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BEHAVIORAL AND PHARMACOLOGICAL MANIPULATIONS OF RESPONDING MAINTAINED BY A FIXED-INTERVAL SCHEDULE OF ELECTRIC-SHOCK PRESENTATION

by

© ELMER RANDY ORLOFF

A THESIS

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies for acceptance, a thesis entitled "Behavioral and Pharmacological Manipulations of Responding Maintained by a Fixed-Interval Schedule of Electric-Shock Presentation," submitted by Elmer R. Orloff in partial fulfillment of the requirements for the degree of Doctor of Philosophy.

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ABSTRACT

Four squirrel monkeys (Saimiri sciureus) were trained to respond under a fixed-interval schedule of electric shock presentation. Following stabilization of performance engendered by this schedule, three of the subjects were exposed to a multiple S^D-S^Δ probe procedure. This procedure was found to exert similar effects upon each of the 3 subjects. Interruption of the fixed-interval by multiple S^Δ periods did not disrupt the 'scalloped' pattern of responding characteristic of fixed-interval reinforcement. Responding during successive S^D periods showed progressive increases accompanied by a 'sub-scalloping' effect which was evident during individual S^D periods.

Modifications of performance, following administration of d-amphetamine were assessed in each monkey. One animal was tested under a simple FI schedule of electric shock presentation, three other monkeys were tested under the multiple S^D-S^Δ probe procedure. Differential effects upon behavior were observed following drug administration. Increases in low rates of responding

and decreases in higher rates of responding were observed at certain doses. The effect of an externally-based discriminative stimulus appeared to lessen the magnitude of drug induced changes in behavior. The effects of amphetamine were reduced following repeated administration. The results are consistent with the effects of an S^D-S^Δ probe procedure and drug administration upon fixed interval performance maintained by food-reinforcement or by shock avoidance. It is suggested that these findings are relatively independent of the reinforcer maintaining behavior and that the schedule is a more fundamental determinant of behavior.

ACKNOWLEDGEMENT

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Elmer R. Orloff

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INTRODUCTION

Operant Behavior

Although most current behavioral experiments with infra-human primates use instrumental conditioning procedures as defined by Skinner (1938), only experiments with certain additional characteristics are consistently described as operant conditioning experiments in current terminology (Ferster, 1953; Kelleher, 1965). The first characteristic is the extensive use of rate and pattern of responding as dependent variables. In operant experiments, some response an animal can repeat frequently without fatigue (such as lever pressing or key pecking) is usually selected for study. The second characteristic is the explicit use of reinforcement schedules. A schedule of reinforcement is the precise specification of a plan according to which discriminative and reinforcing stimuli will be presented, contingent upon the animal's behavior. Many different schedules of reinforcement have been studied in the laboratory and it is quite clear that particular schedules produce extremely stable rates of responding for as long as the

schedule is continued (Ferster & Skinner, 1957). However, even slight changes in the schedule can produce dramatic differences in behavior (Morse, 1966; Stretch, 1969).

Fixed-Interval Behavior

There have been numerous investigations (Dews, 1956; Ferster & Skinner, 1957) which have shown that fixed-interval (FI) schedules of reinforcement generate characteristic sequences of responses. Under a fixed-interval (FI) schedule of reinforcement, a response is followed by a reinforcing stimulus after a fixed interval of time has elapsed since the previous occurrence of reinforcement. When a subject is exposed to fixed-interval reinforcement, a pattern of responding usually emerges in which the frequency of responding increases as the interval progresses (Ferster & Skinner, 1957; Dews, 1962). Thus performance on the FI schedule is characterized by an initial pause followed by positively accelerated responding; this pattern of responding, when plotted cumulatively, is commonly called an FI 'scallop'. It was assumed for a time (Ferster & Skinner, 1957) that the FI scallop was mediated by a response chain.[1] If the

[1] A response chain is defined by Kelleher (1966) as ". . . a response sequence in which each response either functions as a discriminative (or eliciting) stimulus or produces a discriminative (or eliciting) stimulus controlling the response that follows. When it is assumed that a response sequence is a response chain, the stimuli in the chain are hypothetical."

sequence of responses constituting an FI scallop is a chain of responses, interrupting the sequence should disrupt the moment-to-moment stimulus control by response-produced stimuli, and should therefore disrupt the pattern of positively accelerated responding.

Dews (1962, 1965a, 1965b, 1966a, 1966b), in an important series of experiments, has described the effects of repeated interruption of FI responding maintained by food presentation. Initially, the key-peck response of pigeons was established under an FI 500 sec. schedule of reinforcement; during this contingency the response key was transilluminated, but the houselight was not. Then, the houselight (HL) was introduced during alternate 50 sec. periods throughout the interval, including the tenth period. The response key was transilluminated throughout each interval; however, reinforcement occurred in the presence of the houselight (S^D)[1] but not in its absence (S^Δ).[2] Under this procedure, S^Δ periods repeatedly interrupted each FI, but did not prolong the minimum interval between reinforcements. The results indicated that responding

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[1] A discriminative stimulus (S^D) is defined by Ferster and Skinner (1957) as ". . . a stimulus in the presence of which a response is reinforced and in the absence of which it goes unreinforced."

[2] An S^Δ period: The acquisition of an operant discrimination may be defined as the process whereby an animal comes to respond more frequently to a stimulus correlated with reinforcement (S^+, or S^D) than to a stimulus correlated with non-reinforcement (S^-, or S^Δ).

increased progressively throughout the periods in which the houselight was present, despite the series of repeated interruptions. Although the response rates were relatively low in the S^{Δ} periods, they tended to increase throughout each FI. Dews (1962, p. 372) concludes, "The general pattern of FI responding is not disrupted by the interposition of repeated S^{Δ} periods during the interval. Therefore chaining of responses from moment to moment consecutively through the interval is not necessary for the maintenance of the overall scalloped pattern characteristic of FI responding."

A similar experiment was conducted using a squirrel monkey as the experimental subject (Dews, 1965a); however, a procedural change was operative in this case. With this procedure, a squirrel monkey was subjected to an FI 600 sec. food reinforcement schedule. During the 600 sec. interval, a transilluminated white circle-stimulus was continuously present. The houselight (HL) was also present during alternate 60 sec. periods, starting each interval with a period when it was present. At the conclusion of the 600 sec. interval, the HL remained off, so that a response was never reinforced during the presence of the HL; the HL was thus an S^{Δ}. This is the converse of the pigeon experiment (Dews, 1962) in which the absence of the HL was S^{Δ}. Again, the results indicated that the rate of responding during presence of

the HL was consistently less than in the preceding and succeeding periods without HL. The S^{Δ} periods were therefore interrupting the subject's progressive sequential responding. Nevertheless, an increase in frequency of responding in successive segments through the interval, characteristic of FI responding, developed.

In general the same results have been obtained whenever an FI schedule of food reinforcement has been interrupted by S^{Δ} periods. In another experiment (Dews, 1965b) it was found that whether intervals were interrupted by 1, 2, or 5 S^{Δ} periods, the general scalloped pattern of FI responding persisted. It was even possible to maintain this scalloped pattern with parameter values of 27 3/4 hr. for the FI and 2 3/4 hr. for the individual S^{Δ} interruptions. It is possible to maintain the FI scallop when the majority of time in the FI is composed of S^{Δ} periods. An investigation by Dews (1966a) utilized pigeons as the experimental subjects. They were exposed to an FI 500 sec. in which an S^{Δ} was present throughout the interval except during the terminal 50 sec. segment and one earlier 50 sec. segment. Very little responding occurred during the presence of S^{Δ}. The rate of responding in the earlier 50 sec. S^{D} segment was lower than in the terminal S^{D} segment. There was a clear trend for the rate of responding in the earlier S^{D} segment to be progressively higher the

later it occurred during the course of the fixed-interval; this trend was shown to parallel the increasing rate of responding in a conventional FI 500 sec. with no interruption by S^{Δ}.

In summary, as was previously mentioned (Ferster & Skinner, 1957), the chaining concept involves the assumption that each response in a sequence of operant responses either functions as or produces the discriminative stimulus for the response that follows. It has often been assumed that the patterns of responding that characterize performance on FI schedules of reinforcement are response chains. If such a chaining analysis were correct, interrupting the sequence of responding on an FI schedule should interrupt the moment-to-moment control by the stimuli in a response chain and consequently should disrupt the response pattern. Several experiments have shown, however, that various procedures for interrupting FI schedules by interpolating S^{Δ} periods did not disrupt response patterns. Results such as these indicate that response chaining is not necessary for positively accelerated responding on FI, and they suggest that other interpretations of this response pattern may be more useful.

FI Behavior Maintained By Electric Shock

The typical pattern of responding, observed under

FI schedules, is not confined to situations in which food presentation constitutes the reinforcer. Using a variety of procedures, the development and maintenance of FI responding has been demonstrated satisfactorily under circumstances in which the sole consequence of responding is the periodic delivery of brief, but intense, electric shocks.

Morse, Mead, and Kelleher (1967) elicited responding in squirrel monkeys by presenting brief, but intense, electric shock every 60 seconds. Each monkey was seated in primate restraining chair (Hake & Azrin, 1963); electric shocks were delivered through two brass plates that rested lightly on the shaved section of the monkey's tail. In previous experiments with squirrel monkeys, Morse and Kelleher noticed during initial training that electric shocks delivered to a monkey's tail caused the animal to persistently pull and bite a leash attached to his collar. When the leash was fastened to a lever mounted at the top of the front panel of the restraining chair, biting and pulling on the leash resulted in repeated closures of a microswitch attached to the lever. Morse et al. (1967) studied this elicited response, leash-pulling, rather than a conditioned operant such as lever pressing. They found that responding elicited by electric-shocks presented every 60 seconds was altered gradually in terms of the temporal

patterning of responses, especially when the shock was also produced by the first response to occur after 30 seconds had elapsed from the preceding shock (A 30-sec. FI schedule of shock presentation). The initially-elicited pattern of responding just after each shock was altered by the recurrent shock and by the added fixed-interval schedule to a pattern in which maximal responding occurred prior to each shock delivery. Most shocks were produced by responses and the response pattern was maintained for several months of daily testing; little responding occurred, however, when shocks were omitted.

Stretch, Orloff, and Dalrymple (1968) conducted a rather different experiment in which, after prolonged stabilization of rates of responding engendered by a free-operant avoidance schedule of the Sidman type (Sidman, 1953; 1966), the lever-pressing of squirrel monkeys was maintained for several months of daily testing by an FI schedule of electric shock presentation. According to the specification of the fixed-interval schedule, the first response to occur after 300 seconds had elapsed from the preceding shock, produced a shock of 300 msec. duration at an intensity of 12 milliamperes; if the monkeys did not emit a response within 15 seconds,

timed from the end of the interval,[1] a shock of identical intensity and duration was presented independently of behavior and the next fixed-interval of 300 seconds began. At first, response-contingent shocks produced appreciable increases in the overall rates of responding, as compared with the previous rate of avoidance responding. However, continued exposure to the fixed-interval schedule resulted in a reduced overall rate of responding accompanied by a significant change in the temporal patterning of responses. Eventually, after 60-70 sessions (approximately 140 hours), a cessation or pause in responding was observed after each presentation of shock; the rate of responding then increased during the interval, often reaching a terminal value preceding shock-presentation.

McKearney (1968; 1969) has also described the effects of superimposing a fixed-interval schedule of electric-shock presentation upon the pattern of responding maintained by an avoidance schedule in squirrel monkeys. This experiment is similar in procedure to that of Stretch et al. (1968) thereby affording

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[1]This aspect of the procedure can be referred to as a limited-hold. In a fixed-interval schedule of food reinforcement with limited-hold, the reinforcer is only available for a limited period, timed from the end of the interval. In the FI schedule of shock presentation, shock is withheld for a limited period and unless a response occurs to produce a shock, the shock is delivered at the end of this period, independently of behavior.

independent confirmation of these results. Kelleher and Morse (1968) in an extensive investigation of the parameters, controlling this pattern of responding maintained by a fixed-interval schedule of electric-shock presentation concluded that ". . . whether response-produced electric shocks suppressed responding or maintained responding depended on the schedule of shock presentation."

Byrd (1969) has observed similar results when cats were used as experimental subjects. Thus, it appears that these results do not represent an isolated phenomenon but may be achieved with a variety of scheduling arrangements and subjects.

Concept of Punishment

The definition of punishment has been discussed by Azrin and Holz (1966). They suggest that "an unequivocal aspect of punishment seems to be that punishment reduces a behavior when the punishment is arranged as a consequence of that behavior." From this position they proceed to define punishment as: "A reduction of the future probability of a specific response as a result of the immediate delivery of a stimulus for that response. The stimulus is designated as a punishing stimulus; the entire process is designated punishment." In the simplest instance, a punishing stimulus is delivered for every

response. A punishment contingency such as this may be designated as continuous punishment by analogy with positive reinforcement. When intermittent punishment has been compared with continuous punishment (Azrin, Holz, & Hake, 1963; Zimmerman & Ferster, 1963), the results have shown the greatest degree of suppression occurs with continuous punishment.

There is considerable evidence (Church, 1963; Azrin & Holz, 1966) to show that responding maintained under schedules of food presentation can be suppressed when each response or a proportion of responses are followed immediately by electric shock; there is an increasing body of evidence, however, to indicate that responding can be maintained by the scheduled presentation of electric shock. The question arises as to how one might explain these apparently conflicting observations.

FI Punishment

According to a fixed-interval schedule of punishment, the punishing stimulus is made contingent upon the first response to occur after a fixed-interval has elapsed since the previous punishment. In 1956, Azrin investigated this arrangement, with several procedural variations. Azrin trained pigeons to peck

a key to obtain food; responding was then maintained by a variable-interval[1] (VI) schedule of food reinforcement. He then compared response-contingent FI punishment with the effects of presenting a punishing stimulus at regular intervals, irrespective of responding, upon the baseline performance generated by the VI schedule of food reinforcement. The results indicated that the contingent punishment was more effective than non-contingent punishment in reducing the overall rate of responding. When the electric shocks were scheduled at fixed-intervals of time as a consequence of responding, the response rate dropped to zero as the moment approached for the scheduled punisher to be delivered. As Azrin and Holz (1966) have remarked, the existence of this anticipatory suppression demonstrates how the effect of punishment can be restricted specifically to the time at which the punishment is scheduled to occur; the temporal patterning of responding appears to be analogous to the temporal patterning observed under FI schedules of food-reinforcement except that negative, rather than positive, acceleration of the response rate is observed.

The frequency and schedule of response-contingent

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[1]A variable-interval schedule (VI) is defined by Ferster and Skinner (1957) as ". . . a schedule of intermittent reinforcement in which reinforcements are programmed according to a random series of intervals having a given mean and lying between arbitrary extreme values."

aversive stimulation are known to be important determinants of the amount, pattern, and duration of suppression. Appel (1968), in an independent confirmation of Azrin's (1956) findings, attempted to specify the quantitative relationships between punishment frequency and other variables. His findings showed that the average rate of bar-pressing maintained by a variable-interval schedule of milk reinforcement, over a wide range of shock intensities, was inversely related to punishment frequency. In all cases the longest FI punishment schedule (lowest frequency of punishment) produced the least amount of suppression at any given intensity.

In general, the effects of a punishing stimulus depend upon a number of important variables. Of these, the manner in which a punishing contingency is first introduced is often critical. Appel (1961) trained two squirrel monkeys to press a lever to obtain food; responding was then maintained by a 6 min. variable-interval (VI 6) schedule of food reinforcement. A punishment contingency was added subsequently in which each response that was made incurred the presentation of an electric shock. Punishment was found not only to suppress the rate of responding under conditions of severe food deprivation in both of the monkeys but it prevented the emission of responses for 50 days (400 experimental hours) after the punishment contingency

had been withdrawn. Appel expressed the view that punishment may have the effect not merely of eliminating a response but also of permanently inhibiting adaptive behavior in higher organisms such as the Primates.

Before accepting these conclusions, however, other experiments pertaining to the manner of introducing the punishment contingency should be considered. Hake, Azrin, and Oxford (1967), using squirrel monkeys as subjects, have given a detailed description of the effects of different intensities of punishment upon responding. Lever-pressing in several squirrel monkeys was maintained by a variable-interval schedule of food reinforcement (VI 30 sec.; VI 1 min.; VI 2 min., in different animals); concurrently, punishment consisting of a brief electric shock followed each response. By gradually increasing the intensity of the punishing stimulus, it was possible to observe response rates lying between the two extremes of complete suppression or elimination of responding and an absence of any suppressive effect upon behavior, respectively. When punishment was discontinued, responding recovered immediately except when suppression had been complete. It is also of interest to note that when the punishment intensity was decreased gradually, more suppression resulted at a given intensity than when the intensity was increased gradually. This finding according to

Hake *et al*. (1967), may represent what they have called "behavioral inertia" effect in which responding at a new punishment intensity is biased toward the amount of responding controlled by the previous intensity.

However, as Stretch, Orloff, and Dalrymple (1968) have noted, the results of the experiment exemplify an important principle: as behavior is modified by a particular stimulus, the effectiveness of that stimulus in producing subsequent modifications of behavior is also altered. The effectiveness of a specific stimulus, such as an intense electric shock, is not invariant but depends upon ongoing patterns of responding.

Punishment can be arranged in such a way that its occurrence constitutes a discriminative stimulus for the presentation of a reinforcer. An interpretation such as this may account for the paradoxical effect of a punishing stimulus increasing the rate of occurrence of a response. Holz and Azrin (1961) examined this possibility; they conducted an experiment in which punishment was related differentially to a positive reinforcer. In the first type of session, responding was reinforced intermittently with food; in addition, every response that occurred was followed by a brief electric shock. In the other type of session (extinction), neither food nor shocks were presented as a consequence of responding. The results showed that

there were considerably more responses emitted in the punishment-reinforcement sessions than in the extinction sessions. Increased responding was found when the food was withheld from the punishment sessions and only the shock was delivered.

An aversive stimulus may become a discriminative stimulus for another punishing stimulus. Dinsmoor (1952) has described an experiment in which fixed periods of time accompanied by punishment alternated with fixed periods of time when no punishing stimulus was presented. The specific schedule employed was a mixed schedule;[1] hence, no external stimulus was used to indicate the change-over from one period to the next. With such a scheduling arrangement, the only means that the subject had available for predicting whether punishment would occur was whether or not the last response had been punished. Under these circumstances the subject soon learned that delivery of the punishing stimulus meant that the next response would also be punished. This was obvious from the fact that shortly after a response was punished, there was an immediate lowering of the probability of the succeeding responses. However, once one or two responses went unpunished, there was a very

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[1] A mixed schedule, is defined by Ferster and Skinner (1957) as ". . . two or more schedules alternating at random. No stimuli are correlated with the schedules as in multiple schedules."

rapid recovery of the response rate to its unpunished level.

Further analysis of the previously-mentioned paper by Azrin, Holz, and Hake (1963) indicates that punishment can also be arranged so that the delivery of punishment is a discriminative stimulus for the absence rather than the presence of additional punishing stimuli. With the initial introduction of FR punishment responses were completely suppressed following each delivery of the punishing stimulus. However, with continued exposure to the schedule the subject soon learned that a response was never punished immediately after the delivery of a punishing stimulus. Thus, stable baseline performances of all subjects indicated that responding resumed immediately after delivery of each punishing stimulus.

The experiments mentioned here are of considerable importance in understanding some of the anomalous effects of punishment that may be observed. When punishment does not always suppress responding it has sometimes been taken as evidence that punishment is an ineffective method of controlling behavior. However, in such cases, the discriminative properties that punishment may have acquired must obviously be considered.

The discriminative properties of a punishing

stimulus appear to be effective in situations in which a response is punished by the same stimulus which has been used previously to maintain avoidance behavior. Under a free-operant avoidance schedule of the Sidman type (Sidman, 1953; 1966), a response delays the delivery of an electric-shock for a fixed period of time (R-S interval); when responses do not occur, shocks follow each other in a regular sequence (S-S interval). It has been pointed out by Azrin and Holz (1966) that results obtained from this procedure show that electric-shock acquires discriminative properties in that the delivery of a shock becomes the occasion for emitting a response to delay additional shocks. Support for this view comes from an experiment with rhesus monkeys conducted by Sidman, Herrnstein, and Conrad (1957) in which it was found that high rates of responding could be maintained by scheduling occasional "free" or unavoidable shocks after avoidance behavior had been stabilized. Appel (1960), also using rhesus monkeys, found increases in responding when punishment for responses alternated with shock-avoidance as the two components of a mixed schedule. He also reported that his monkeys were able to discriminate the avoidance contingency, in which failure to respond engendered shock presentation, from the punishment condition, in which responses were followed by shocks.

These, and other experiments (Herrnstein & Sidman, 1958; Kelleher, Riddle, & Cook, 1963; Black & Morse, 1961; Migler, 1963), have established the fact that responding can be maintained by unavoidable shocks, sometimes under conditions where responses have no programmed consequences and sometimes under conditions in which responses engender or produce the punishing stimulus. It is evident that the customary reductive or suppressive effects of punishment upon responding can be reversed by a previous history or by a concurrent procedure which allows the punishing stimulus to acquire discriminative properties (Azrin & Holz, 1966).

Several recent experiments (Morse, Mead, & Kelleher, 1967; McKearney, 1968, 1969; Kelleher & Morse, 1968; Stretch, Orloff, & Dalrymple, 1968; Byrd, 1969), involving the establishment and maintenance of responding by relatively intense electric-shocks in squirrel monkeys have shown that the manner in which shocks are scheduled to occur, or the previous history of a monkey with respect to shock presentation, are critical factors if a reversal of the customary effects of a punishing stimulus are to be observed.

Under some conditions responding may be suppressed completely by response-contingent presentation of electric-shocks; however, under other conditions, as these experiments have shown, responding can be

maintained indefinitely when the only scheduled consequence of responding is the presentation of intense, and presumably aversive, stimulation. Furthermore, the pattern of responding maintained by a fixed-interval schedule of electric-shock presentation resembles, in every major respect, the pattern of behavior which can normally be observed under fixed-interval schedules of food reinforcement. The question arises as to how we may account for this phenomenon.

It has been pointed out by McKearney (1968), for example, that an untrained animal exposed immediately to a fixed-interval schedule of electric shock presentation would have little tendency to press the response key. Similarly, an animal that had been trained under a schedule in which each response produced food would quickly cease responding if the response requirement were to be increased abruptly to several hundred, but would develop a stable pattern of responding if the requirement were increased in gradual steps to the same value. Thus, it is being suggested that the past history of the organism is a critical determinant of the manner in which he will respond to a changed contingency; furthermore, the dependence of schedule-controlled performances upon prior behavior is not peculiar to experiments involving electric-shock presentation. Hence, the effectiveness of a specific stimulus, such as electric-shock is not

invariant but depends upon the past history of the subject and upon present patterns of behavior. As McKearney (1968) has stated: "The schedule of (stimulus) presentation, and the ongoing behavior at the time the schedule is imposed, are critically important determinants of the effects of electric-shock presentation."

Behavioral Pharmacology

Experiments designed to investigate the effects of drugs on behavior have been classified by Dews and Morse (1961) into two major divisions: 1) the effects of drugs on unconditioned behavior, 2) the effects of drugs on conditioned behavior. The former type of study is concerned with gross behavioral changes following drug administration. For example, the lethal dosage (LD50) of amphetamine has been shown to depend upon environmental circumstances (Gunn & Gurd, 1940). Some of these environmental determinants are: size of cage, ambient temperature and noise, and state of hydration (Chance, 1946, 1947). However, a different approach was necessary in order to identify the behavioral effects of drugs in detail. This has been supplied by the administration of drugs in dosages which are not lethal to the subject, but are sufficient to induce changes in

behavior. A further aspect of this approach is that the dosage is administered to the animal conditioned to perform a given response under carefully specified experimental conditions. Thus, following a detailed specification of the subject's performance under these conditions, the behavioral effects of a drug can be evaluated in terms of deviation from this control behavior pattern following the administration of the drug to the subject.

One approach has been to evaluate the effects of various drugs against a variety of baseline performances maintained by different schedules of reinforcement. Many workers in this area have shown that the effects of amphetamine and other drugs which exert pronounced behavioral effects, are determined by the pattern of ongoing behavior. The work of Dews (1956) is of particular relevance. Similar findings have been reported for a great number of drugs, and the work of Dews (1958a,b), Morse (1964), Weiss and Laties (1964), amongst others, has lent support to the important principle that ongoing behavior is a major determinant of the behavioral effects of drugs.

Since d-amphetamine sulphate was employed in the present study, it will be examined in greater detail in terms of its pharmacological and behavioral properties.

d-Amphetamine sulphate i) Pharmacological properties. d-Amphetamine is described as a sympathomimetic noncatecholamine. Dextro-amphetamine is the d-isomer of the compound, and is usually prepared in the form of the d-amphetamine sulphate salt. Goodman and Gilman (1965) describe this drug as one of the most potent of the sympathomimetic amines with respect to the stimulation of the central nervous system. Subjects which have been given a sufficient dosage of d-amphetamine characteristically show muscular tremor, increased motor activity, agitation and sleeplessness (see review by Weiss and Laties, 1962). Pharmacologists have suggested that these effects are due to cortical stimulation, and possibly, to stimulation of the reticular activating system (Bradley & Key, 1957). The drug also stimulates the respiratory center (Killam, 1962), increases heart rate (Bradley, 1957), and tends to exert an anorexic effect (Stowe & Miller, 1957).

ii) Behavioral effects.

One of the earliest demonstrations of the effects of the amphetamines on behavior was reported by Dews (1958b). This study investigated the effects of methamphetamine on behaviors maintained by four different schedules of food presentation in the pigeon. Relatively high rates of responding (more than 1/sec.) were maintained by two

of these schedules, a 1 min. VI and a 50 response fixed-ratio (FR).[1] Methamphetamine similarly affected performances on both of these schedules. In both instances, relatively low doses had little effect on the rate of responding, while higher doses produced progressive decreases in response rates. The other two schedules were a 15 min. FI and a modified 900 response FR. Both of these schedules were characterized by low rates of responding (0.1 to 0.2 resp./sec.) with periods of no responding being present. Again performances under both schedules were similarly affected by methamphetamine. The effect here, however, showed low doses causing marked increases in responding while higher doses decreased the response rate. In all four cases the dose that decreased rates of responding was 1 mg/kg. Dews suggested that the frequency of occurrence of the behavior under study was an important determinant of the behavioral effects of amphetamines. Specifically, he concluded that amphetamines tended to increase responding which occurred at low rates, but would decrease responding occurring at high rates.

The results of many studies using a variety

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[1]A fixed ratio (FR) schedule is defined by Ferster and Skinner (1957) as "a schedule of intermittent reinforcement in which a response is reinforced upon completion of a fixed number of responses counted from the preceding reinforcement." (p. 272)

of different procedures and reinforcers in the pigeon, rat, and monkey are consistent with Dew's interpretation. When food, intracranial stimulation, or heat is presented following every lever pressing response in the rat, the relatively low rates of responding that develop (0.1 response per sec. or less) are markedly increased by amphetamines (Weiss & Laties, 1963; Stein, 1964). However, under variable-interval or fixed-ratio schedules that maintain high rates of responding, amphetamines in small doses have little effect, while larger doses decrease rates of responding (Owen, 1960; Hearst, 1961).

The rate-dependent effects of amphetamines have also been shown with multiple schedules[1] of reinforcement comprising components that maintain high and low rates of responding (Kelleher & Morse, 1964; Smith, 1964; Rutledge & Kelleher, 1965). For example, Kelleher and Morse (1964) studied the effects of amphetamine on schedules which generated high and low rates of responding while also being maintained by different reinforcers. One group of monkeys was food deprived and responded under a multiple fixed-ratio fixed-interval

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[1]A multiple schedule is defined by Ferster and Skinner (1957) in the following manner: "Reinforcement is programmed by two or more schedules, alternating, usually at random, each schedule accompanied by an appropriate stimulus as long as the schedule is in force."

schedule of food reinforcement. A small rectangular window in front of the monkey could be transilluminated by a pattern of horizontal lines, a red light, or a white light. When the horizontal pattern was presented, responding had no programmed consequences and food was never delivered. In the presence of the red light, a fixed-ratio of 30 responses was in effect. While in the presence of a white light, a 10 min. fixed-interval schedule was operative. A second group of monkeys responded under a multiple fixed-ratio fixed-interval schedule of termination of stimuli correlated with occasional electric shocks. Again, in the presence of the horizontal lines, responding had no consequences and shocks were never delivered. In the presence of the red light, shocks were scheduled to occur every 30 seconds; the 30th response terminated the red light and produced the pattern of horizontal lines. In the presence of the white light, shocks were scheduled to occur at 1 sec. intervals after 10 minutes; the first response after 10 minutes terminated the white light and produced the pattern of horizontal lines.

These two multiple schedules maintained similar patterns of responding, even though the performances were maintained by different reinforcers. The fixed-ratio component of each multiple schedule yielded performances that were characterized by sustained high rates of

responding (approximately 2.3 resp./sec.) while performance under the fixed-interval component of each multiple schedule was characterized by a pause (no responding) followed by acceleration of responding to a steady rate; the average rate in the interval was about 0.6 responses per second. The effects of d-amphetamine were to increase response rates under the two fixed-interval schedules, except at the highest dose level (1.0 mg), but decreased rates of responding under both fixed-ratio schedules. Findings such as these lend support to the view that a major determinant of a drug effect is the ongoing behavior of the subject. These results strongly support also the conclusion that the behavioral effects of drugs are largely independent of the type of reinforcer maintaining the behavior. Such studies show clearly that any dependence of drug effects upon type of reinforcer is relatively small compared to the critical dependence of drug effects upon schedules of reinforcement.

Results which have been presented so far indicate that the interpretation suggested by Dews (1958b) applies to different rates of responding maintained under a number of different conditions. Recent findings suggest that the net effect of amphetamines on overall rates of responding under specific schedules can be analyzed in terms of the effects on rates of responding in different

temporal periods of the schedule.

As was previously mentioned, responding under a fixed-interval schedule is characterized by increased responding during the interval, following the initial pause. In a study of the effects of drugs on the behavior of the pigeon under a multiple fixed-ratio fixed-interval schedule of food reinforcement, Smith (1964) compared the effects of d-amphetamine (0.01 to 10 mg/kg) on behavior during the first and last minute of the 5 minute fixed-interval component. The results showed that d-amphetamine greatly increased the low rates of responding typical of the first minute while decreasing the high rates of responding characteristic of the last minute. The maximal increase in average rates of responding was produced by 3 mg/kg dosages; this same dose significantly increased the rate of responding in the first minute and lowered the rate in the fifth minute. The dose of 10 mg/kg, which decreased average rates of responding, produced a greater increase in rates in the first minute than did 3 mg/kg, but also produced a more marked decrease in rates during the last minute. Hence, the change in average rate of responding with d-amphetamine was the net result of its rate-increasing and decreasing effects.

It appears that there is a graded relation between the increase in low rates of responding and the

decrease in high rates of responding after amphetamine administration. That the change in rate of responding after an appropriate dose of amphetamine is related to the pre-drug rate of responding is confirmed by the available evidence (see Kelleher & Morse, 1968).

It is interesting to note that drugs generally classified with amphetamine as stimulants, exert a similar effect. It was demonstrated by Stretch and Skinner (1967) that the administration of methylphenidate to rats in which performance was maintained by a free-operant avoidance schedule, was followed by an increased response rate. Another finding was that when a warning signal was introduced which preceded shock delivery, the administration of methylphenidate was followed by an increase in the occurrence of short response latencies after signal onset.

What then are the effects of drug administration on performance where a discriminative stimulus is programmed to occur? A study by Weiss and Laties (1966) demonstrated that the effects of d-amphetamine on behavior maintained by an FI schedule were markedly offset when a stimulus known as an added clock[1] was introduced into the

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[1]An added clock is defined by Ferster and Skinner (1957) as follows: "A stimulus, some dimension of which varies systematically with time, usually measured from the preceding reinforcement, but possibly from some other point."

program. They were attempting to verify the suggestion by Dews (1955, 1958a,b) and Morse and Herrnstein (1956) that behavior controlled by internal stimuli may be more sensitive to modification by drugs than behavior controlled by exteroceptive stimuli. The experimental specifications were as follows: The length of the interval was 300 sec. and the clock when present, consisted of 5 different visual symbols projected on the response key in an invariant order. Each symbol represented a 1 min. period within the interval. Under control conditions the subjects tended to place their responses in the last minute of the interval when the clock was present, and this tendency persisted following the injection of d-amphetamine sulphate. However, when the clock was absent, an administration of amphetamine was followed by an overall increase in response rate in the earlier part of the interval, which is in accord with Dews' (1956) findings.

The preceding review of the behavioral effects of the amphetamines suggests the following conclusions:

1. The effects of amphetamine are determined to a considerable extent by the rate and patterning of ongoing behavior; available evidence shows that the administration of amphetamine within a specified range of dosages is followed by an enhancement of relatively low response rates and a decrement in relatively high rates

of responding irrespective of the reinforcer that maintains responding.

2. The greater the degree of control of ongoing behavior exerted by schedule parameters, the smaller the magnitude of behavioral changes that follow the administration of amphetamine.

3. When performance is controlled effectively by exteroceptive stimuli, the behavioral effects of amphetamine are attenuated (Weiss & Laties, 1966).

Specific Aims

The specific aims of the present investigation were two-fold. Dews (1962) has demonstrated that a fixed-interval schedule maintained by food presentation survives repeated interruption by S^{Δ} periods. More recent studies have shown that typical FI patterns of responding are generated by the fixed-interval presentation of electric shock. The present study was concerned with the question of whether FI performance maintained by electric shock presentation would survive repeated interruption by S^{Δ} periods. Results comparable to those of Dews (1962) would further substantiate the general similarity of FI performances maintained either by the scheduled presentation of food or by electric shock as the reinforcing stimulus,

respectively.

Second, the present study was concerned with the modifications of FI performance following administration of d-amphetamine sulphate. Results of a study by Kelleher and Morse (1964) showed the effects of amphetamine upon behavior to be independent of the reinforcer maintaining the behavior. Low doses of amphetamine were found to increase responding while high doses had a suppressive effect despite differences in the reinforcing stimulus (i.e., food reinforcement versus shock-escape). Similar results, when the reinforcing stimulus is shock presentation, would support the working hypothesis that the behavioral effects of drugs are largely independent of the type of reinforcer used to maintain behavior.

METHOD

Subjects

Four adult male squirrel monkeys (*Saimiri sciureus*) designated O1, R5, R6, and R7, respectively, were used as subjects. Each animal was caged individually in a temperature-controlled colony room and was permitted unrestricted access to food (Purina New World Monkey Chow #25) and water except during each experimental session. At the start of the experiment the subjects' weights were 730g., 760g., 890g., and 790g. respectively. The subjects had acquired no previous experimental histories prior to the present work.

Apparatus

The experimental chamber was a Lehigh Valley Electronics small primate restraining chair (Model LVE 1619) situated within a ventilated, sound-attenuating cubicle. Electric shocks were delivered through two brass plates that rested on a shaved section of the monkey's tail; electrode paste (EKG Sol) ensured a

low-resistance electrical contact between the electrodes and tail. The operandum was a Lehigh Valley Electronics (Model LVE 1352) rat lever mounted on the front wall of the chamber, situated 4 1/8 in. above waist level and 3 3/8 in. from either side. Lever dimensions were 1 in. by 1 1/8 in. by 3/8 in. A small stimulus light was mounted behind a transparent Plexiglas wall in front of the monkey. In addition, the chamber was fitted with four Chicago Miniature No. 304 28V dc houselights, and a 4 ohm speaker mounted within the cubicle, delivered "white noise" at an intensity of 75 db s.p.l. as measured by a Dawe Type 1400F sound level meter. The shock source was 117 volts a-c at 60 Hz; the current delivered to the electrodes through series resistors was 10 ma. for 500 msec. The experimental conditions were controlled automatically by a system of relays, stepping switches, and timers located in an adjoining room. Data were recorded by Sodeco digital counters and a Gerbrands cumulative-response recorder.

Procedure

The study consisted of four consecutive phases.

Phase 1. Free-operant shock avoidance training

During this period, experimental sessions were of 144 min. duration with approximately 21 hr. elapsing between consecutive sessions for each subject.

Each monkey was trained to respond by reinforcing successive approximations to the lever press. Reinforcement consisted of interrupting, for 20 seconds, brief inescapable shocks which otherwise occurred every 10 seconds. After subjects had acquired the response, each monkey was transferred to a free-operant avoidance schedule of the Sidman type (Sidman, 1953) which was programmed for the next 35 consecutive sessions. According to the parameters of the schedule, a 10 ma. shock of 500 msec. duration was presented at regular 10 second intervals (the shock-shock interval), if a response did not occur. If the subject pressed the lever, however, the next shock was delayed for 20 seconds (the response-shock interval). Each response that was made reset the response-shock interval, thus permitting the subject to avoid shock presentation indefinitely. Shock presentation was not averted by prolonged depression of the lever. It should also be noted that no exteroceptive stimulus preceded an impending shock. Each shock that occurred was of 500 msec. duration, and could not be terminated by a response. The subject postponed shock

presentation each time it pressed the lever. During the experimental sessions of this phase, a white light above the lever, and the houselight were illuminated in the test chamber, and white noise was present continuously, throughout each session.

Phase 2. Responding maintained by a fixed-interval schedule of electric shock presentation

The second part of the experiment began after the last session of avoidance training. The avoidance schedule was replaced by a fixed-interval schedule (FI) of electric-shock presentation. According to this new contingency, the first response to occur after 300 seconds had elapsed, timed from the preceding shock, produced a 10 ma. shock for a duration of 500 msec. If the animal did not emit a response within 5 seconds,[1] after the end of the fixed-interval, a shock of identical intensity was presented independently of behavior, and the next interval began. Immediately following the delivery of shock, the scheduling contingency began a 60 sec. time-out (TO)

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[1]This aspect of the procedure can be referred to as a limited-hold. In a fixed-interval schedule of food reinforcement with limited-hold, the reinforcement is only available for a limited period, timed from the end of the interval. In the FI schedule of electric-shock presentation shock is withheld for a limited period and unless a response occurs to produce a shock, the shock is delivered at the end of this period, independently of behavior. Any shock which is response contingent will be referred to as a produced shock.

period during which the houselights and masking noise were extinguished and a green cue light was presented on the Plexiglas display panel in front of the subject. During this time-out period responses had no programmed consequences. A daily session was composed of 20 consecutive fixed-interval cycles, with each cycle beginning immediately after the termination of the previous time-out period. All animals received 40 consecutive sessions under these conditions. Following stabilization of responding, the schedule of electric-shock presentation was changed from FI 300" TO 60" to FI 600" TO 120". Under the changed parameters, the session ended after 10 cycles of the FI 600 sec. TO 120 sec. schedule but, in all other respects, conditions remained unchanged. Each monkey was exposed to this contingency for 30 consecutive sessions.

Phase 3. Effects of an S^{Δ} probe upon a fixed-interval schedule of electric-shock presentation

Monkeys R5, R6, and R7 served as subjects for the main experiment; monkey O1 was not exposed to the S^{Δ} probe contingency, in order that the effects of drugs (Phase 4) could be assessed upon behavior engendered by a fixed-interval schedule of shock presentation, without multiple S^{Δ} interpolation.

For phase 3 of the experiment (monkeys R5, R6, and R7), the houselight (HL) and noise (N) were present only during alternate 60-sec. periods through the interval; specifically, the HL and N periods were 2,4,6,8, and 10. At the end of the 10th period, which coincided with the end of the FI, these stimuli remained until a shock occurred; thus, the presence of HL and N during even-numbered segments of the interval constituted S^D periods. Since a response made in the absence of the HL and N was never followed or associated with shock, periods 1,3,5,7, and 9 of each interval may be referred to as S^Δ periods each consisting of a 60 sec. interruption of the stimulus conditions subsequently present at the time of shock-presentation and during the other S^D periods comprising the interval. Monkeys R5, R6, and R7 were exposed to this procedure for 30 consecutive sessions, comprising phase 3, and for the remainder of the experiment.

Phase 4. Assessment of the effects of d-Amphetamine sulfate upon fixed-interval performance

During phase 4, modifications of performance following administration of d-Amphetamine sulfate were observed at several dosages. Determinations of the effects of the drug were carried out in an identical manner for all subjects. Three dosage levels of

d-amphetamine were evaluated, and are stated below in terms of milligrams of the drug per kilogram of body weight of the subject.

d-Amphetamine

0.10 mg/kg

0.30 mg/kg

1.00 mg/kg

Four determinations of each dose of d-amphetamine were made for each subject. The effects of the drug upon behavior maintained by the fixed-interval schedule of electric-shock presentation with (subjects R5, R6, & R7) and without (subject O1) repeated S^{Δ} probe were assessed. Two types of control sessions were interspersed between individual drug sessions. Control sessions consisted of either no injection or an injection of isotonic (0.9%) saline. The second procedure permitted evaluation of any behavioral effects resulting from the injection procedure itself that may have obscured the drug effect. Intramuscular injections were given 10 minutes prior to the start of each experimental session. Volume of all injections was kept as constant as possible, within the limits 0.25 to 0.35 cc.

Behavioral Measurements

During succeeding phases of the experiment, the

following measures were obtained:

Phase 1. The rate of avoidance responding per second and average number of shocks received per hour for each session.

Phase 2. The average rate of responding per second throughout the FI and the percentage of shocks which were produced by the subject.

Phase 3 and 4. The average rate of responding per second for the complete session and the average rates in S^D and S^Δ periods respectively. The percentage of produced shocks was also recorded.

RESULTS

The material in this section is presented in terms of the results obtained from each of the phases of the experiment as described in the Method section. The order of presentation of these phases also adheres to that adopted in the Method section.

Phases 1,2. Free-operant shock avoidance training; Maintenance of responding by a fixed-interval schedule of electric-shock presentation

Because the first two phases of the experiment constituted periods in which behavioral baselines were established and no experimental manipulations were conducted, the data for these periods will be presented together.

Table 1 presents the number of sessions, response rate per second and the number of shocks received per hour for all subjects under the free-operant avoidance procedure.

TABLE 1

Subject	No. of Sessions	Response/Sec.	Shocks/Hr.
R-5	35	0.26	2.15
R-6	35	0.32	1.72
R-7	35	0.20	3.65
O-1	35	1.13	0.70

The overall response rate per second and the number of shocks per hour are based on the data obtained from the last 10 sessions under the shock avoidance procedure.

The results from both sections of the second phase are presented in Table 2. Shown are the number of sessions, response rate per second, and the percentage of shocks which were produced[1] by each subject, under the FI 300 sec. TO 60 sec. and FI 600 sec. TO 120 sec. schedules, respectively.

TABLE 2

Subject	Schedule	No. of Sessions	Response/Sec.	% Produced Shocks
R-5	FI 300" TO 60 "	40	0.15	89%
	FI 600" TO 120"	30	0.23	100%
R-6	FI 300" TO 60 "	40	0.26	98%
	FI 600" TO 120"	30	0.17	95%
R-7	FI 300" TO 60 "	40	0.19	98%
	FI 600" TO 120"	30	0.21	93%
O-1	FI 300" TO 60 "	40	0.74	89%
	FI 600" TO 120"	30	0.65	79%

The overall response rates per second and the percentage of

[1]Produced shocks: (See footnote number 1, page 36, Method section).

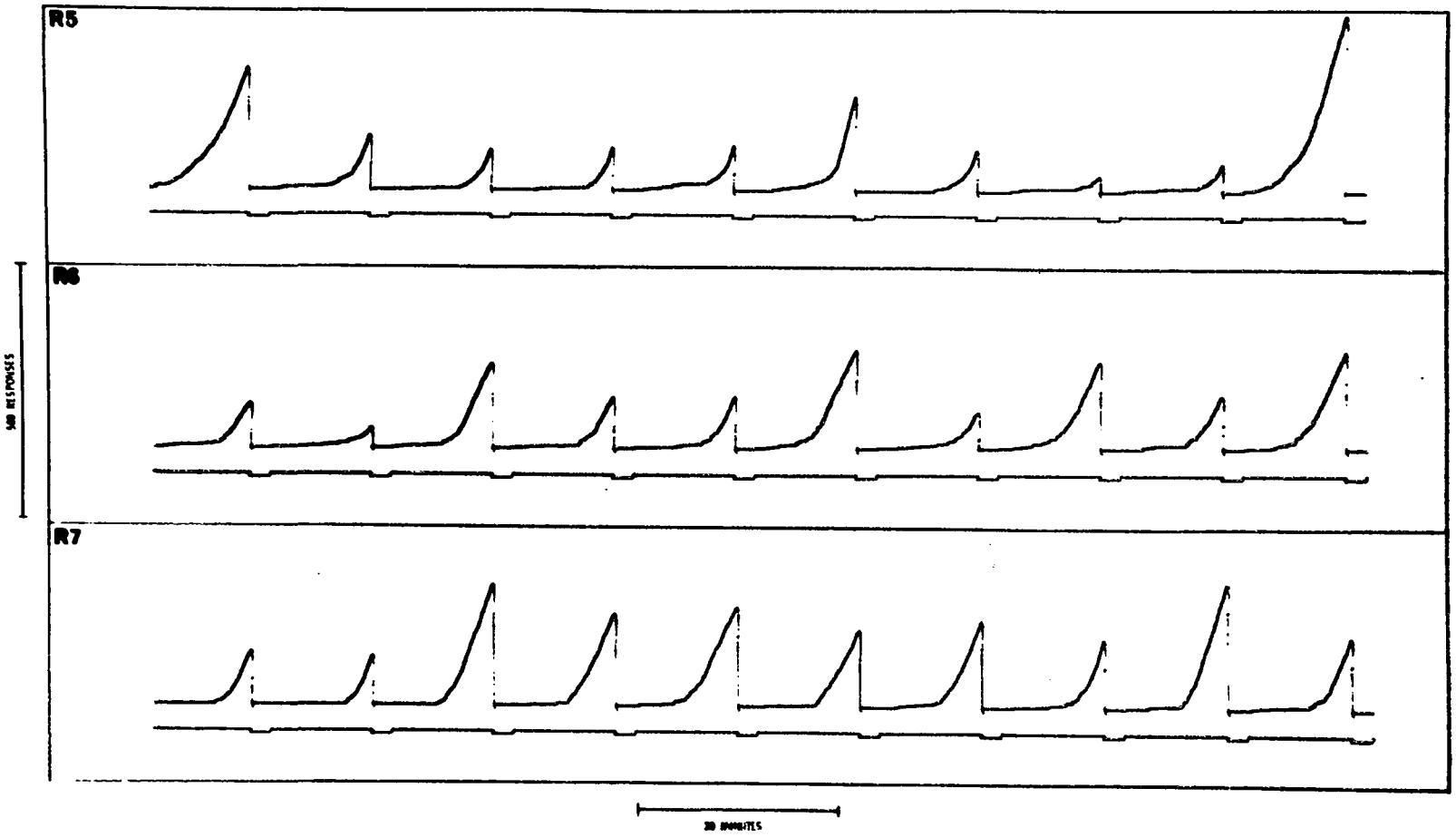
shocks produced in Table 2 are based on the data obtained from the last 10 sessions under each of the FI procedures.

That performances under the fixed-interval schedule of shock presentation were relatively stable is supported by the segments of cumulative-response records for each subject, shown in Figure 1. The upper record was obtained from subject R-5 during the 66th session of this phase. The response rate per second for the complete session was 0.21 and 100 percent of the shocks that occurred were produced by the subject during this session. The center record was obtained from subject R-6 during the 68th session of fixed-interval shock presentation. The overall response rate was 0.18 per second with 100 percent of the shocks being produced by the subject. The third trace is a record of the performance of monkey R-7 during the 70th session of this phase. For this subject the response rate was 0.27 responses per second with 100 percent of the shocks being produced by the animal. The control session for O-1 is shown in Figure 9. This figure graphically presents performance of monkey O-1 during the 33rd session of this phase. The response rate for O-1 was 0.64 responses per second with 80 percent of the shocks being produced by the subject.

Each animal produced cumulative-response records

which are consistent with fixed-interval performance. Typically, the response rates of each monkey were very low immediately after a time-out and then gradually increased until the next shock was presented, giving rise to the customary 'scalloped' patterning of responses observed under FI reinforcement.

Fig. 1. Selected cumulative response records showing stable performance under the FI 600 sec. TO 120 sec. schedule of electric shock presentation. The cumulative response pen was reset at the end of each FI; deflection of the event pen indicates a time-out (TO) period; responses during TO do not appear on the cumulative response record.


R5
R6
R7

Phase 3. Effects of an S^{Δ} probe upon behavior controlled by a fixed-interval schedule of electric shock presentation

Table 3 summarizes data obtained from each monkey under phase 3 of the experiment.

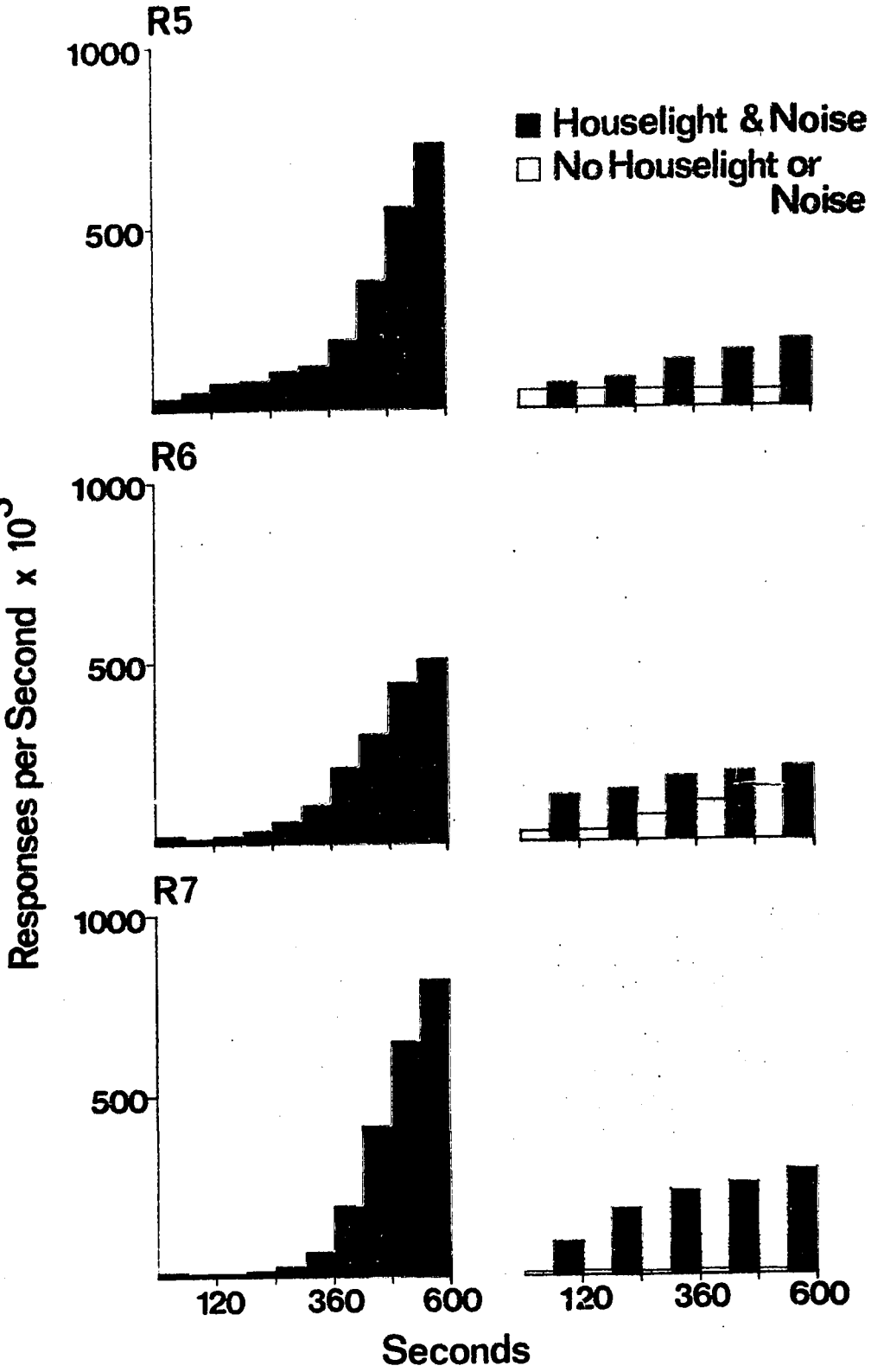
Table 3

Subject	Schedule	No. of Sessions	Responses/Sec.	% Produced Shocks
R-5	FI 600 sec. TO 120 sec. with S^{Δ} probe	30	0.08 (S^{D}, 0.12) (S^{Δ}, 0.04)	93%
R-6	FI 600 sec. TO 120 sec. with S^{Δ} probe	30	0.12 (S^{D}, 0.17) (S^{Δ}, 0.07)	95%
R-7	FI 600 sec. TO 120 sec. with S^{Δ} probe	30	0.11 (S^{D}, 0.21) (S^{Δ}, 0.01)	79%

Overall response rates per second and percentages of response-produced shocks are based on data obtained from the last 10 sessions under the multiple S^{Δ} probe procedure. The respective response rates during S^{D} and S^{Δ} periods of phase 3 are given in parentheses.

Figure 2 plots the rates of responding in successive 60-sec. segments during the last 10 FI control sessions (phase 2) and the last 10 sessions with S^{Δ} interruption (phase 3). Since there were 10 intervals per session, each bar is the average of 100 periods of 60 sec. It is evident that responding is suppressed in the

Fig. 2. Rates of responding in successive 60-sec. segments of the FI 600 sec. TO 120 sec. schedule of electric-shock presentation. The bar graphs to the left refer to the performance of each monkey, as labelled, for the last 10 control sessions of phase 2; those on the right show the effects of multiple S^{Δ} periods superimposed for alternate 60-sec. segments of the FI 600 sec. TO 120 sec. schedule (phase 3). Note the increased responding in successive S^{D} periods as the FI elapses, despite the suppressive effect of S^{Δ} periods through the interval.


R5
1000
500
Houselight & Noise
No Houselight or Noise
R6
1000
500
R7
1000
500
Responses per Second x 10^3
120
360
600
120
360
600
Seconds

S^{Δ} periods; individual differences between monkeys are apparent in the extent to which S^{Δ} periods reduced responding at different points along the interval. However, a progressive increase in rate of responding during successive S^{D} periods is evident for each animal.

The overall rates of responding per session were reduced considerably following the interpolation of S^{Δ} periods in phase 3 as compared with the overall rates during phase 2 (compare Tables 2 & 3). However, responding during S^{D}, as compared with S^{Δ} periods, shows a clear differentiation; these data appear in parentheses in Table 3.

Figures 3, 5, and 7 present the performance of each subject graphically following introduction of multiple S^{Δ} periods (phase 3). In all cases, rates of responding are considerably lower in the S^{Δ} than S^{D} periods comprising the interval. S^{Δ} periods clearly interrupt the progressive responding of each subject through the interval, as compared with control performances (Fig. 1). Nevertheless, the rate of responding increases in successive S^{D} segments as the interval elapses, indicating that the overall 'scalloped' pattern of responding, maintained by the schedule, survives repeated interruption.

All subjects show reductions in the overall

rates of responding per session following interpolation of S^{Δ} periods in phase 3. However, inspection of the representative cumulative records (Figs, 3, 5, 7) shows that a clear discrimination became established between S^{D} and S^{Δ} periods. The data presented in Table 2 (see parentheses) further indicates that the reduced rate is due to a decrease in responding during S^{Δ} periods, together with the development of 'sub-scalloping' in S^{D} periods. Inspection of S^{D} segments of Figs. 3, 5, and 7 often reveals a pause in responding after the onset of an S^{D} period, followed by a gradually-increasing rate which is then interrupted by the onset of the next S^{Δ} period or the occurrence of a shock at the end of the FI; this effect is more clearly seen toward the end than during earlier S^{D} segments of the interval.

Phase 4. Assessment of the effects of d-amphetamine sulphate

The previous review of work in behavioral pharmacology has indicated that drug-induced modifications in performance are most evident in the individual subject. The first portion of this section will report the effects of d-amphetamine sulphate upon performance of each individual subject; the last portion will be concerned with a presentation of overall trends.

The effects of d-amphetamine sulphate on the

performance of each subject, at each of the three dosage levels in terms of the four behavioral measures used, are summarized in Table 4. Values presented in this table are averages obtained from 17 control (saline) sessions interspersed during the series of drug administrations, and the four determinations of each dosage level per subject.

Monkey R-5

Even with a low control rate of responding (0.04 resp/sec) a good discrimination between S^D and S^Δ periods was present. Overall rate of responding in S^D periods was 0.06 responses per second while the rate in S^Δ periods was 0.02 responses per second. Inspection of cumulative records (Fig. 3) and graphical representation of control performance for this subject further substantiates this point. It is evident that the overall response rate increases as the interval elapses; the response rate in the S^Δ segments, however, remains relatively constant throughout.

In this subject, the effects of d-amphetamine at various dose levels appear to be quite constant. Similar overall increases in response rate per second are obtained with all doses. None of the doses employed produced any rate-decreasing effect in this subject. It can also be seen that the rate-increasing effects of

The effects of each dosage level of d-Amphetamine sulphate on the overall performance of all subjects under an FI schedule of shock-presentation

	R-5					R-6					R-7					O-1*			
	Measure					Measure					Measure					Measure			
Dose level in mg/kg	1°	2°	3°	4°	Dose level in mg/kg	1°	2°	3°	4°	Dose level in mg/kg	1°	2°	3°	4°	Dose level in mg/kg	1°	2°	3°	4°
Control	.04	.06	.02	61%	Control	.23	.26	.21	96%	Control	.07	.14	.00	93%	Control	.39	-	-	64%
0.1	.08	.13	.03	53%	0.1	.46	.51	.42	100%	0.1	.13	.24	.01	93%	0.1	.68	-	-	78%
0.3	.07	.12	.02	62%	0.3	.51	.66	.39	95%	0.3	.28	.57	.01	97%	0.3	.33	-	-	50%
1.0	.07	.12	.01	55%	1.0	.19	.25	.15	52%	1.0	.07	.14	.00	45%	1.0	.12	-	-	25%

* O-1 was tested on a non-probed FI 600".

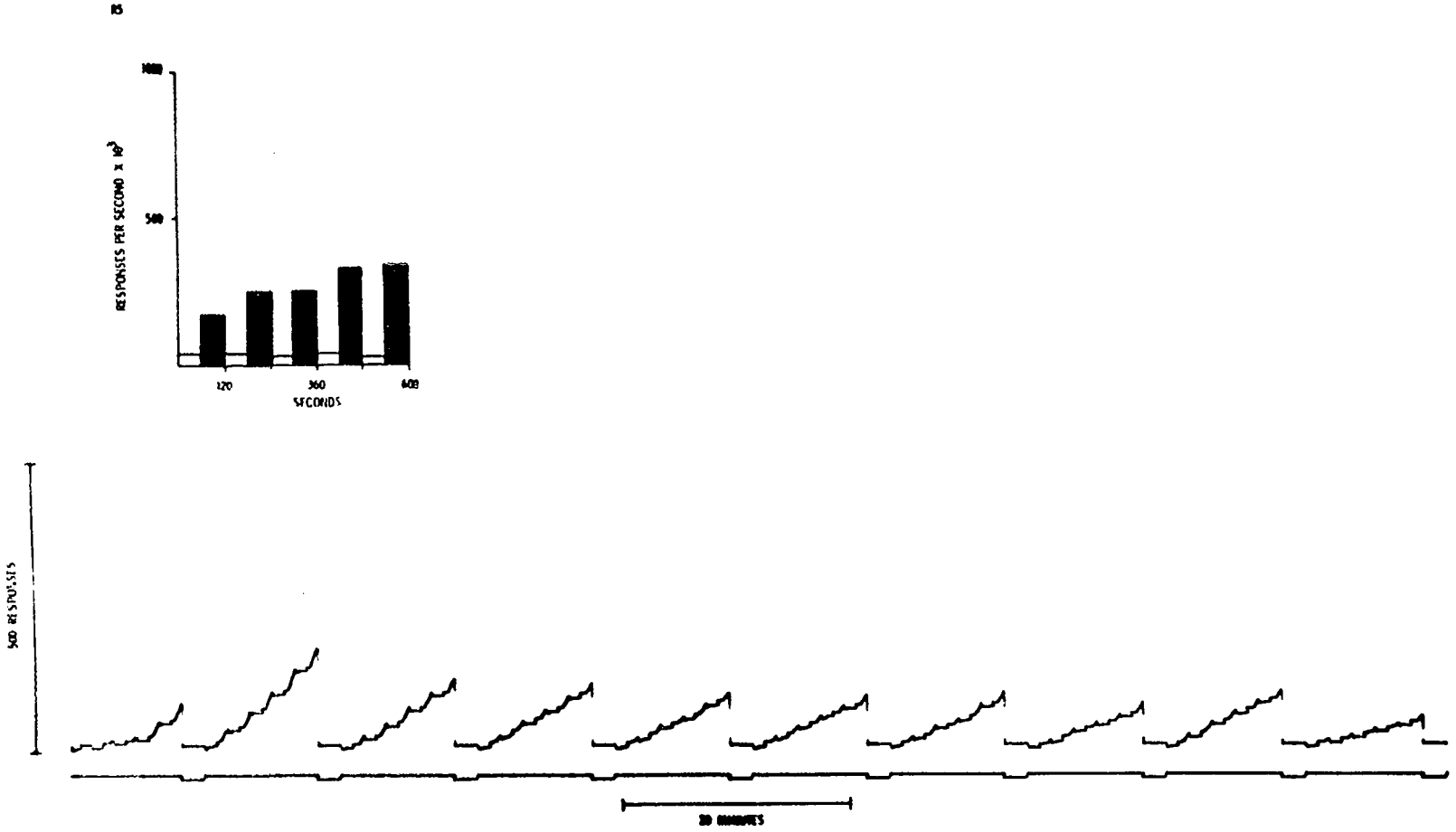
1° Overall response rate per second for each session.

2° Overall response rate per second for S^D periods.

3° Overall response rate per second for S^Δ periods.

4° Percentage of shocks produced by each subject.

Fig. 3. The histogram plots rates of responding for monkey R-5 during a complete session of successive 60-sec. segments of the FI 600 sec. TO 120 sec. schedule of electric shock presentation. Columns in black represent S^D periods (HL & N present); columns in white denote S^Δ periods (HL & N absent). The cumulative response record appearing in the lower portion of the figure is a presentation of a control performance under the specified schedule. The cumulative response pen was reset by presentation of shock at the end of each FI; deflection of the event pen beneath the cumulative-response record indicates a TO period; responses during TO do not appear on the cumulative-response record. The cumulative response pen is displaced in a downward direction to indicate each S^Δ period. The overall response rate per second for this complete session was 0.15.


RESPONSES PER SECOND x 10³
500
120
360
SECONDS
500 RESPONSES
20 MINUTES

d-amphetamine are selective since responding in S^{Δ} periods is unaffected by drug administration. Figure 4 shows the effects of a 0.3 mg/kg injection of d-amphetamine sulphate. This graphical presentation shows that responding in S^{Δ} periods is not affected by drug treatment, whereas responding in S^{D} segments shows a reduction in response rates during the terminal segment of the interval while a constant rate of responding is evident for the preceding S^{D} components. The gradual increase in response rate is no longer evident; instead, a constant rate of responding in all S^{D} periods can now be observed.

Monkey R-6

Results obtained from subject R-6 over the same four measures differed in some respects from those of R-5. The overall rate of responding under control conditions was higher than the rate of R-5 (0.23 resp/sec vs. 0.04 resp/sec). There is also a difference in the distribution of responding between S^{D} and S^{Δ} periods. Whereas R-5 showed little responding in S^{Δ} segments (0.02 resp/sec), R-6 shows a greater tendency (0.21 resp/sec) to respond during these components of the fixed-interval (see Fig. 5), however, the rate of responding in the S^{Δ} segments is consistently lower than in the corresponding S^{D} periods.

Fig. 4. The histogram plots rates of responding for subject R-5 during a complete session of successive 60-sec. segments of the FI 600 sec. TO 120 sec. schedule of electric shock presentation. Columns in black represent S^D periods (HL & N present); while columns in white denote S^Δ periods (HL & N absent). The cumulative response record appearing in the lower portion of the figure is a presentation of performance following a 0.3 mg/kg injection of d-amphetamine. The cumulative response pen was reset by a presentation of shock at the end of each FI; deflection of the event pen beneath the cumulative response record indicates a TO period; responses during TO do not appear on the cumulative-response record. The cumulative response pen is displaced in a downward direction to indicate each S^Δ period. The overall response rate per second for this complete session was 0.09.

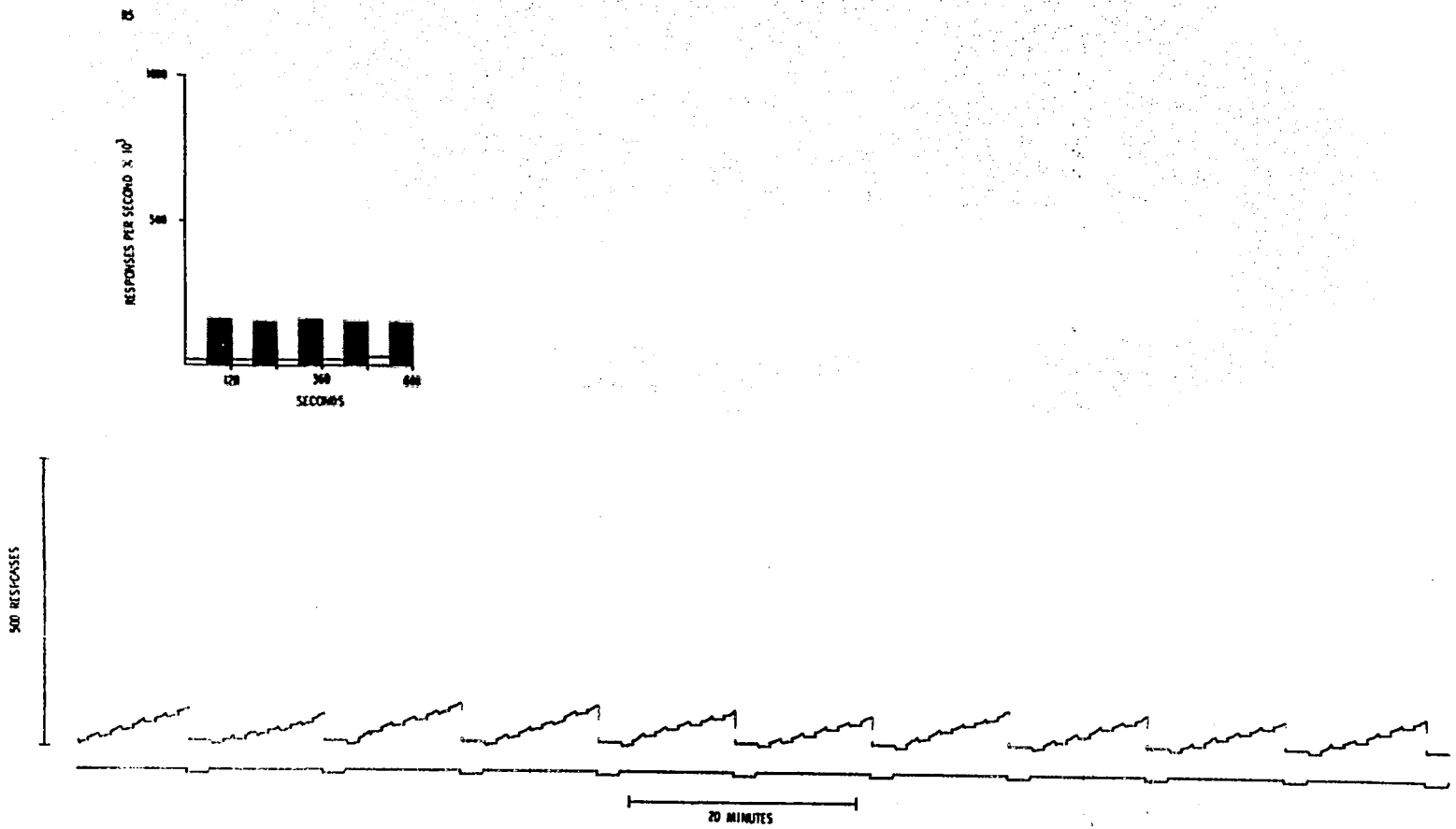
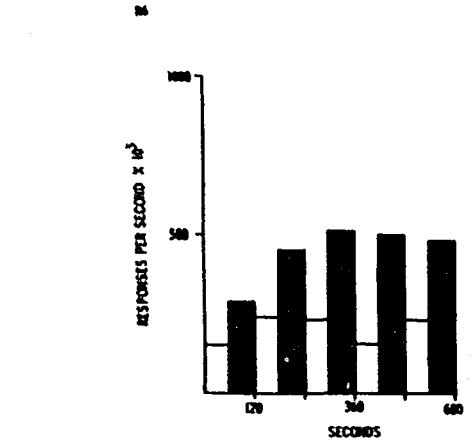
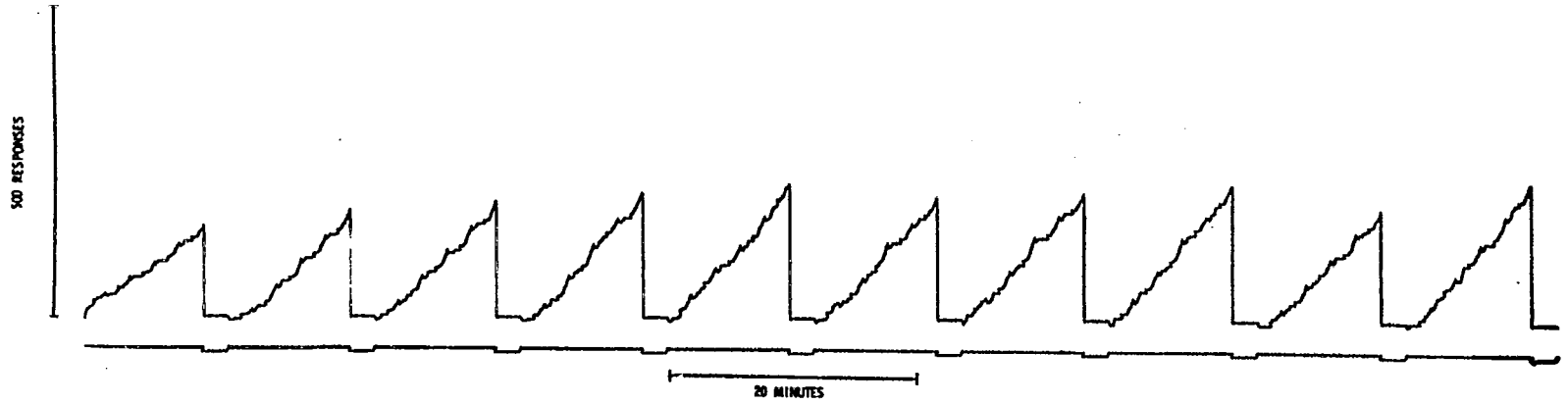

RESPONSES PER SECOND X 10³
SECONDS
500 RESPONSES
20 MINUTES

Fig. 5. The histogram plots rates of responding for monkey R-6 during a complete session of successive 60-sec. segments of the FI 600 sec. TO 120 sec. schedule of electric shock presentation. Columns in black represent S^D periods (HL & N present); while columns in white denote S^Δ periods (HL & N absent). The cumulative-response record appearing in the lower portion of the figure is a presentation of a control performance under the specified schedule. The cumulative response pen was reset by presentation of shock at the end of the FI; deflection of the event pen beneath the cumulative-response record indicates a TO period; responses during TO do not appear on the cumulative-response record. The cumulative response pen is displaced in a downward direction to indicate each S^Δ period. Overall response rate per second for this session was 0.32.


RESPONSES PER SECOND x 10³
1000
500
120
360
600
SECONDS

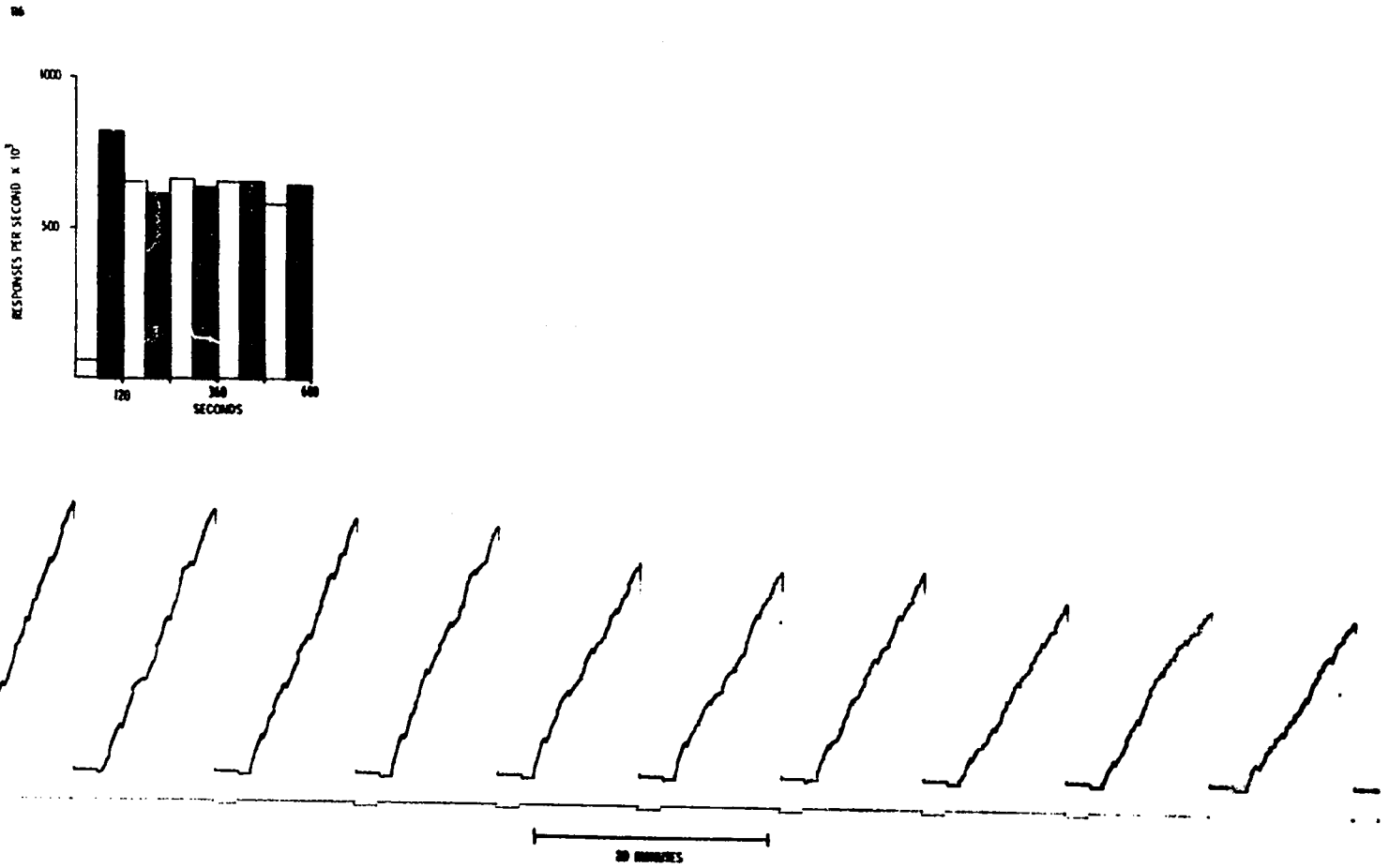

500 RESPONSES
20 MINUTES

Rate increasing effects were found with the administration of 0.1 and 0.3 mg/kg of d-amphetamine, with a trend being for the higher dose to produce higher rates of responding. A dosage of 1.0 mg/kg produced a rate-decreasing effect that yielded rates slightly below the control level. Figure 6 graphically presents the effects of a 0.3 mg/kg dose of d-amphetamine. Again the major rate-increasing effect occurs during the early portions of the FI. The rate-increasing effects of the drug upon low rates of responding is evident in both the overall fixed-interval and during individual S^D-S^Δ periods (compare Figs. 5 & 6). Rates of responding during S^Δ components show a greater rate-increasing effect with drug administration than the response rates in S^D components. The percentage of shocks produced by the subject was not affected differentially by the administration of d-amphetamine, except at a dose of 1.0 mg/kg when a 54 percent reduction was observed.

Monkey R-7

The control performance of R-7 was characterized by a low rate of responding (0.07 resp/sec). The discrimination between S^D and S^Δ periods was so accurate that the overall response rate for S^Δ periods approached zero responses per second. When d-amphetamine was administered no increases were observed in the overall

Fig. 6. The histogram plots rates of responding for monkey R-6 during a complete session of successive 60-sec. segments for the FI 600 sec. TO 120 sec. schedule of electric shock presentation. Columns in black represent S^D periods (HL & N present); while columns in white denote S^Δ periods (HL & N absent). The cumulative response record appearing in the lower portion of the figure is a presentation of performance following a 0.3 mg/kg injection of d-amphetamine sulphate. The cumulative response pen was reset by presentation of shock at the end of the FI; deflection of the event pen beneath the cumulative-response record indicates a TO period; responses during TO do not appear on the cumulative-response record. The cumulative-response pen is displaced in a downward direction to indicate each S^Δ period. Overall response rate per second for this session was 0.58.


1000
500
RESPONSES PER SECOND x 10³
120
360
600
SECONDS
500 RESPONSES

rates of responding for S^{Δ} periods.

However, the overall response rate per second for the fixed-interval was increased under doses of 0.1 mg/kg and 0.3 mg/kg, with the major rate-increasing effects being obtained following the larger of the two doses. Hence, the overall rate-increasing effects are restricted to increased responding during S^{D} periods. A dose of 1.0 mg/kg yields response rates identical to that obtained under control conditions. Once again, the rate-increasing effects of the drug are obtained by increased responding in the early segments of the FI where normally low rates are in evidence (compare histograms in Figs. 7 & 8). Performance under a 0.3 mg/kg dose of d-amphetamine in Figure 8 shows that the effect of the drug is to eliminate the 'scalloped' effect and to produce a more constant rate of responding both overall and within individual S^{D} segments.

No change in the percentage of shocks produced by the subject was observed, except with a 1.0 mg/kg dose when a decrease was apparent.

Monkey O-1

Inspection of the data for O-1 yields somewhat different findings. Administration of d-amphetamine produces suppression of responding at doses greater than 0.1 mg/kg; at 0.1 mg/kg, the drug exerted a substantial

Fig. 7. The histogram plots rates of responding for monkey R-7 during a complete session of successive 60-sec. segments for the FI 600 sec. TO 120 sec. schedule of electric shock presentation. Columns in black represent S^D periods (HL & N present); columns in white denote S^Δ periods (HL & N absent). The cumulative response record appearing in the lower portion of the figure is a presentation of a control performance under the specified schedule. The cumulative response pen was reset by presentation of shock at the end of the FI; deflection of the event pen beneath the cumulative-response record indicates a TO period; responses during TO do not appear on the cumulative response record. The cumulative response pen is displaced in a downward direction to indicate each S^Δ period. Overall response rate per second for this session was 0.21.

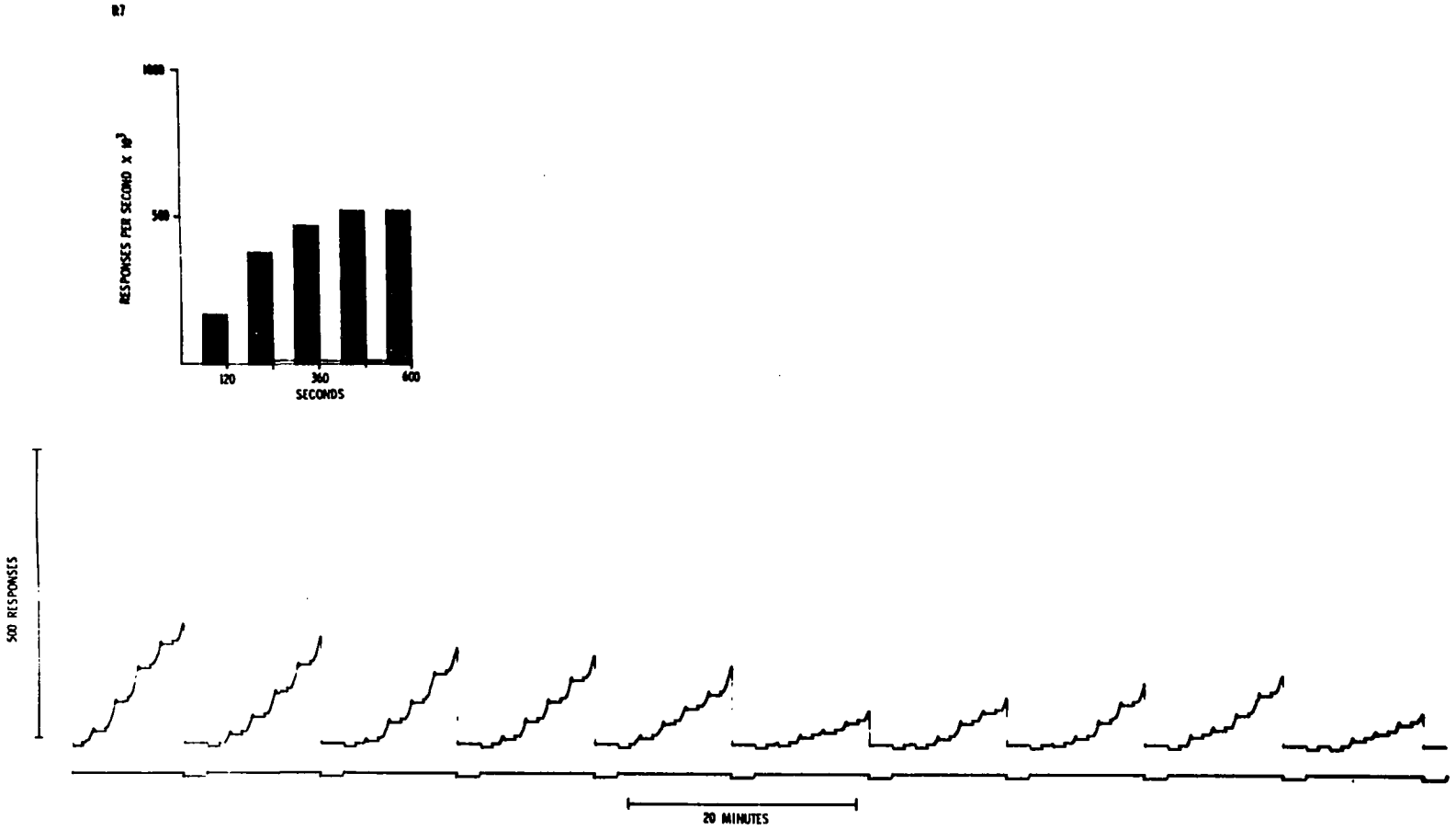
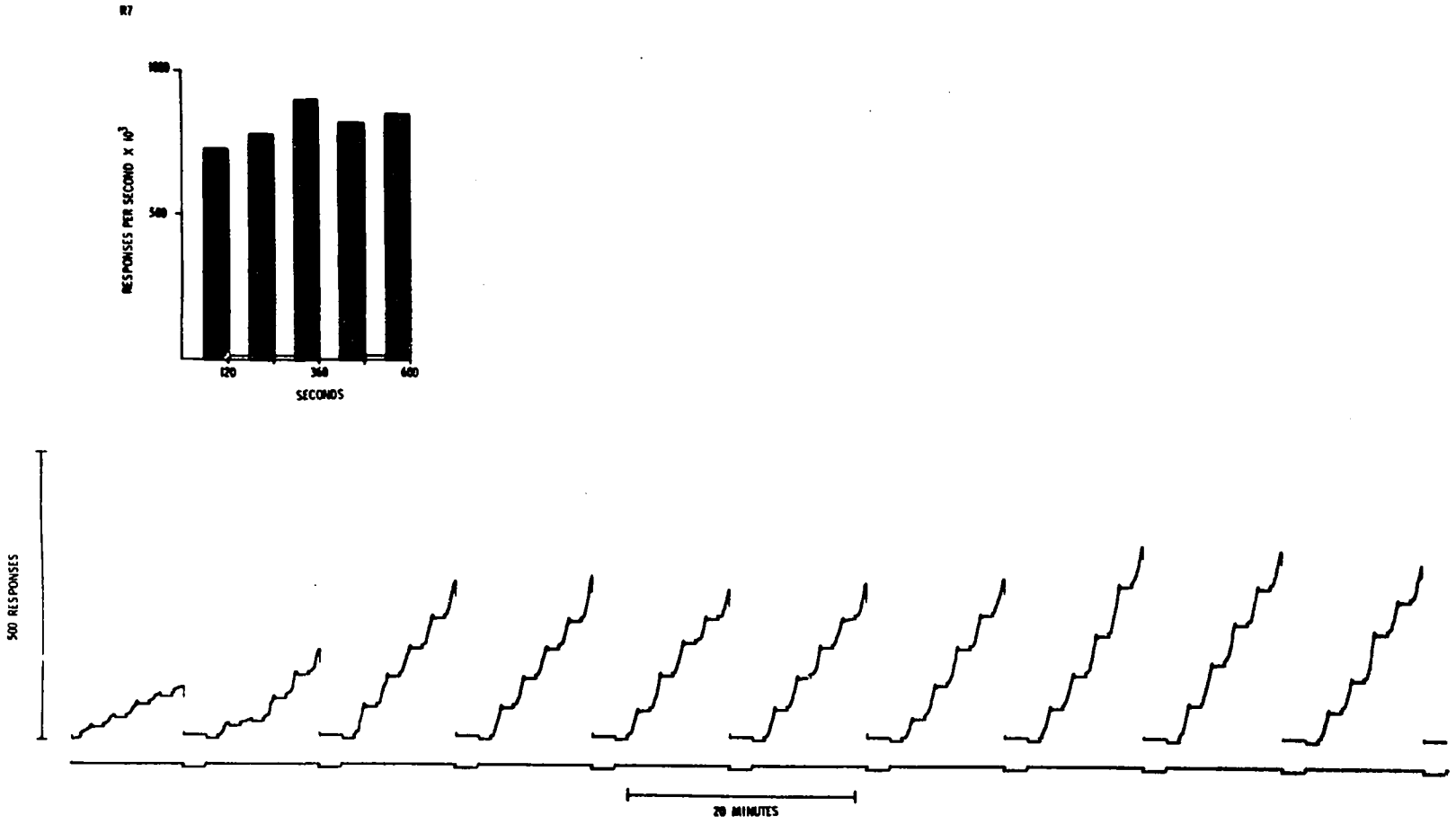

B7
RESPONSES PER SECOND x 10³
120
360
600
SECONDS
500 RESPONSES
20 MINUTES

Fig. 8. The histogram plots rates of responding for monkey R-7 during a complete session of successive 60-sec. segments for the FI 600 sec. TO 120 sec. schedule of electric shock presentation. Columns in black represent S^D periods (HL & N present); columns in white denote S^Δ periods (HL & N absent). The cumulative response record appearing in the lower portion of the figure is a presentation of performance following a 0.3 mg/kg injection of d-amphetamine sulphate. The cumulative response pen was reset by presentation of shock at the end of the FI; deflection of the event pen beneath the cumulative-response record indicates a TO period; responses during TO do not appear on the cumulative response record. The cumulative response pen is displaced in a downward direction to indicate each S^Δ period. Overall response rate per second for this session was 0.40.


R7
1000
500
RESPONSES PER SECOND X 10³
120
360
600
SECONDS
500 RESPONSES
20 MINUTES

rate-increasing effect. A dose of 0.3 mg/kg reduced responding to a level slightly below the control baseline while a dose of 1.0 mg/kg exerted an appreciable suppressive effect.

A comparison of control performance (Fig. 9) and a cumulative record of performance after an injection of 0.1 mg/kg (Fig. 10) indicates that the observed rate-increasing effects obtained with this dose were attributable largely to increases in the low rates of responding within the fixed-interval. It is also evident from the histogram in Figure 10 that with a dose of 0.1 mg/kg, the subject is unable to maintain the high terminal rates of responding which is observed under control conditions (Fig. 9).

Figures 11 and 12 allow for a more detailed examination of the effects of d-amphetamine sulphate on components of ongoing behavior. Figure 11 presents the overall rates of responding in S^D and S^Δ periods for each subject over all drug conditions. In comparing the results, it is apparent that the major rate increasing effects for subjects R-6 and R-7 occurred with a 0.3 mg/kg dose while R-5 shows rate-increases of smaller magnitude at each dosage. Monkey O-1 (simple FI without probe), on the other hand, shows substantial response rate-increases with a 0.1 mg/kg dose. Where response rates are absent, or very low (S^Δ periods for R-5 and R-7), the

Fig. 9. The histogram is a plot of responding for monkey O-1 during a complete session of successive 60-sec. segments of the FI 600 sec. TO 120 sec. non-probed schedule of electric shock presentation. The cumulative response record appearing in the lower portion of the figure is a presentation of a control performance under the specified schedule. The cumulative response pen was reset by the presentation of shock at the end of each FI; deflection of the event pen beneath the cumulative-response record indicates a TO period; responses during TO do not appear on the cumulative-response record. The overall response rate per second for the complete session was 0.64.

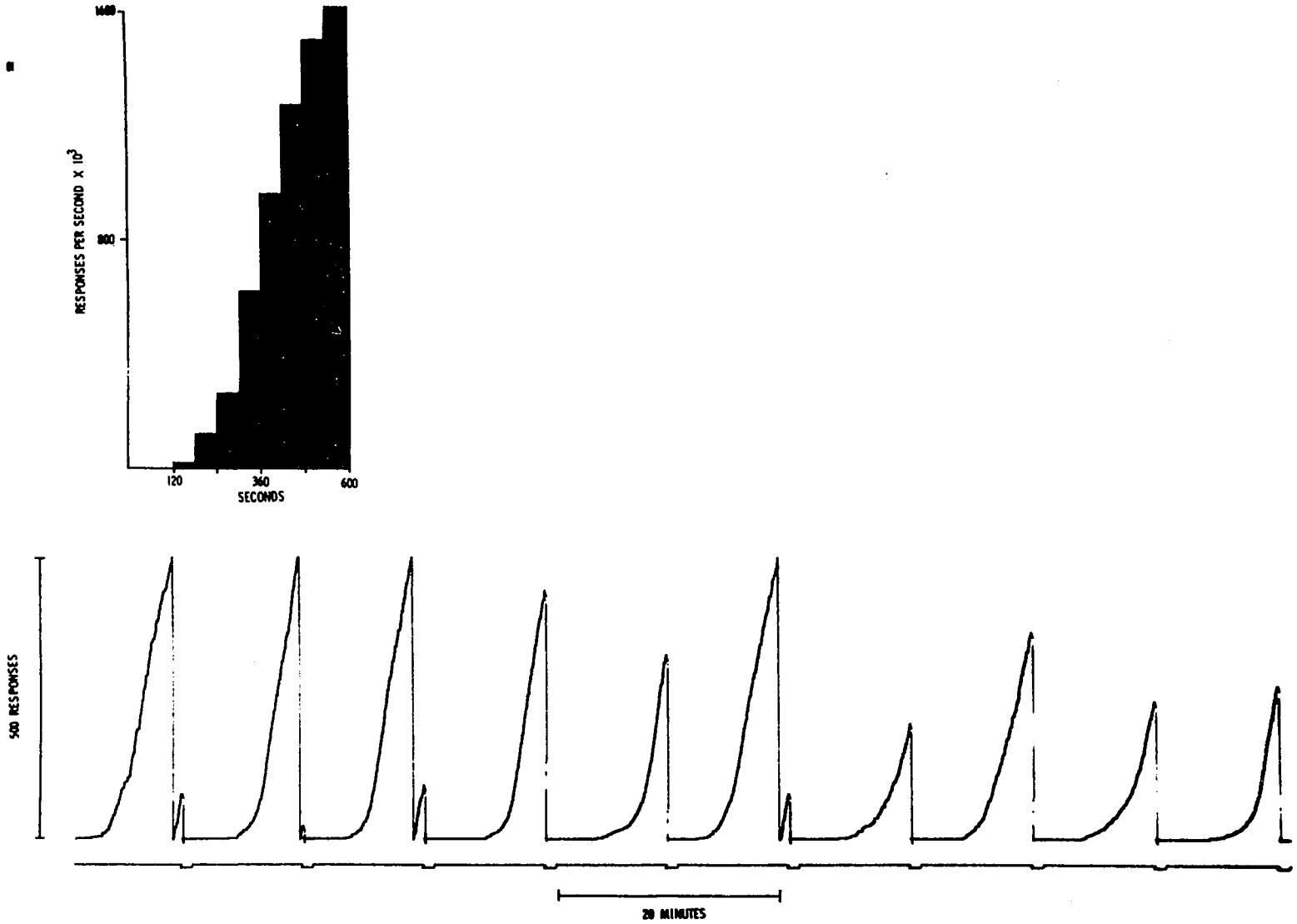
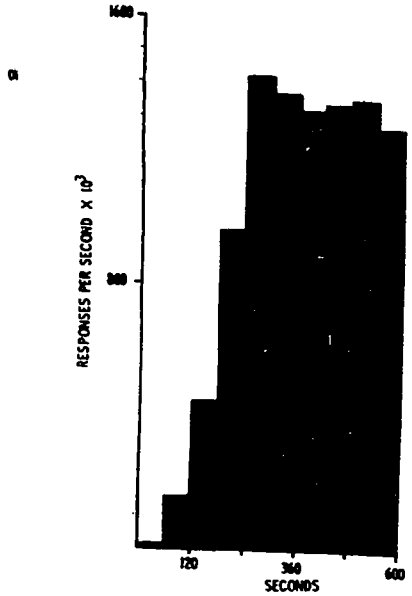

RESPONSES PER SECOND X 10³
800
120
360
600
SECONDS
500 RESPONSES
20 MINUTES

Fig. 10. The histogram is a plot of responding for subject O-1 during a complete session of successive 60-sec. segments of the FI 600 sec. TO 120 sec. non-probed schedule of electric shock presentation. The cumulative response record appearing in the lower portion of the figure is a presentation of performance following administration of a 0.1 mg/kg dose of d-amphetamine sulphate. The cumulative response pen was reset by the presentation of shock at the end of each FI; deflection of the event pen beneath the cumulative-response record indicates a TO period; responses during TO do not appear on the cumulative-response record. The overall response rate per second for the complete session was 0.96.


1600
800
RESPONSES PER SECOND X 10³
120
360
600
SECONDS

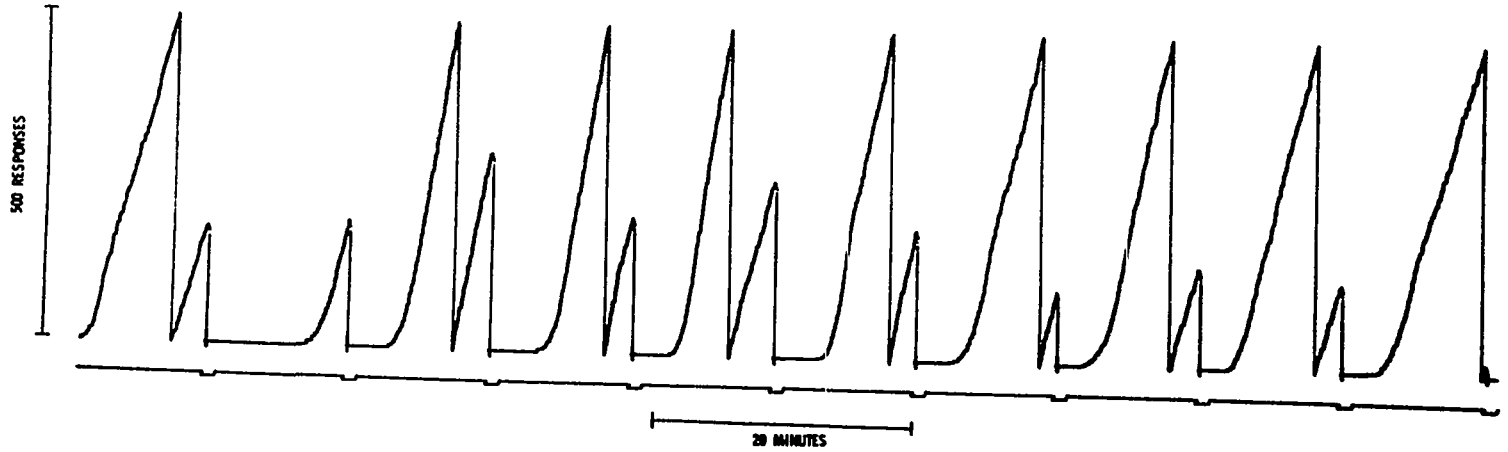

500 RESPONSES
20 MINUTES

Fig. 11. The histogram presents the overall response rate per second for each subject over all conditions. Columns in black represent S^D periods (HL & N present); columns in white denote S^Δ periods (HL & N absent). Vertical lines denote the range in each case.

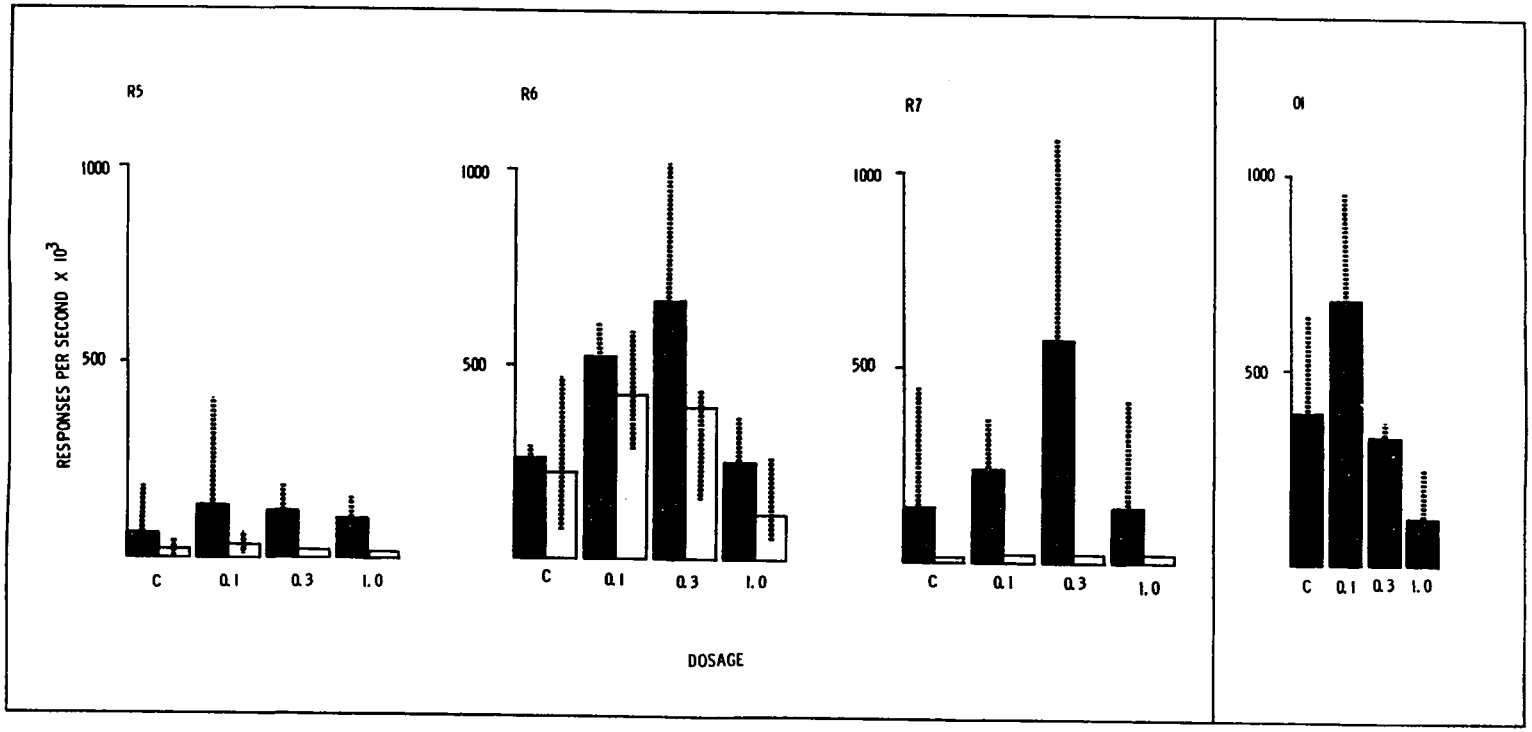
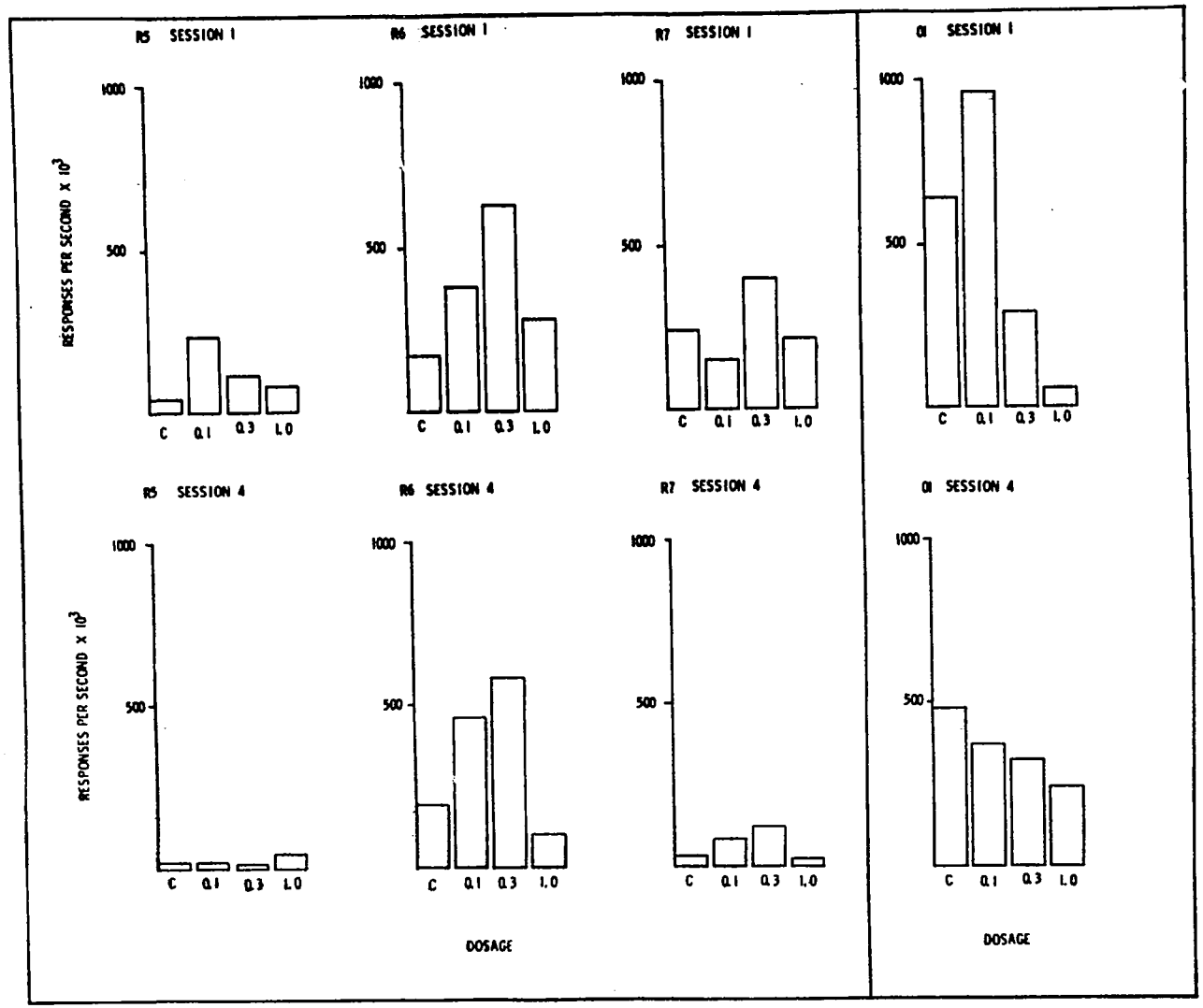

R5
R6
R7
OI
1000
500
RESPONSES PER SECOND X 10^3
C
0.1
0.3
1.0
DOSAGE

Fig. 12. The histogram presents a comparison of overall response rates per second, for each subject across all drug conditions, between the first and last drug administrations. The upper graphs plot response rates per second following the first administration of each dose level. The lower graphs show rates of responding for each subject following the last administration of each dosage.


R5 SESSION 1
R6 SESSION 1
R7 SESSION 1
OI SESSION 1
R5 SESSION 4
R6 SESSION 4
R7 SESSION 4
OI SESSION 4
RESPONSES PER SECOND X 10³
1000
500
C
0.1
0.3
1.0
DOSAGE

administration of d-amphetamine has no detectable effect. Whereas monkey R-6 shows substantial rate-increasing effects in S^{Δ} periods with 0.1 mg/kg and 0.3 mg/kg doses. Hence, if responding is present in S^{Δ} periods, amphetamine exerts a comparable effect to that produced during S^{D} periods, although to a lesser extent. If little or no responding is present during S^{Δ} periods, the administration of d-amphetamine does not induce any measurable increase in responding.

None of the monkeys under the S^{D}-S^{Δ} schedule show any degree of suppression with a 1.0 mg/kg dose, although the overall response rates for each subject do return to the original control level. The response rate per second of O-1 is slightly suppressed by a 0.3 mg/kg injection, whereas this dosage in the other subjects has substantial rate-increasing effects. Further inspection of Figure 11 indicates that when the control rate of responding is relatively low (R-5 & R-7), administrations of d-amphetamine have a less pronounced rate-increasing effect than in those subjects (R-6 & O-1) where the control rates are relatively high.

The presentation of ranges in Figure 11 shows a great deal of variability in the overall response rates per second during the series of drug administrations. The data shown in Figure 12 permit an explanation to be given for the observed variability. When comparing the overall

rates of responding between the first and last administration of the drug, at each dosage, it is evident that the response rates are lower following the last administration of each dose as compared with the first. Following repeated injections an overall decrease in the rate of responding under control conditions is also evident. Even with the overall drop in response rates the general trends are still maintained within each subject. In R-7 a 0.3 mg/kg injection still produces a rate-increasing effect relative to the control rate; however, the absolute rates obtained for the last administration are much lower than the rates of responding observed after the first administration. Continued exposure to drug administration in O-1 had a somewhat different effect. A similar lowering of response rates from the first to the last drug session was observed; however, for each dose, the last administration of the drug had the effect of suppressing responding when compared with the control baseline.

DISCUSSION

A discussion of the findings of this study is best handled under two major headings: i) effects of behavioral manipulations, ii) effects of d-amphetamine injections.

The first behavioral manipulation, following stabilization of responding under the free-operant avoidance procedure, was the introduction of a fixed-interval schedule of electric-shock presentation. The fact that it was possible to establish and maintain responding under this procedure adds confirmation to the results of Morse, Mead, and Kelleher (1967), Stretch, Orloff, and Dalrymple (1968), and McKearney (1968, 1969). In each of the four subjects, used in this experiment, it was possible to establish the typical pattern of responding, characteristic of FI reinforcement, in which the only consequence of responding was the delivery of an intense electric shock.

It is appropriate, at this point, to preface the discussion of the effects of repeated interpolation of S^{Δ} periods throughout the interval by reference to the general findings of other workers in this area. It was

noted, in the Introduction, that the results of several previous experiments support Dews' (1962) claim that S^{Δ} periods affect the pattern of responding whenever present. However, the general 'scalloped' pattern of FI responding survives repeated interruption. Specifically, the results obtained by Dews (1962, 1965) have indicated that, although responding is clearly suppressed during the S^{Δ} periods, there is a progressive increase in responding during S^{D} and S^{Δ} periods.

Within the conditions of the present experiment the results agree with those of previous investigations insofar as the fixed-interval pattern of responding survives repeated interruption by S^{Δ} periods. This effect was clearly marked in each of the subjects exposed to the contingency. Each subject showed a clear reduction in responding during each of the S^{Δ} periods as compared to corresponding periods under control conditions, with S^{D} periods showing progressive increases in response rates throughout the interval.

The performance of subject R-6 during S^{Δ} periods under the FI schedule, also supports previous findings, since responding was not completely suppressed but indicated a progressive increase in response rates during successive S^{Δ} periods. However, for subjects R-5 and R-7 interruption of the interval by S^{Δ} periods was followed by a consistently low rate of responding during these

periods without any progressive increase in responding being evident. In fact, within certain individual fixed-intervals responding during S^{Δ} segments was completely suppressed. These results do not contradict Dews' findings, but they do point out the need for careful examination of his work. His general statement that the overall FI 'scallop' survives repeated interruption by S^{Δ} periods has been confirmed by the present work. However, his data which show progressive responding during S^{Δ} periods appear to be questionable. This general pattern of behavior has been repeatedly observed in pigeons exposed to this particular type of scheduling arrangement. Only one study (Dews, 1965) has been described where a monkey has been used as an experimental subject. In this particular case, the subject showed a progressive increase in responding during S^{Δ} periods. Hence, the experimental literature in which primates have been exposed to the S^{D}-S^{Δ} probe shows that some subjects show progressive increases in responding during S^{Δ} periods while the others have shown suppression of responding during S^{Δ} periods.

The second major experimental manipulation was the administration of d-amphetamine sulphate. It is necessary, once again, to preface the discussion of the effects of d-amphetamine with reference to the general findings of other experiments in this area. It has been

reported by Dews (1956) that the behavioral effects of the amphetamines are dependent upon the ongoing response rate engendered by the schedule maintaining behavior. Specifically, Dews claimed that amphetamines tend to increase a relatively low rate of responding and decrease a relatively high response rate.

Within the range of doses of d-amphetamine used in the present work, the results are in agreement with those of previous investigators insofar as the relatively low response rate was, in general, increased following the administration of d-amphetamine. The results obtained from subject R-5 do not show the same degree of consistency as was found with the other subjects. Subjects R-6 and O-1, which had relatively high response rates, did not show percentage increases in overall responding that were as great as those obtained with monkeys R-5 and R-7 which had relatively low rates of responding under control conditions. Subject R-5 showed similar increases in responding under all three dosages, whereas, R-6 and R-7 showed major increases in response rates with a 0.3 mg/kg dosage while increases in responding were evident in O-1 with a 0.1 mg/kg dose.

Subject O-1, which had the highest control baseline and was not exposed to the S^D-S^Δ probe procedure, was the only monkey which showed suppression of responding at higher doses of d-amphetamine. At a

dosage of 0.3 mg/kg, rates of responding slightly below the control baseline were observed; with a higher dose, rates of responding far below that obtained under control conditions were observed. Results such as these do not contradict Dews' statement, but they do emphasize the necessity for careful interpretation of his assertions.

One of Dews' most important findings which supports his statement concerning the effect of amphetamines on behavior was that these drugs increase low rates of responding and decrease high response rates in performances maintained by a fixed-interval (FI) schedule. The typical pattern of responding on an FI schedule consists of a pause immediately following a reinforcement. The subject responds at a low but gradually increasing rate until the next reinforcement is delivered. With administration of d-amphetamine, the pause is reduced, and the relatively high terminal rate of responding preceding reinforcement, is diminished. d-Amphetamine exerted a similar effect upon subjects in the present experiment. This effect was most evident for each of the subjects exposed to the S^D-S^Δ probe procedure at a 0.3 mg/kg dosage, whereas monkey O-1 showed the effect at a dose of 0.1 mg/kg. Figure 9 indicates that the major rate-increasing effects obtained in O-1 were attributable to increased rates of responding during the

earlier portions of the interval. The effect of d-amphetamine upon subjects R-5, R-6, and R-7 (Figs. 4, 6, and 8, respectively) indicates a similar overall rate-increasing effect. Inspection of these cumulative records indicates that the same effect occurs with respect to the 'sub-scalloping' present in each of the individual S^D periods. Examination of the data for subject R-6 (Fig. 6) following a 0.3 mg/kg dose of d-amphetamine indicates that the drug has a similar rate-increasing effect upon responding S^Δ periods. However, the data from subjects R-5 and R-7 (Figs. 4 & 8) indicate that in those cases where responding was not a prominent feature of performance during S^Δ periods, the administration of d-amphetamine did not increase responding. Kelleher and Morse (1964) have presented evidence to show that amphetamine, which has an obvious tendency to increase rates of responding, does not restore responding that has become suppressed. Hence, the overall rate-increasing or rate-decreasing properties of amphetamine are not a sufficient basis to account fully for the effects of the drug on responding.

The work of Laties and Weiss (1966) which was reviewed in the Introduction, provides further insight into the selective action of amphetamine. An important section of their study was concerned with the influence of amphetamine on behavior controlled by internal and

external stimuli. Their findings indicated that greater changes in response distribution were produced by amphetamine when no external stimulus was available. This confirmed the hypothesis that behavior controlled largely by externally-based discriminative stimuli is more resistant to drug-induced changes than behavior controlled by internal stimuli. It is reasonable to assume that monkeys R-5 and R-7, which showed very little responding during S^{Δ} segments of the interval, were under better discriminative control than subject R-6 which displayed higher rates of responding during S^{Δ} periods. The results from the present study support those of Laties and Weiss (1966), since it is evident that d-amphetamine exerted a lesser effect upon responding when the behavior was under effective stimulus control (e.g. R-5 and R-7) than when poor discriminative control was observed (R-6). Monkey R-6 showed responding during S^{Δ} periods and, following the administration of 0.3 mg/kg of d-amphetamine, rate-increasing effects during these periods are evident, whereas monkeys R-5 and R-7, showing little responding during S^{Δ} periods, and thus were under greater discriminative control, did not show increased responding during S^{Δ} periods, following drug-administration.

Further evidence concerning the effects of externally based discriminative stimuli comes from a comparison of the data from subject O-1 with that from

monkeys exposed to the S^D-S^Δ probe procedure. Monkey O-1 was tested under a simple fixed-interval schedule, where the only discriminative stimuli available during the interval are those arising from within the subject's own body or those produced by its own behavior. Anger (1963) has called these "temporal stimuli" because their association with the passage of real time is presumed to give them some discriminative control over behavior. When comparing the effects of d-amphetamine upon behavior engendered by each of the two scheduling contingencies it is apparent that performance under the control of externally based discriminative stimuli is more resistant to the effects of d-amphetamine. For monkey O-1, rate-increasing effects of amphetamine were observed at a 0.1 mg/kg dosage, while higher doses exerted suppressive effects; each monkey exposed to the S^D-S^Δ probe procedure showed the largest rate-increasing effects at a dose of 0.3 mg/kg. A possible alternative explanation to the differences in drug effects between O-1 and the monkeys exposed to the S^D-S^Δ probe is that monkey O-1 had a control response rate that was much higher than those of the other subjects. Hence, with a high rate of responding certain doses will have a greater tendency to suppress responding than if the rate of responding were initially low. This interpretation must be considered.

Inspection of the data in Figure 12 indicates

that a change in overall response rates was obtained for each condition following repeated administration of amphetamine at each dosage. Repeated administration of the drug had the effect of lowering the control baseline for each subject. Hence, it was impossible to regain the original control baseline following drug administration. Two different patterns of performance obtained under the same schedule parameters for the same animal, one before and one after an intervening condition, have been described by Staddon (1965) as metastability. It may be, as suggested by Morse and Kelleher (1966), that metastability is a typical characteristic of performance under schedule-complex termination. Similar results have been obtained following drug administration (Dalrymple, 1968) and response-contingent punishment (Goforth, 1969).

The present work represents an attempt to clarify the determinants of behavior maintained by the scheduled presentation of electric-shock. Assessment has been made in terms of interruption of the interval by means of S^{Δ} periods and the effects of d-amphetamine sulphate upon this behavior. The result can be summarized in terms of the conceptual framework within which these experiments were undertaken.

The general pattern of fixed-interval responding, maintained by the scheduled presentation of brief, but intense, electric-shocks is not disrupted by repeated

interpolation of S^{Δ} periods during the interval. As a consequence, the results of the present experiment resemble closely the findings obtained by Dews (1962, 1965, 1966) for fixed-interval performances maintained by the presentation of food as the reinforcing stimulus. Since the fixed-interval pattern of responding was maintained in each monkey despite repeated interruption by S^{Δ} periods, the present results indicate that the concept of response chaining is unnecessary for the positively-accelerated pattern of responding observed under FI reinforcement. More generally, the results of the present study illustrate the overall similarity of the pattern of responding maintained by fixed-interval schedules, despite differences in the type of reinforcing stimulus (food vs. electric-shock presentation) that is contingent upon responding. It is in this sense that a schedule of reinforcement, controlling behavior, can be regarded as a more fundamental determinant of that behavior than the <u>type</u> of reinforcing stimulus used in behavioral control. Under other circumstances, an intense electric-shock would exert quite different effects upon behavior than those observed in this and related experiments (Morse, Mead, & Kelleher, 1967; Kelleher & Morse, 1968; Stretch, Orloff, & Dalrymple, 1968; McKearney, 1968, 1969; Byrd, 1969); the manner in which electric-shocks affect patterns of responding depends upon

the schedule of presentation and ongoing behavior when the contingency is first imposed. Morse and Kelleher (1966) have stated ". . . the behavior brought into a situation is important in determining how the environment will affect the behavior. The effectiveness of an event in maintaining a sequential pattern of responding depends on the ongoing pattern of responding itself."

These statements are of a general nature; a more specific explanation of FI performance maintained by response-contingent electric shocks is needed.

Hendry (1969) has offered the following account of the phenomenon which seems to merit experimental analysis:

> One very puzzling behavioral phenomenon may be interpreted in terms of a reinforcing effect of a safe signal. If a squirrel monkey has a history of making a particular response in a situation in which he is occasionally shocked, the response can be brought under the control of the shock by presenting the shock on a fixed-interval schedule for responding. The final performance resembles the pattern of accelerated responding typical of fixed-interval schedules of positive reinforcement. The monkey persists, apparently indefinitely, in emitting at relatively high rates responses whose only effect is the periodic production of electric shock (Morse, Mead, & Kelleher, 1967; Stretch, Orloff, & Dalrymple, 1968).
>
> The clue to the explanation of this behavior may be that the probability of response is initially high enough to ensure some shocked responses and some unshocked responses in an experimental session. That is a condition of uncertainty, the animal being unable to predict when a response will be shocked, or, in other words, it is

> a situation with no effective stimulus that signals shock. Given that the probability of response is not reduced to zero by this initial condition, it must happen that responses immediately after a shocked response are never shocked. In fact, the conditions of training in the reports cited are such as to ensure that, initially, the highest probability of a response is immediately after shock. We may assume that the monkeys discriminate these contingencies of punishment. It follows that, given always that the probability of response is not zero, the only safe signal is the shock itself. The shock alone initiates a fixed period when no shocks can be received. Therefore, the shock itself should become a conditioned reinforcer.

The effects of d-amphetamine upon a fixed-interval schedule maintained by electric-shock which has been subjected to interruption by S^{Δ} periods has yielded findings similar to that obtained with fixed-intervals which are maintained by food reinforcement or shock escape. Administration of d-amphetamine was found to increase low rates of responding while decreasing high response rates. The use of external discriminative stimuli have substantiated the hypothesis (Laties & Weiss, 1966) that behavior is more resistant to drug-induced changes when under the control of an external stimulus. Hence, the results of the present work parallel the findings obtained by Dews (1956), Kelleher and Morse (1964), and Laties and Weiss (1966).

These previously described studies have shown

the effects of d-amphetamine upon behavior maintained by either food reinforcement or shock escape. Work by Kelleher and Morse (1964) showed that the effects of d-amphetamine upon interval schedules are independent of the reinforcer maintaining the behavior. Findings obtained from the present work extend the applicability of this statement to situations in which the behavior is maintained by electric-shock. As a consequence, further support is given to the point of view that schedules are fundamental determinants of the nature of the behavioral change induced following drug administration. The same principle, that schedules are fundamental determinants of the behavioral effects of drugs, can be applied when examining the effects of drug administration upon behavior maintained by the scheduled presentation of electric shock.

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