OVERT "MEDIATING" BEHAVIOR DURING TEMPORALLY SPACED RESPONDING[1]

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A rat was trained on a schedule that programmed reinforcements only when a minimum waiting time between successive responses was exceeded (DRL schedule). It was observed to fill much of the pause between lever presses with a stereotyped behavioral chain: it would take its tail in its mouth and nibble it. This behavior was shown to be functionally related to the efficiency with which the subject spaced its responses. It is thought to have served as mediating behavior, providing discriminating stimuli for appropriate lever presses.

There are many descriptions of spontaneously arising response chains on reinforcement schedules that require subjects to space responses in time (Bruner and Revusky, 1961; Dews and Morse, 1958; Hodos, Ross, and Brady, 1962; Holz, Azrin, and Ulrich, 1963; Kapostins, 1963; Laties and Weiss, 1962; Malott and Cumming, 1964; Segal and Holloway, 1963; Stoddard, 1962; Wilson and Keller, 1953). This collateral behavior is usually thought to serve as *mediating behavior* in the sense conveyed by the Ferster and Skinner definition of the term: "Behavior occurring between two instances of the response being studied . . . which is used by the organism as a controlling stimulus in subsequent behavior" (Ferster and Skinner, 1957, p. 729). In only one case has such behavior been subjected to intensive analysis in an attempt to determine whether it is, in fact, serving a mediating role. While studying EEG correlates of the performance of monkeys on a DRL schedule, Hodos *et al.* (1962) found that their records were being contaminated by movement artifacts; one of their monkeys was regularly jerking its head to one side and the second animal was regularly licking its water bottle holder. Procedures that interfered with this behavior

also decreased the efficiency of the lever pressing behavior. Because of the potential importance of such mediating behavior in governing performance, we thought it appropriate to attempt a detailed analysis of a particularly good example of an overt chain when it appeared in a rat being trained for another experiment.

METHOD

The subject, an adult male albino rat of the Sprague-Dawley strain, had been working on a multiple schedule. A fixed ratio was in force when the house light alone was on in the Foringer chamber. After 10 reinforcements this was followed by a 2-min extinction period with the house light off. The house light, a white cue light, and a loud clicking stimulus (about 10 per sec) then came on and remained on while a DRL 22-sec contingency was in force for 10 reinforcements. After a second 2-min extinction period, the cycle was repeated. A masking noise was on continuously to eliminate the influence of sounds from the programming and recording equipment in an adjoining room. A force of 21 g was necessary to depress the lever 4 mm to close a microswitch. A telegraph sounder gave a feedback click for each response.

The rat was maintained, with dry lab chow, at about 80% of its *ad lib* weight. Sweetened condensed milk, diluted 1:1 with tap water, was used as the reinforcer. A tone sounded during the upswing of the 0.1 cc dipper that delivered the milk. The reinforcement cycle lasted 6 sec.

The rat had worked on DRL 22 sec EXT 2 min FR 30 EXT 2 min for approximately 35 hr when a very regular pattern of behavior was noted during the pauses between responses on the DRL component and only at that time. The rat appeared to be biting its tail and moving its mouth over the surface from one end to the other while holding the tail in its front paws. The skin was never broken by these mouth-tail contacts. By having an observer depress a hand-held switch while the animal's mouth was touching its tail (*cf.* Segal, 1963), a record was obtained on the event pen of the cumulative recorder that indicated the duration of each mouth-tail contact. The judgment proved quite easy to make and separate observers gave comparable records (Fig. 1). In addition, a printing counter was pulsed at the rate of 6 per sec while the switch was closed. It printed out the total count and reset to zero each time the observer released the switch, thereby yielding a measure of the duration of each mouth-tail contact. To monitor such contacts, experiments were run with the box open and a 15 w fluorescent lamp about 4 ft above it. The rat quickly adapted to these conditions.

In Anger's (1963) words: "It should be possible to determine whether the collateral behavior affects the [temporal] discrimination by manipulation of either and observation of whether the other is changed with mainte-
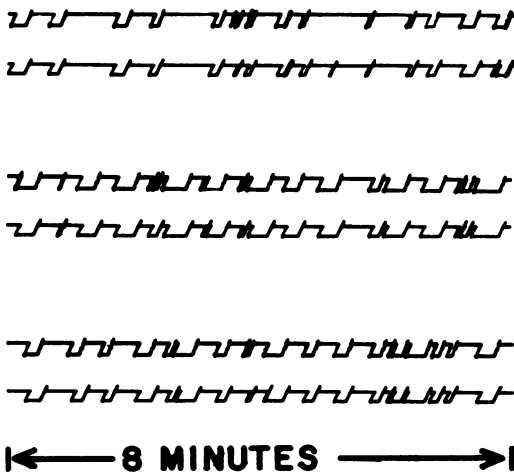

|◄━━━━8 MINUTES ━━━━━►|

Fig. 1. Three records of the rat's mouth-tail contacts made by two independent observers simultaneously. The rat had its tail in its mouth whenever the pen is deflected down. The top record was made in each instance by the same observer. The total observation period was 24 min.

nance of some relation between the two" (p. 493). We did this by examining the relation between mouth-tail contacts and DRL performance in four ways:

1. *Extinction and reconditioning of lever pressing.* After a 30-min control period, the milk reinforcement dish was removed and lever pressing allowed to extinguish (criterion: no responses for 3 min). The response was then reconditioned by replacing the milk dish.

2. *Removal of lever.* The lever was removed from the chamber to see if the mouth-tail contacts would extinguish. To provide for a temporal control, alternating 15-min periods were run with and without the lever present. It took 2-3 min to make the change; during this time the rat was removed from the chamber and held. This alternation scheme provided an opportunity to see if the mouth-tail contacts could be put under stimulus control, with the lever serving as the discriminative stimulus.

3. *Suppression of mouth-tail contacts.* Immediately after a 15-min control period, the rat's tail was painted with cycloheximide (Acti-Dione, Upjohn), a substance that dissuades rats from chewing wires coated with it (Weeks, 1962). Three concentrations were used: 0, 0.1, and 1.0% solutions in water. The rat was held for 2 min and replaced in the chamber for a 30-min period.

4. *Pharmacologic modification of lever pressing rate by amphetamine.* The effects of amphetamine sulfate were explored to see how a drug known to elevate the response rate of the rat on this schedule of reinforcement (Sidman, 1955) would modify the behavior during the pauses between these responses. Intraperitoneal injections were made at the end of 15-min control periods. The rat was replaced in the box and the experiment immediately resumed. Doses of 0 (saline), 0.25, 0.50, 0.75, and 1.00 mg/kg were used, with the 0, 0.50, and 1.00 mg/kg doses replicated once.

RESULTS

If tail nibbling was playing a role in the temporal spacing of lever presses, then the duration of nibbling should be correlated with interresponse time (IRT). The 11, 15-min pre-treatment periods from the drug and suppression experiments and the 30-min control period from the extinction experiment have

Table 1

Relation between amount of tail nibbling and
reinforcement. Responses less than 2.75 sec
apart have been ignored.

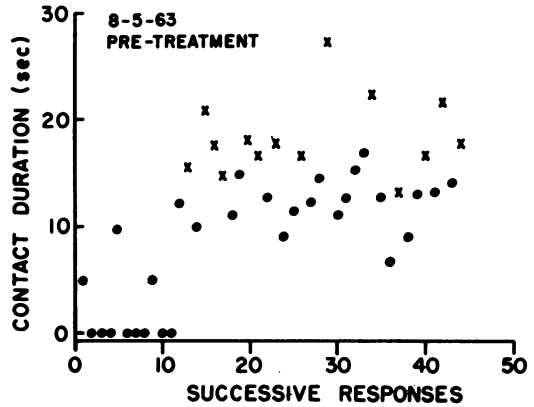| Contact Duration (sec)	Total Responses	Reinforced	Percent Reinforced
0	98	9	9.2
0-5	40	10	25.0
5-10	98	32	32.6
10-15	161	73	45.3
15-20	115	102	88.7
20-25	30	30	100.0
> 25	7	7	100.0

Fig. 2. Relation between reinforcement and duration of mouth-tail contacts. For each response, the amount of tail nibbling falling in the preceding pause is plotted. If that pause was long enough to insure reinforcement—greater than 22 sec—the contact duration is denoted by an "X". If the pause was shorter than 22 sec, the contact duration is denoted by a dot. Omitted are responses less than 2.75 sec apart (see legend of Fig. 3).

been pooled for the analysis summarized in Table 1. It shows that the longer durations of mouth-tail contacts were more likely to be followed by reinforcement. Thus, of the 98 responses made without previous tail nibbling, only nine occurred long enough after the previous lever press to produce reinforcement. If the rat had nibbled on its tail for at least 25 sec, it would always have been reinforced; the required minimum time between responses was 22 sec. Intermediate amounts of tail nibbling were associated with intermediate percentages of reinforcement, the greatest change occurring in the step from contact durations of 10-15 to 15-20 sec, the associated percentage of reinforced responses changing from 45.3 to 88.7.

Data for one 15-min period are plotted in Fig. 2, which gives the mouth-tail contact duration for the pause preceding each lever press. Whether a particular contact duration preceded a reinforced or unreinforced response is indicated by the symbol used to indicate the contact duration ("X" = reinforced, ● = unreinforced). It is clear that the rat nibbled on its tail longer during pauses preceding reinforced responses. (The cumulative record of this 15-min period appears as the pre-treatment section of the top record in Fig. 6.) Demarcation was sharp between that amount of tail nibbling rarely reinforced and that amount almost always reinforced. This is evidence that amount of mouth-tail contact could have served as a discriminative stimulus for lever pressing.

Effects of extinction and reconditioning. The cumulative records are shown in Fig. 3. Histograms showing the distribution of IRTs and mouth-tail contact durations are given

above the original records. During the first 30 min the animal responded at a rate of approximately 3 per min. The erratic mouth-tail contacts of the first few minutes (*cf.* Fig. 5, 6, and 7) are probably due to the immediately prior handling of the rat. The milk reinforcement tray was withdrawn while the dipper was delivering the reinforcement shown at (a). The rat continued to respond at its usual rate for a few minutes. Foreshortening the record shows that rate slowed after the eleventh presentation of the empty dipper. Mouth-tail contacts also continued undisturbed for a few minutes. These contacts then became more variable in duration and, except for one momentary contact, ceased after 10.5 min of extinction. Responses continued to be emitted but with great variability in IRTs. The milk tray was replaced during the reinforcement cycle at (b); the rat had not pressed the lever for about 3.5 min. The first milk reinforcement is shown at (c). The rat resumed its mouth-tail contacts almost immediately and the response rate on the lever returned to its pre-extinction value. The distribution of contact durations took on its pre-extinction shape.

The same data can be examined in another way that better displays the effect of the extinction procedure on tail nibbling. Figure 4 shows the duration of mouth-tail contacts before each response during the session, ignoring
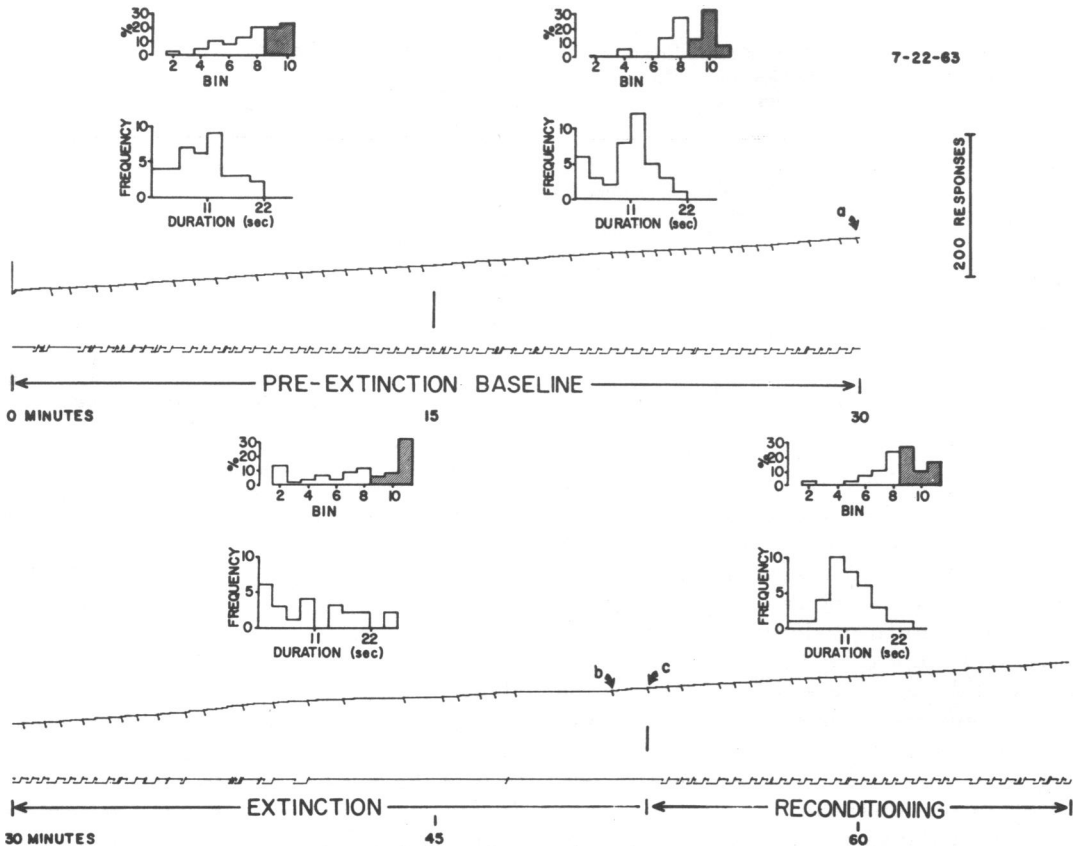
Fig. 3. Extinction and reconditioning of lever pressing on a DRL 22-sec schedule. The associated record of mouth-tail contacts lies below the cumulative record of lever presses, with the pen in the down position while the rat's mouth was in contact with its tail. Oblique lines on the cumulative record mark reinforcements, except during extinction, when they mark presentations of the empty dipper. The IRT distributions and the distributions of mouth-tail contact durations refer to the 15-min segments of the records directly below them. Both distributions use bins 2.75 sec wide. Shaded portions of the distributions of IRTs indicate responses that occurred more than 22 sec apart. The IRT distributions here and elsewhere have been made ignoring IRTs less than 2.75 sec apart, these responses being mainly the result of a few bursts of responding and probably of different origin from the other responses (Sidman, 1956; Hodos, 1963). For the four distributions shown here, the 0-2.75 sec totals were 4, 3, 4, and 1.
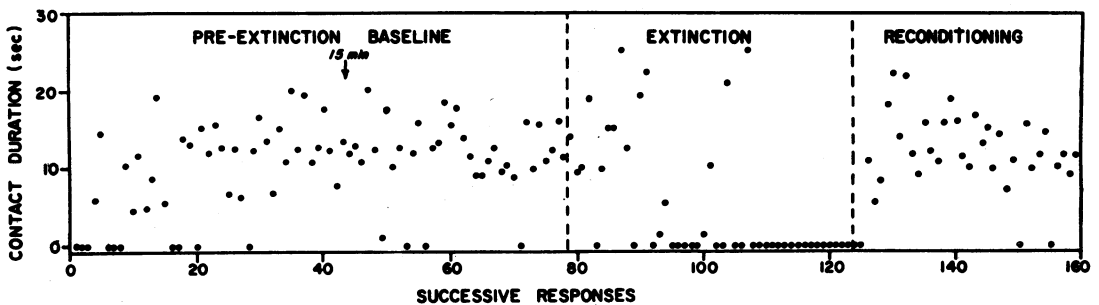

Fig. 4. Effect of extinction and reconditioning on duration of mouth-tail contacts. Each point denotes the amount of tail nibbling occurring during the pause preceding each response. Omitted are responses less than 2.75 sec apart (see legend of Fig. 3).

12 responses less than 2.75 sec apart. It is clear that these contacts were most variable in duration between the 86th response, soon after extinction had begun, and the 107th response, the last preceded by a significant amount of tail nibbling.

Effects of removal of the lever. As a result of the alternating periods of "lever in" and "lever out", the rat's mouth-tail contacts came under the discriminative control of the lever (Fig. 5). The contacts gradually decreased in number and increased in variability from one "lever out" period to the next until they all but disappeared in the fifth such period. The contact duration distributions continued to
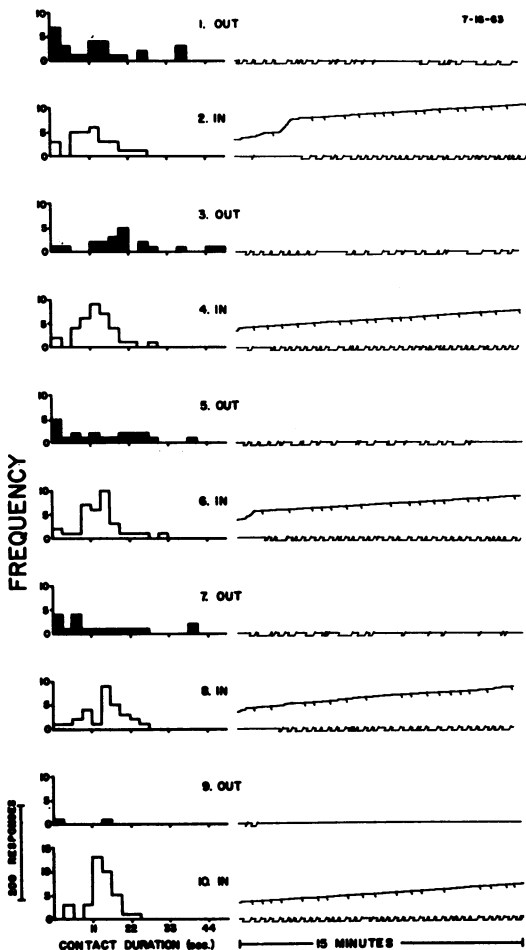

Fig. 5. Effects of removal of lever. Records 1, 3, 5, 7, and 9 show the rat's mouth-tail contacts during periods within which the lever was absent. Records 2, 4, 6, 8, and 10 show both the rat's mouth-tail contacts and its performance on the DRL schedule when the lever was present. Distributions of mouth-tail contact durations are given to the left.

show their usual form in the intervening "lever in" periods, despite some disturbance of performance that can be seen in the first minute of the cumulative records displayed in Fig. 5. The occasional bursts of responses seen in the cumulative records, here and elsewhere, may reflect the rat's experience with the fixed ratio schedule (*cf.* Kelleher, Fry, and Cook, 1959; Sidman, 1960, p. 312).

Effects of suppression of the mouth-tail contacts. Figure 6 shows the three cumulative records for the three levels of cycloheximide. A pair of histograms represents, for each 15-min segment of each record, the IRT distribution (top) and a frequency distribution of mouth-tail contact durations (bottom). It is clear that painting the tail with the 1.0% cycloheximide solution changed both the frequency of mouth-tail contacts and the IRT distribution of lever presses. The 0.1% dose disturbed the mouth-tail contacts only temporarily and had a lesser effect on lever pressing. During the time that the rat's tail nibbling was completely abolished, it got six reinforcements. During the first part of the control period that day, it got nine. Figures for like segments of the zero dose were six and six. After the high dose, the rat earned four reinforcements in a comparable time against nine for the same portion of the control period.

Effects of amphetamine. The effects of 0.5 mg/kg of amphetamine are shown in Fig. 7. Mouth-tail contacts continued for about 10 min after the drug had been given. They then disappeared, to reappear only rarely for the rest of the 1-hr session. When they did occur, they tended to be brief, often scarcely more than a momentary touch. As the contacts decreased in frequency and duration, the rat more often pressed the lever prematurely; reinforcements dropped from 24 during the 15-min pre-drug period to 13, 8, 7, and 12 during the four quarters of the 1-hr post-drug session.

Three aspects of the complete drug data are summarized in Fig. 8, and the same picture emerges as in the single record of Fig. 7. Rather than show the development of the drug effect over time, the mean for the whole hour after drug administration was computed and corrected for the pre-drug performance on that day. The top graph shows that reinforcement rate decreased; the middle graph, that the number of mouth-tail contacts decreased; and the bottom graph, that the mean duration
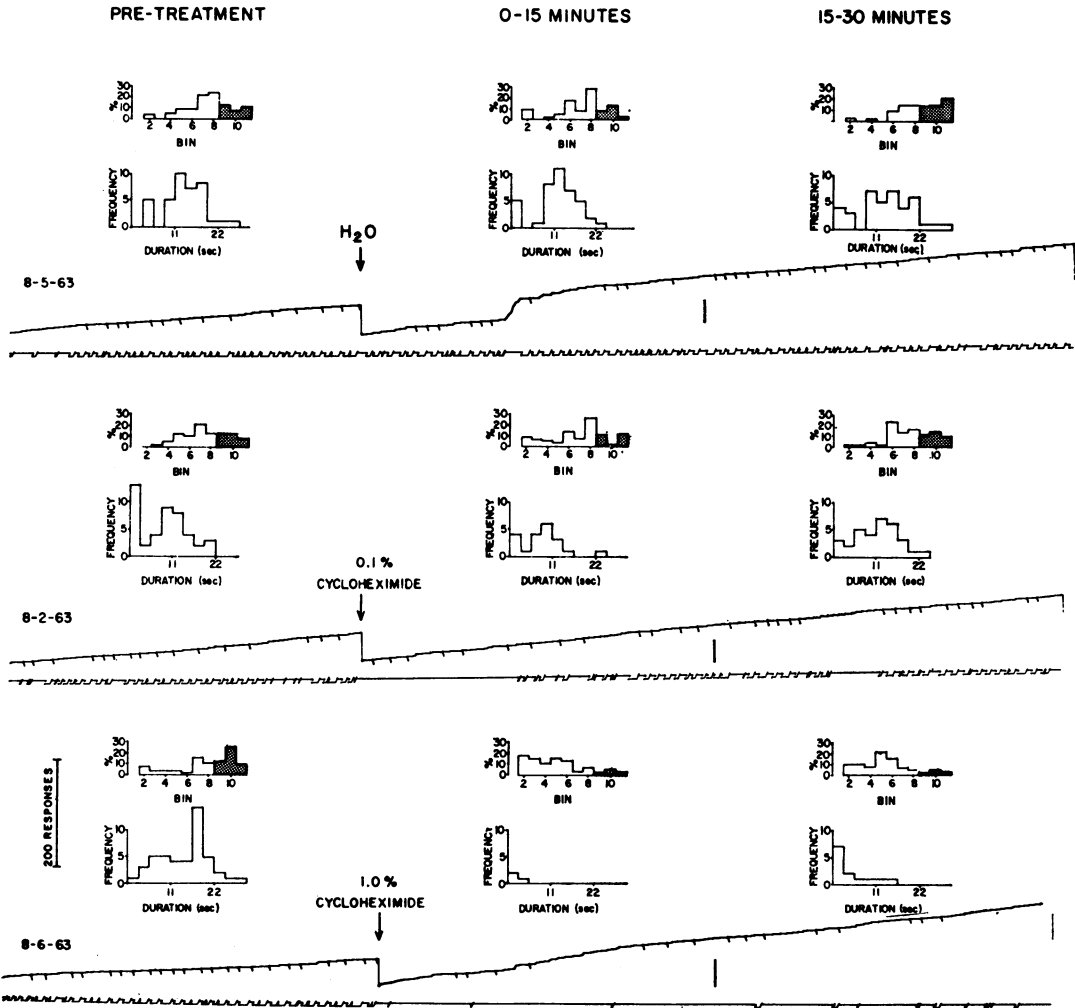
Fig. 6. Suppression of mouth-tail contacts with cycloheximide. The segments differ slightly in length because the clock timing the 15-min periods did not run during the 6-sec reinforcement cycle but the recorder did. The 0-2.75 sec totals were: Control: 6, 61, 9; 0.1%: 7, 7, 3; and 1.0%: 4, 22, 6.

of these contacts also decreased. Mean changes for response rate, again given as deviations from the control levels, were −0.71, −0.11, 0.47, −0.34, and 1.32 responses/min for 0, 0.25, 0.50, 0.75, and 1.00 mg/kg respectively.

DISCUSSION

If tail nibbling was in fact part of the chain of responses leading to reinforcement, withdrawal of reinforcement should have caused it to cease earlier than the cessation of lever pressing, since the adventitiously conditioned tail nibbling was farther removed from reinforcement (Hull, 1943). This is just what happened (Fig. 3). As with withdrawal of re-

inforcement, withdrawal of the lever led to extinction of the mouth-tail contacts (Fig. 5). This also is compatible with the notion that the tail nibbling was part of a chain of responses that occasionally produced reinforcements. The fact that it was possible to bring mouth-tail contacts under stimulus control, coupled with the ease with which they were extinguished and reconditioned, shows that they were operant in nature. Related to this point is the observation that the rat was never seen to nibble its tail in its home cage or during other components of the multiple schedule on which it was originally trained.

The suppression data (Fig. 6) are comparable to what Hodos *et al.* (1962) found in the
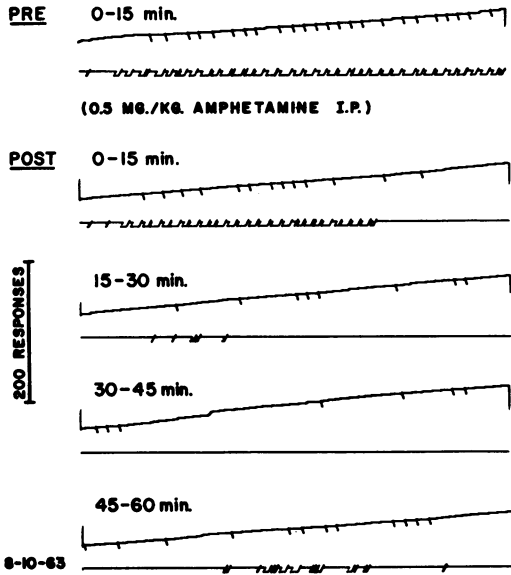
Fig. 7. Effects of 0.5 mg/kg of amphetamine sulfate on lever pressing on a DRL schedule of reinforcement and on mouth-tail contacts.

pography of adventitiously conditioned behavior is labile and tends to drift. During many successful pauses, the rat did spend part of the time between responses poking its nose into a small hole in the front wall of the chamber or sniffing at the floor in the far corner. We also may have been only partially successful in suppressing the actual mediating behavior; as Hodos *et al.* (1962) have pointed out for the response patterns they observed, the mouth-tail contacts were only part of a more complex chain, some of which remained after the feature that we were recording disappeared. Thus, the rat often would touch the lever lightly, crouch to sniff the hole through which reinforcements were delivered, and then rise again and depress the lever completely. This part of its response chain was usually not disturbed by procedures that abolished mouth-tail contacts. Finally, since many rats do learn to work efficiently on spaced responding schedules without displaying any systematic overt

monkey. With one subject they suppressed licking of the water bottle holder either by painting the holder with quinine or by erecting a physical barrier. They injected procaine into the neck muscles of the other monkey to stop it from rhythmically jerking its head. These procedures led to shifts of the IRT distribution toward lower values. The suppression data are also consistent with the finding of Segal (1961) that the introduction of a concurrent VI performance leads to a temporary increase in variability of behavior on the DRL schedule.

The high dose of cycloheximide caused a marked shift of the IRT distribution which led to a large decrease in the frequency of reinforcement. It also almost wholly abolished mouth-tail contacts. This supports the belief that the tail nibbling was important in governing the behavior of the rat on the lever. That it was not the whole story is shown by the fact that the rat still earned 15 reinforcements after its tail was painted, but only four of these were preceded by contact with the tail (Fig. 6, bottom). There are several possible explanations. One is that other behavior emerged to mediate successful pauses, perhaps a collateral chain that had been learned previously but had been supplanted by the more efficient chain. It is well known that the to-
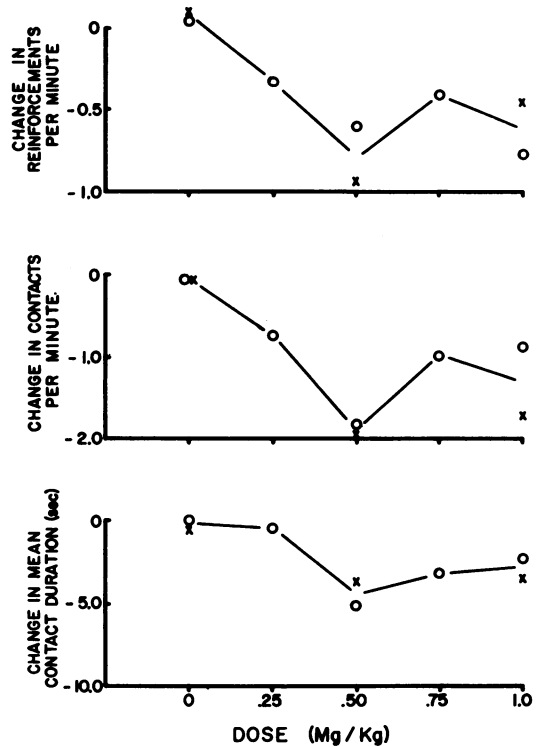

Fig. 8. Effects of amphetamine sulfate on (a) reinforcement rate; (b) number of mouth-tail contacts; and (c) the mean duration of mouth-tail contacts. Negative values represent decreases from the pre-drug performance levels (see text). The second experiments with the same dose have been indicated by crosses.

collateral behavior (Anger, 1956; Kelleher, Fry, and Cook, 1959), it is possible that internal events that vary with time—what Anger (1963) has called "temporal stimuli"—played some role in the rat's performance after tail nibbling had been eliminated. How likely is it that such stimuli were important in this case? It is conceivable that the emission of lever presses was controlled by temporal stimuli and that the rat moved to the lever when some time-related source of stimulation reached an appropriate, previously conditioned, value. Even when the rat's tail nibbling was not artificially suppressed, temporal stimuli conceivably might have been the sole source of discriminative control of lever pressing. The tail nibbling could have been an epiphenomenon, as it were, an interesting example of adventitiously reinforced behavior having no role in the maintenance of the temporal discrimination. Such an explanation seems unlikely. We have shown that the rat spent more time nibbling its tail during pauses preceding reinforced lever presses than during pauses preceding unreinforced ones (Table 1, Fig. 2). This is a state of affairs that would arise if reinforcement had been deliberately arranged to be contingent upon both appropriate spacing of responses and a certain minimum amount of mouth-tail contact. This procedure is also the one that would be used to make tail nibbling a discriminative stimulus: in the presence of a certain amount of tail nibbling, reinforce responding on the lever; in its absence, do not. We know too that the rat is capable of forming discriminations based upon cues from its own overt behavior—*e.g.*, Ferster and Skinner (1957) have shown that a rat working on a mixed schedule (mix FR 20 FR 160) comes to pause consistently after making approximately the number of responses in the smaller FR. In view of the presence of the appropriate conditions, it would be surprising if a certain minimum amount of tail nibbling did not in fact achieve the status of a discriminative stimulus. This argument, coupled with the ease with which we were able in several ways to show covariation between amount of tail nibbling and efficiency of spaced responding suggests to us that the most parsimonious account of *this* rat's performance is in terms of its behavior *vis-à-vis* its tail becoming a source of discriminative stimuli for appropriate spacing of lever press-

ing. It might be noted, in passing, that the proposition that internal events varying with time can come to provide cues for spaced responses rests upon the same assumption of a "ubiquitous discrimination process" (Anger, 1963, p. 479) used here to refer to tail nibbling.

This study does not address the question of whether precise temporal discriminations are possible without aid from some type of collateral chain, covert if not overt. A reasonable guess would be that an organism comes to depend upon whatever correlated stimuli are available in a given environment, be they generated by the animal's behavior or by physiological processes. If a heterogeneous chain that takes precisely the minimum amount of time necessary to prime the reinforcement circuit happens to be strengthened through adventitious reinforcement, then less distinct internal stimuli will be unimportant. If such a chain does not develop, the internal stimuli will become more important. Whether the overt chain develops may itself be a function of how discriminable are the internal stimuli. One source of such internal stimuli is the reinforcer itself (Skinner, 1938). If the presentation of the reinforcer produces gross internal changes that decay in time, the momentary state of the organism may come to serve as a discriminative stimulus for lever pressing. An example of this may be drawn from some work on behavioral thermoregulation (Weiss and Laties, 1961). The temperature of an animal working in a cold room for bursts of radiant heat comes to serve as a discriminative stimulus, governing the rate at which it works for heat: increasing the intensity of the heat reinforcer immediately decreases the response rate, longer pauses now occurring between successive responses.

In the amphetamine experiment, the aim was to work with doses that would not interfere with eating (Teitelbaum and Derks, 1958; Weissman, 1959). In this we were successful, no reinforcements ever being refused after any drug dose. The decrease in reinforcement frequency reflects the often described effect of amphetamine on response rate during the DRL schedule (Sidman, 1955). The effect of the drug on mean duration of mouth-tail contacts resembles that described by Segal (1962) for performance on the DRL component of a concurrent variable interval, DRL schedule. She concluded that disruption of a temporal

discrimination by amphetamine was a "secondary effect, produced not by interference with an internal timing mechanism, but rather by increasing the rate of emission of all overt behavior" (p. 111). This is an appealing hypothesis, and our data are in partial accord with it: those mouth-tail contacts that remained after amphetamine did decrease in duration (Fig. 8, bottom). This type of effect has also been seen by Mechner and Latranyi (1963) with their fixed consecutive number schedule. On this schedule the rat has to press one lever at least a fixed minimum number of times before a response on a second lever yields a reinforcement. Shifting prematurely to the second lever resets the counter to zero. Methamphetamine consistently increased the speed with which these response chains were run off. On the other hand, Hodos *et al.* (1962) found with amphetamine that while the IRT distribution of lever presses shifted toward shorter values, the distribution of frequency of head movements shifted in the opposite direction. The contradiction may be only superficial; the authors argue that since the monkey gave a similar distribution of head movements during a time out, the movements may have become "uncontrolled" and, presumably, of little use to the animal as mediators of the interval. In the case of their second monkey, abolition of the presumed mediating chain by amphetamine was accompanied by an increased rate of responding on the lever.

If an animal is working on a schedule of reinforcement that allows development of a superstitious chain, its performance after a drug will partly reflect the effects of the drug on the chain itself. This notion, originally put forth by Sidman (1960, p. 375) with reference to mediating behavior during delayed response experiments, is supported by the data cited above for the DRL schedule. In addition, Lindsley (see Jetter, Lindsley, and Wohlwill, 1953) has reported some relevant data on dogs that responded by pushing a panel. During performance on a 1-min VI schedule, the dogs displayed superstitious chains. One dog "bowed" under control conditions and showed even more bowing under amphetamine. The bowing apparently competed with panel pushing and the response rate on the panel decreased markedly under drug. In two other dogs, superstitious barking and licking were

abolished by the same drug with an attendant increase in rate of panel pushing.

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