted as in Fig. 1.

effect of the small dose on the key rate was in the same direction as its effect on the observing rate. Decreases in the key rate, of course, could be due to lowered observing rates under the drug with consequent decreases in signal frequency. The converse, however, does not hold. Increases in observing rate did not in-

crease the frequency of signals. Hence, the large increases in key rate in Monkeys M2 and M4 at 0.125 mg/kg represent "extra" non-reinforced responses to the dark or green key. Increased response rates occurred only in these two animals and only at the smallest dose. Also, these were the two subjects that displayed "extra" key responses in the absence of the drug.

Cumulative records of the performance of two monkeys under saline and at each dose of *d*-amphetamine appear in Fig. 3 and 4. The data of Monkey M3 are in Fig. 3. Under saline this subject displayed a moderately high rate on the observing lever with almost no extra responses on the detection key. Under 0.125 mg/kg *d*-amphetamine, responding on both operanda ceased for about 70 min, beginning 25 min after the start of the session and recovering toward the end. As indicated by the arrow and displacement of the observing recorder pen, a red stimulus was present on the key for about 75 min during the time responding was eliminated. A few observing responses occurred at the beginning of this period in the presence of the red keylight, and a single observing response was emitted about 3 min before sustained responding resumed with a key response terminating the red stimulus. Behavior like this never occurred in any subject in the absence of the drug. The latency of responses on the key after onset of the red stimulus was almost always between 0.25 and 0.50 sec and very rarely exceeded 1.0 sec in any subject. Since signals were terminated so quickly under control conditions, there was no opportunity for observing responses in the presence of signals. It is apparent in Fig. 3 that larger doses of amphetamine abolished both observing and detection behavior for progressively longer periods. The exception is the 25-min period of sustained low rate observing behavior that occurred in the presence of a red keylight after 0.50 mg/kg *d*-amphetamine. This was the only case in which responding on the lever was sustained in the presence of a red keylight. Extended periods in which the red light remained on were observed, however, in every subject at the larger doses and in Monkeys M3 and M8 at smaller doses.

Performance of Monkey M4 under saline and at each dose of *d*-amphetamine is shown in Fig. 4. This subject displayed the highest

control rate of the observing response. Also, as indicated in the saline records of Fig. 4 and in Fig. 2, Monkey M4 reliably emitted "extra" key responses in the absence of the red stimulus. Figure 4 shows the increase in both observing and key rates obtained from this animal at 0.125 mg/kg. As noted above, increased rates at the smallest dose were obtained from Monkey M2 as well as M4. The effects of the larger two doses in Fig. 4 were similar to those obtained from the other subjects. Both observing and detection behavior were concurrently abolished for periods that increased as a function of dose. At the 0.50 mg/kg dose in Fig. 4, a red stimulus remained on the key for nearly the entire session without either response being emitted. This is similar to the effect seen in Monkey M3 at 1.0 mg/kg.

DISCUSSION

Under the conditions of this experiment the principal effect of *d*-amphetamine was to eliminate both observing and detection behavior concurrently. Both responses were abolished for longer periods by larger doses. Intermediate effects were seen only briefly. Otherwise, animals responded normally or not at all. Thus, the graded effects above 0.125 mg/kg in Fig. 1 and 2 were due to the elimination of responding for progressively longer periods. So far as response rates are concerned, amphetamine did not have different effects on observing behavior and on discriminated instrumental behavior. Where either response increased in rate, both increased. And, with the one exception noted above in Fig. 3, where either response ceased, both ceased. During periods when neither response was emitted all animals were observed to be hyperactive. Typically, this activity consisted of continually circling the cage or weaving in figure eights without orientation toward the key or lever. At the larger two doses, similar behavior continued in the home cage for 1 to 2 hrs after the experimental session.

Dews (1958a, 1958b) has proposed that the principal determinants of the direction of amphetamine effects are the dose and the rate of responding in the absence of the drug. Small doses increase the frequency of short interresponse times, while large doses also increase the frequency of long interresponse times. According to this hypothesis, high rates

MONKEY:M3   OBSERVING   RI 1min

Fig. 3. Cumulative records of performance of Monkey M3 under saline and at each dose of *d*-amphetamine. The entire 2-hr session is shown in each case. The upper record of each pair cumulates observing (lever) responses. Key (detection) responses are concurrently cumulated in the lower record of each pair. Recorders were reset after about 550 responses and at the end of a session. The pen is displaced in the observing response records upon production of a red keylight ("signal") and released upon termination of the red light by a key response. Slash marks on the lower record indicate reinforced key responses ("detections"), recorders being stopped during the feeder cycle. Arrows pointing to the observing response records indicate points at which a red stimulus was produced but not immediately terminated by a key response.

MONKEY:M4   OBSERVING   RI 1min

Fig. 4. Cumulative records of performance of Monkey M4 under saline and at each dose of *d*-amphetamine. The records are arranged and labelled as in Fig. 3.

of responding should be unaffected by small doses and should decrease with increasing dose; low rates should increase as a function of dose; and intermediate rates should be increased by small doses and decreased or unaffected by larger doses. Peak increases in intermediate rates should occur at lower doses where the baseline rate is higher. (Very large doses, of course, eliminate responding under all baseline conditions.) Dews' hypothesis has been supported by data from a wide range of experimental conditions (Dews, 1958a; Dews and Morse, 1961; Kelleher and Morse, 1964; Clark and Steele, 1966; McMillan, 1968, 1969; Kelleher and Morse, 1968).

The present findings support Dews' hypothesis in that doses above 0.125 mg/kg abolished both observing and detection behavior for periods of time that increased as a function of dose. The effects of the smallest dose, however, differed among the subjects. As noted above, both key and observing rates increased in two animals at the small dose, and both rates decreased or were unaffected in the other two animals. It is possible that a dose somewhat smaller than 0.125 mg/kg would yield rate increases in all four subjects or in the two whose rates failed to increase at this dose. The preliminary dosings that preceded the experiment are relevant to this question. These included a dose of 0.125 mg/kg in all subjects and a dose of one half this much, or 0.0625 mg/kg. The smaller of these two doses had no effect in any subject. The trial dose of 0.125 mg/kg, however, had effects on the rate of both responses which were in the same direction as those seen above in Fig. 1 and 2 for each subject. While this does not eliminate the possibility of different effects at other small doses it does indicate that the results obtained at 0.125 mg/kg are reliable and that an account should be given of them.

There are differences in the performances of the four monkeys under the observing schedule that may be responsible for the different effects seen at the smallest dose. First, as noted above, differences in the effect of the small dose on the observing rate are related to effects of the same dose on the key rate. In particular, increased observing rates occurred only when the key rate showed a concomitant increase. Second, examination of key response rates under saline according to the different stimulus conditions, under which key responding

could occur, reveals an interaction between the effect of the small dose on the key rate and the control or pre-drug probability of that response. Responses on the key could occur under three stimulus conditions, when a red or green light was present on the key (immediately after observing responses), or when the key was dark. The number of responses on the red key was controlled primarily by the schedule of signal availability. Because key responses occurred within 0.5 sec after onset of a red light, the rate of responding was high when the key was red. Increases in the rate of key responding under amphetamine took place only when the key was green or dark. In two subjects (M3 and M8), responses on the green or dark key almost never occurred under saline. Nor did increased key response rates occur in these subjects under amphetamine. In the other two monkeys (M2 and M4), however, a low rate of responding on the key was maintained in the absence of red lights. It was in these two subjects that the key rate increased at 0.125 mg/kg.

The number of responses emitted on the red, green, and dark key by Monkeys M2 and M4 under saline and under 0.125 mg/kg *d*-amphetamine is shown in Fig. 5. The number of responses on the red key was determined, of course, by the number of signals in the session. Figure 5 shows that, under saline, M2 most often emitted extra responses on the key when it was dark; M4 most often responded when the key was green. (Since M4's saline observing rate was higher, the green stimulus was present a higher proportion of the time.) "Extra" key responses in the absence of signals were emitted by these two monkeys at an average rate of from 0.25 to 0.50 responses per minute. In both subjects, the increase under amphetamine was primarily in responding while the key was dark. M4's rate in the green was also increased substantially, perhaps because of the higher green exposure time resulting from his observing rate.

It is apparent that key rates were increased under the 0.125 mg/kg dose only where there was appreciable responding on the key in S^A or in the absence of stimuli. This is in accordance with Dews' hypothesis: high rates of responding on the key (all subjects in the presence of red lights) were unaffected or decreased by small doses of amphetamine; low rates (subjects M2 and M4 in the presence of green or

Fig. 5. Number of key responses in each stimulus condition during one saline session and at 0.125 mg/kg *d*-amphetamine for Monkeys M2 and M4. These are the two animals that emitted "extra" key responses and whose observing and key rates increased at the smallest dose.

dark keys) were increased by small doses. Where there was no responding on the key (subjects M3 and M8 in the absence of red lights), there was no effect of the small dose of *d*-amphetamine. Previous experiments have shown that amphetamine increases responding in S^Δ if there is a low rate, but not if the rate is essentially zero (Clark and Steele, 1966; Kelleher and Morse, 1968). A similar relationship may hold with other drugs (Clark, 1969). Thus, changes in key rates as a function of

d-amphetamine dosage can be understood in terms of differences in probability of response in the three stimulus conditions under which key responding could occur.

Changes in the observing rate at the small dose cannot be similarly related to individual differences in observing rate under saline. That is, the two subjects that displayed increased observing rates at 0.125 mg/kg did not have low observing rates in the absence of the drug. Rather, their key rates also increased at this dose. This suggests an interaction between the key and observing responses in Monkeys M2 and M4. Since both these animals responded on the key when it was green or dark, these key responses were followed by lever responses. Thus, a key response could become the occasion for reinforcement of a subsequent observing response. Monkeys M3 and M8, on the other hand, almost never responded to the key unless it was lighted red. A key response was unlikely to become an occasion for observing in these subjects because the feeder cycle normally intervened. Thus, the increased observing rates obtained from animals M2 and M4 at the smallest dose of *d*-amphetamine may have been dependent upon the concomitant increase in key rate in these subjects. To the hypothesis of chaining between the two responses may be added the observation that increased key responding necessarily brings the animal into proximity with the lever.

These conclusions regarding different effects of the small dose of *d*-amphetamine in different animals may be summarized. Observing rates were increased if key rates were increased, and key rates were increased where there was already appreciable responding on the key in S^Δ or no stimulus. Between-subjects differences in drug effects such as those seen above are not uncommon. Since the performances generated in different subjects under the same experimental conditions are seldom identical, ostensibly idiosyncratic drug effects may often arise from within group drug-behavior interactions. For example, Verhave (1961) observed decreases in avoidance behavior under methamphetamine which could be obtained only from animals exhibiting a high rate of responding immediately after shocks. The removal of an apparently idiosyncratic dose-response relationship by manipulation of a property of the baseline behavior has been demonstrated by Clark and Steele (1963).

Thus, where different behavior has been generated under the same experimental conditions, different drug effects are commonly obtained. Conversely, similar drug effects may be obtained where similar behavior has been generated by different procedures (Kelleher and Morse, 1964, 1968).

Both of the hypotheses advanced above in connection with the effects of 0.125 mg/kg are speculative in the sense that neither was tested in this experiment. Both, however, are testable. Nor are they speculative in the same degree. The hypothesis that changes in the overall key rate at the small dose are determined by the individual subject's control rate of responding in the absence of signals is supported by the considerable literature cited in connection with it. That small doses of amphetamine increase responding in S^A if and only if there is responding in S^A seems well established. The hypothesis that increases in observing rate at the smallest dose depended upon a concomitant increase in key rate carries less weight. It may also carry more promise. There is no reason to suppose that all dose-response functions in situations where several responses are concurrently maintained should be of the same form as in situations where only one response is maintained. In this connection, the present data suggest that research into the influence of drugs upon interactions and dependencies among different response classes may prove fruitful.

The possibility that the present data indicate effects of amphetamine on the discriminative control of behavior should be mentioned. As with many problems concerning stimulus control, this is not a unitary question. Observation of the subjects suggested that amphetamine induced behavior that not only competed with experimentally defined responses but also was incompatible with orientation toward relevant discriminative stimuli. Both increased detection times, obtained at larger doses, and increased key responding in the absence of signals, obtained at the smallest dose, could be taken as indicating changes in the discrimination of key colors. This would be under the assumption that subjects continued to be stimulated by the key colors. But, as indicated above, these changes in key rate may be accounted for in terms of interaction of the drug with the control rate under the different stimulus conditions. The behavior

of Monkey M3 at 0.50 mg/kg might be taken as more direct evidence for a breakdown of discriminative control between the two recorded response classes. In this case the subject continued to emit observing behavior in the presence of a signal previously established as an S^D for the key response. This was the only case in which such behavior was obtained, however, and observation of the subject during this period revealed no orientation toward the stimulus display. Thus, the red keylight may have been ineffective as a stimulus. Nevertheless, discriminative effects of the drug cannot be excluded, since lever responses were occasions for orienting on the display under control conditions. It would seem that the data bear only indirectly on questions about the possible discriminative effects of amphetamine.

Finally, it should be noted that amphetamine had only deleterious effects on observing and detection behavior in this experiment. At large doses, observing behavior was abolished and detection times greatly increased. At small doses the rate of key responding in the absence of signals was increased in some subjects. In monitoring terminology this would be described as an increase in the rate of false detections. It is true that some of the conditions under which amphetamine has increased the efficiency of human monitoring performance (N. Mackworth, 1948; J. Mackworth, 1965) were absent in the present case. Neither decrements in observing rate nor increases in detection latency occurred as a function of elapsed time within sessions. In this connection it has been remarked previously (De Lorge *et al.*, 1967) that behavior was under stronger control under the present conditions than is usual in human monitoring situations. In this experiment, amphetamine had obvious concomitant effects on orientation toward discriminative stimuli, on the emission of stimulus producing behavior, and on responding to terminate discriminative stimuli. Assignment of these diverse effects to a behavioral state labelled "attention" or "vigilance" would not contribute to their analysis.

REFERENCES

- Clark, F. C. Effects of chlorpromazine on behavior maintained by a multiple schedule of reinforcement. *Journal of Pharmacology and Experimental Therapeutics*, 1969, 166, 179-188.

- Clark, F. C. and Hull, L. D. The generation of random interval schedules. *Journal of the Experimental Analysis of Behavior*, 1965, **8**, 131-133.
- Clark, F. C. and Steele, B. J. Some observations on the interaction of chlorpromazine and free operant avoidance bursts. *Psychopharmacologia*, 1963, **4**, 221-231.
- Clark, F. C. and Steele, B. J. Effects of *d*-amphetamine on performance under a multiple schedule in the rat. *Psychopharmacologia*, 1966, **9**, 157-169.
- Cook, L. and Kelleher, R. T. Drug effects on the behavior of animals. *Annals of the New York Academy of Sciences*, 1962, **96**, 315-335.
- De Lorge, J. O., Hess, J., and Clark, F. C. Observing behavior in the squirrel monkey in a situation analogous to human monitoring. *Perceptual and Motor Skills*, 1967, **25**, 745-767.
- Dews, P. B. Studies on behavior, IV. Stimulant actions of methamphetamine. *Journal of Pharmacology and Experimental Therapeutics*, 1958, **122**, 137-147. (a)
- Dews, P. B. Analysis of psychopharmacological agents in behavioral terms. *Federation Proceedings*, 1958, **17**, 1024-1030. (b)
- Dews, P. B. and Morse, W. H. Behavioral pharmacology. In W. C. Cutting, R. H. Driesbach, and H. W. Elliott (eds.), *Annual review of pharmacology*. Palo Alto: Annual Reviews, Inc., 1961. Pp. 145-174.
- Farmer, J. Properties of behavior under random interval reinforcement schedules. *Journal of the Experimental Analysis of Behavior*, 1963, **6**, 607-616.
- Holland, J. G. Human vigilance. *Science*, 1958, **128**, 61-67.
- Kelleher, R. T. and Morse, W. H. Escape behavior and punished behavior. *Federation Proceedings*, 1964, **23**, 808-817.
- Kelleher, R. T. and Morse, W. H. Determinants of the specificity of behavioral effects of drugs. *Ergebnisse der Physiologie, biologischen Chemie, und experimentellen Pharmakologie*, 1968, **60**, 1-56.
- McMillan, D. E. The effects of sympathomimetic amines on schedule-controlled behavior in the pigeon. *Journal of Pharmacology and Experimental Therapeutics*, 1968, **160**, 315-325.
- McMillan, D. E. Effects of *d*-amphetamine on performance under several parameters of multiple fixed-ratio, fixed-interval schedules. *Journal of Pharmacology and Experimental Therapeutics*, 1969, **167**, 26-33.
- Mackworth, J. F. The effect of amphetamine on the detectability of signals in a vigilance task. *Canadian Journal of Psychology*, 1965, **19**, 104-110.
- Mackworth, N. H. The breakdown of vigilance during prolonged visual search. *Quarterly Journal of Experimental Psychology*, 1948, **1**, 6-21.
- Payne, R. B., Hauty, G. T., and Moore, E. W. Restoration of tracking proficiency as a function of amount and delay of analeptic medication. *Journal of Comparative and Physiological Psychology*, 1957, **50**, 146-149.
- Verhave, T. A depressant effect of methamphetamine on avoidance behavior. *Federation Proceedings*, 1961, **20**, 395.
- Weiner, H. and Ross, S. The effects of "unwanted" signals and *d*-amphetamine sulfate on observer responses. *Journal of Applied Psychology*, 1962, **46**, 135-141.
- Wyckoff, L. B., Jr. The role of observing responses in discrimination learning. *Psychological Review*, 1952, **59**, 431-442.

Received 5 December 1968.