FURTHER OBSERVATIONS ON OVERT "MEDIATING" BEHAVIOR AND THE DISCRIMINATION OF TIME[1]

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When the lever-pressing behavior of five rats was maintained by a DRL schedule (reinforcement was scheduled only when a specified waiting time between successive responses was exceeded), collateral behavior developed that apparently served a mediating function. In two cases this behavior did not arise until the experimental environment included pieces of wood that the rats started to nibble. When collateral behavior first appeared, it was always accompanied by an increase in responses spaced far enough apart to earn reinforcement. If collateral behavior was prevented, the number of reinforced responses always decreased. Extinction of lever pressing extinguished the collateral behavior. Adding a limited-hold contingency to the schedule did not extinguish collateral behavior. It appears that the rat can better space its responses appropriately when concurrently performing some overt collateral activity. The amount of this activity apparently comes to serve as a discriminative stimulus. To assume the existence of internal events that serve as discriminative stimuli in temporal discriminations is, at least under some circumstances, unnecessary.

Questions concerning the discrimination of time are often phrased in terms of the discrimination of on-going physiological events. Dimond (1964) reflected this viewpoint when, in reviewing the "structural basis of timing", he wrote:

"The stream of sensory impulses gathered from the environment is distributed in time. It is supposed that the duration of stimuli and the intervals between them are compared with an internal standard. Such a standard could be represented by the steady functioning of some mechanism of the body."

The notion of some sort of internal standard or "clock" appears in much of the literature in the traditional field of time perception

(Fraisse, 1963; Treisman, 1963). The discrimination of stimuli associated with mechanisms of this type may, indeed, play some part in the discrimination of duration, especially when an effort is made to exclude other discriminative stimuli, such as those associated with human counting (e.g., Laties and Weiss, 1962). But recent work has shown that the externally observable behavior emitted by an organism between responses on a lever (collateral behavior) may adventitiously come to be important in determining response distributions on temporally defined schedules (e.g., Davis and Wheeler, 1967; Hodos, Ross, and Brady, 1962; Laties, Weiss, Clark, and Reynolds, 1965; Nevin and Berryman, 1963; Segal-Rechtschaffen, 1963). A previous report from this laboratory described a rat with a stereotyped pattern of behavior between lever presses maintained by a schedule—DRL (for Differential Reinforcement of Low rate)— that arranged reinforcement only for responses separated from the immediately preceding response by a minimum interval of time (Laties et al., 1965). The rat gnawed its tail between responses (without breaking the skin), and we concluded that this unscheduled collateral behavior was "mediating" behavior; i.e., it appeared to be ". . . behavior . . . used by the organism as a controlling stimulus in subsequent behavior . . ." (Ferster and Skinner, 1957, p. 729). The present series of ob-

servations further explored the nature of the collateral behavior often seen in rats maintained on this schedule.

METHOD

The subjects were five male albino rats (Carworth Farms, CFN), maintained with dry Purina lab chow at about 75% of their predicted free-feeding weight. When 14 weeks old, they were trained to eat from the dipper that delivered the reinforcer (sweetened condensed milk, diluted 1:1 with tap water). Next, the first 50 lever presses were each reinforced. The reinforcement schedule then became DRL 18-sec; that is, reinforcement occurred only when a response on the lever followed the preceding response by at least 18 sec. If a response was reinforced, the 18-sec period was timed from the end of the reinforcement cycle. With rare exceptions, the rats were tested at approximately the same time, five days a week. Except when otherwise indicated, sessions were 1-hr long.

A force of 35 g was necessary to depress the lever 4 mm and close a microswitch. A telegraph sounder gave a feedback click for each such response. The lever, a 0.5-in. diameter, 2-in. long steel rod, was mounted 3.5 in. above the grid floor on the front wall. A tone sounded during the upswing of the 0.1-cc dipper that delivered the milk reinforcer. The reinforcement cycle lasted 6 sec. A broadband masking noise was on continuously.

The experimental chamber (Foringer and Company, Rockville, Md.) was 10.5-in. long by 10-in. wide. The glass top was 6 in. from the floor at the front of the box and 7 in. from it at the rear. The 0.25-in. diameter stainless steel bars that comprised the floor were 0.8-in. apart. The chamber had been modified in the following way. Doors had been cut in the two side walls; when open, they led to a 7-in. wide by 7-in. high alley that surrounded the chamber on three sides. The outside lengths of the three legs of the alley were 26, 24, and 26 in. The floor of the alley was of pressed fiberboard (Masonite) and the outer side and top were of wire mesh, supported by small wooden posts. The apparatus was set into a larger box of wall board; one side and the top of this box were Plexiglas. The scheduling and recording equipment were located in an adjoining room. A one-way mirror in the door

of this room, plus a mirror mounted at a 45-degree angle over the chamber, allowed the experimenter to watch the subject.

The general plan was to await the development of collateral behavior that appeared to serve a mediating function, then thwart its expression and record the effects on the DRL performance (*cf.*, Davis and Wheeler, 1967; Deadwyler and Segal, 1965; Hodos, Ross, and Brady, 1963; Laties *et al.*, 1965). With three of the rats (randomly chosen), the doors to the alley remained closed. These were to constitute the control group of an experiment that, as will be seen, did not work out as planned. The other two rats always had access to the alley so that it would be possible for their movement through the alley to be reinforced adventitiously, thereby making instances of collateral behavior especially easy to observe and measure. Various one- and two-rat subgroups were used for the several supplementary studies listed in Table 1 and outlined in detail below.

Table 1
Summary of Procedures

| | Subjects | | | | |
	2-1	3-1	3-2	2-0	3-0
Development and thwarting of collateral behavior	X	X	X	X	X
Extinction and reconditioning				X	X
Addition of limited-hold requirement	X	X			
Addition of collateral behavior to limited-hold performance				X	
Comparison of two types of collateral behavior			X		X
Increase in lower limit of DRL requirement		X			

RESULTS

Initial Development of Collateral Behavior and Effects of Interference

All five subjects developed patterns of overt collateral behavior. In each case, it could be shown that interfering with the collateral behavior changed the DRL performance. However, provision of the alley through which two of the subjects could run did not generate any stable collateral behavior. We can only guess why this procedure failed. Perhaps it was because a circuit of the alley took only a few seconds. Both subjects were seen to run through it early in training but the frequency

with which such a circuit was followed by a reinforced lever press may not have been great enough to support the behavior.

Rat 2-1, which worked with the alley doors open, rarely left the inner chamber after the first few sessions. Beginning with the eighth session, it spent most of the time between lever presses nibbling and licking the front bar of the grid floor. Before the eighth session, it had earned between 30 and 50 reinforcements. From the eighth to the twentieth session, the number of reinforcements varied between 68 and 98, increasing gradually over time. In order to determine the relationship between this oral behavior and the increased number of reinforcements, a Plexiglas floor was installed before the twenty-first session, thereby preventing the rat from reaching the grid bar. The floor effectively prevented nibbling of the grid bar, although midway in the session the rat started to lick the front wall. The results were dramatic (Fig. 1). The response rate increased markedly, the number of reinforced responses decreased, and as a result the "efficiency ratio" of reinforcements to responses fell (Brady and Conrad, 1960). These measures returned to about their pretreatment levels when the false floor was removed and the rat could (and immediately did) return to gnawing the front grid bar.

Rat 3-1 also had access to the alley and spent more time there than Rat 2-1. Occasionally, it would run halfway through the alley, spend some time exploring, then run back to the inner chamber and press the lever. Such behavior occurred during the early sessions on many occasions and frequently would occur before each of a sequence of responses, but it was unstable and did not persist. Beginning with Session 21, the rat started to display a stereotyped pattern of behavior that proved quite stable: after a response it would leave the inner chamber, go to one of three wooden posts that comprised part of the framework of the alley, gnaw on it for some time, then move rapidly back to the lever. As can be seen in Fig. 2, the number of reinforcements doubled in the first session during which it gnawed wood in the alley. When the doors to the alley were closed, the number of reinforcements dropped almost to the original level. This was the only rat that showed an increase in interresponse-time variability when showing overt collateral behavior, a finding perhaps related to the fact that it did not appear to favor any one post over the others.

The other three rats at no time had access to the outside alley.

Rat 3-2 developed collateral behavior that took advantage of a design peculiarity of the apparatus. The pressed wood (Masonite) floor of the alley projected under the doors to the chamber by about 0.5 in. Sometime before the tenth session, this rat began to gnaw between lever responses at the pressed wood under one door. The number of reinforcements per session rose quickly. Figure 3 shows the effects of a Plexiglas barrier that prevented the rat from gnawing the pressed wood; of the rat transferring its gnawing activity to the
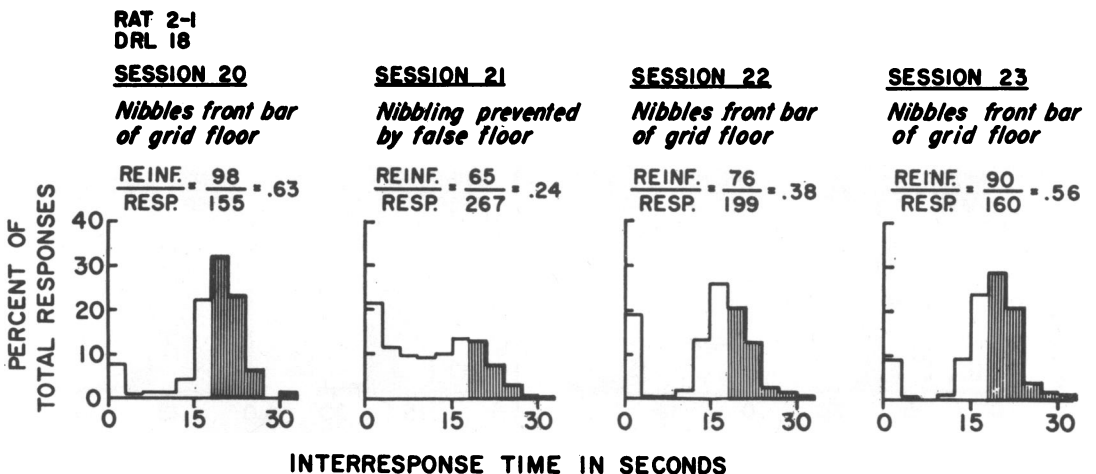

Fig. 1. Effects of barring Rat 2-1 from access to the grid floor it had been nibbling and licking between lever presses. A false floor was added only for Session 21. Shading indicates interresponse times that led to reinforcement.

RAT 3-1
DRL 18

SESSION 20 | SESSION 21 | SESSION 22 | SESSION 23

No nibbling seen | *Nibbles wood in alley* | *Continues nibbling* | *Nibbling prevented*

$\dfrac{REINF.}{RESP.} = \dfrac{40}{290} = .14$ | $\dfrac{REINF.}{RESP.} = \dfrac{80}{206} = .39$ | $\dfrac{REINF.}{RESP.} = \dfrac{78}{181} = .43$ | $\dfrac{REINF.}{RESP.} = \dfrac{45}{234} = .19$

PERCENT OF TOTAL RESPONSES
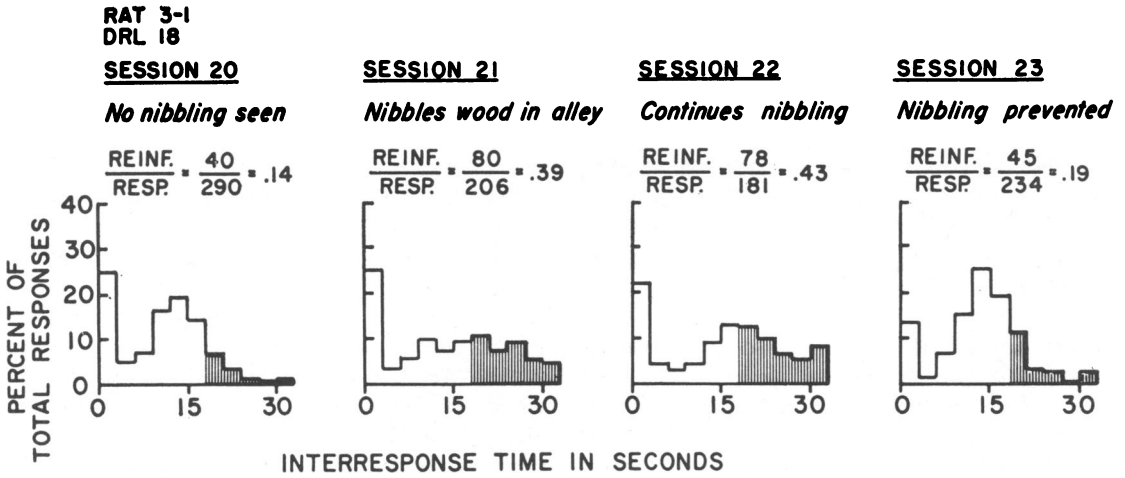
INTERRESPONSE TIME IN SECONDS

Fig. 2. Effects of barring Rat 3-1 from access to the wood it had been nibbling between lever presses. Wood nibbling was first seen during Session 21. The entrances to the alley containing the wood were closed just before Session 23. Shading indicates interresponse times that led to reinforcement.

wood under the other door; and of a second barrier to prevent gnawing there, too. It seems clear that the gnawing played an important role in maintaining appropriately spaced responding.

Rat 2-0 did not display any consistent collateral behavior during its first 31 sessions. At the end of that time it was earning fewer reinforcements than the three rats that had developed stereotyped chains. In hopes of stimulating the formation of such behavior, a

piece of wood (pine), 1 in. by 2 in. by 10 in., was wedged into the rear half of the chamber before the thirty-second session. The rat sniffed the wood occasionally but did not gnaw it. After the first 10 min of the next session, with the same piece of wood again in place, it started to gnaw between most lever presses. The wood chips were later collected from the waste pan; they weighed 5.5 g. The number of reinforcements doubled. The same piece of wood was reinserted for the next

RAT 3-2
DRL 18

SESSION 24 : $\dfrac{REINF.}{RESP.} = \dfrac{47}{313} = .15$

SESSION 25 : $\dfrac{REINF.}{RESP.} = \dfrac{67}{245} = .27$

Continues nibbling on other side

SESSION 22 | SESSION 23 | SESSION 26 | SESSION 27

Nibbles masonite on one side | *Barrier added; starts nibbling on other side near end of session* | *Continues nibbling on other side* | *Second barrier added; nibbling stopped*

$\dfrac{REINF.}{RESP.} = \dfrac{95}{172} = .55$ | $\dfrac{REINF.}{RESP.} = \dfrac{52}{290} = .18$ | $\dfrac{REINF.}{RESP.} = \dfrac{91}{193} = .46$ | $\dfrac{REINF.}{RESP.} = \dfrac{26}{305} = .08$

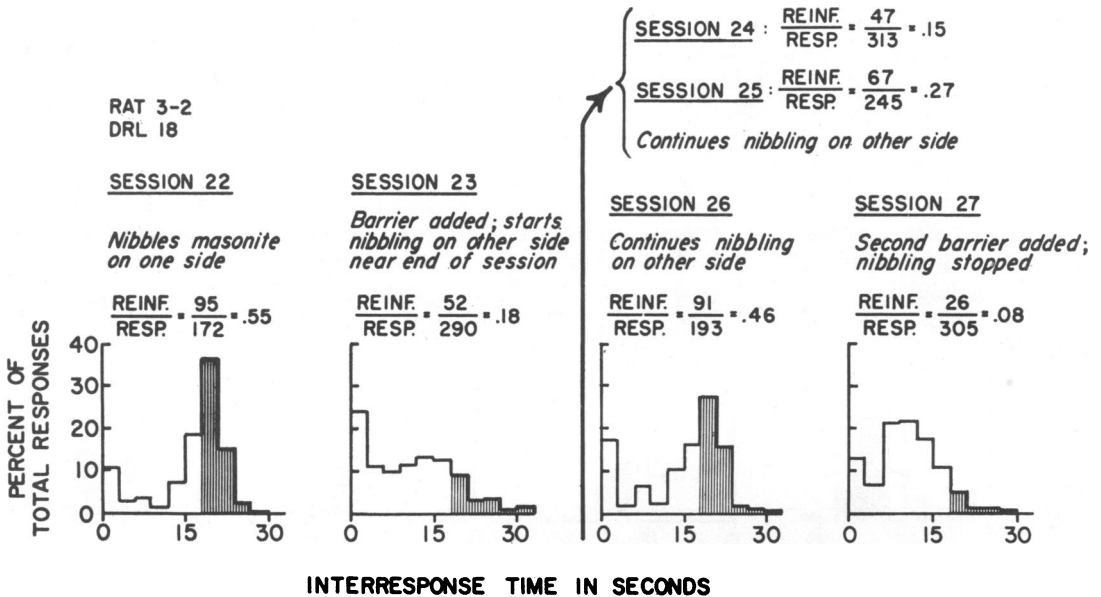PERCENT OF TOTAL RESPONSES

INTERRESPONSE TIME IN SECONDS

Fig. 3. Effects of barring Rat 3-2 from access to the pressed wood it had been nibbling between lever presses. Shading indicates interresponse times that led to reinforcement.

several sessions and reinforcements continued to increase, as one would expect if the amount of gnawing was serving as a discriminative stimulus. Two aspects of the behavior of the rat are summarized in the left half of Fig. 4, top. (The data on extinction shown in the right half are discussed in the next section.) This chart shows the number of reinforcements earned during each session; those sessions during which wood was available to the rat are indicated by the use of an "X" instead of a dot. In addition, the amount of wood that had dropped through to the waste pan is charted for sessions where that measure is relevant. After the fourth session with wood in the chamber, the wood was removed for one session. The number of reinforcements halved. Replacing the wood for the next session raised the number of reinforcements to its previous level.

Rat 3-0, the fifth subject, did not develop a reliable sequence of overt behavior between lever responses during its first 22 sessions. An attempt to induce licking of the front bar of the grid floor was then made, in the twenty-third through the thirtieth sessions, by smear-

ing sweetened condensed milk on the bar before the rat was placed in the chamber. Each time, it licked off the milk immediately and then proceeded to respond as it had during the preceding sessions, earning about 30 reinforcements each time (Fig. 4, bottom). A piece of wood (similar to that used with Rat 2-0) was wedged in the chamber from the thirty-first through the thirty-fifth sessions, removed for the thirty-sixth, and returned for the thirty-seventh, with results that replicated the findings with Rat 2-0. The drop in reinforcements earned for the session without wood was smaller than for the comparable session for Rat 2-0. Midway through this hour, Rat 3-0 started nibbling on its tail, and from that point in the session reinforcement rate increased markedly. This tail nibbling disappeared when wood was reintroduced for the next session.

Collateral Behavior During Extinction

The responses of both Rat 2-0 and Rat 3-0 were put on extinction in order to explore further the relation of wood nibbling and lever pressing. (The milk was removed but the
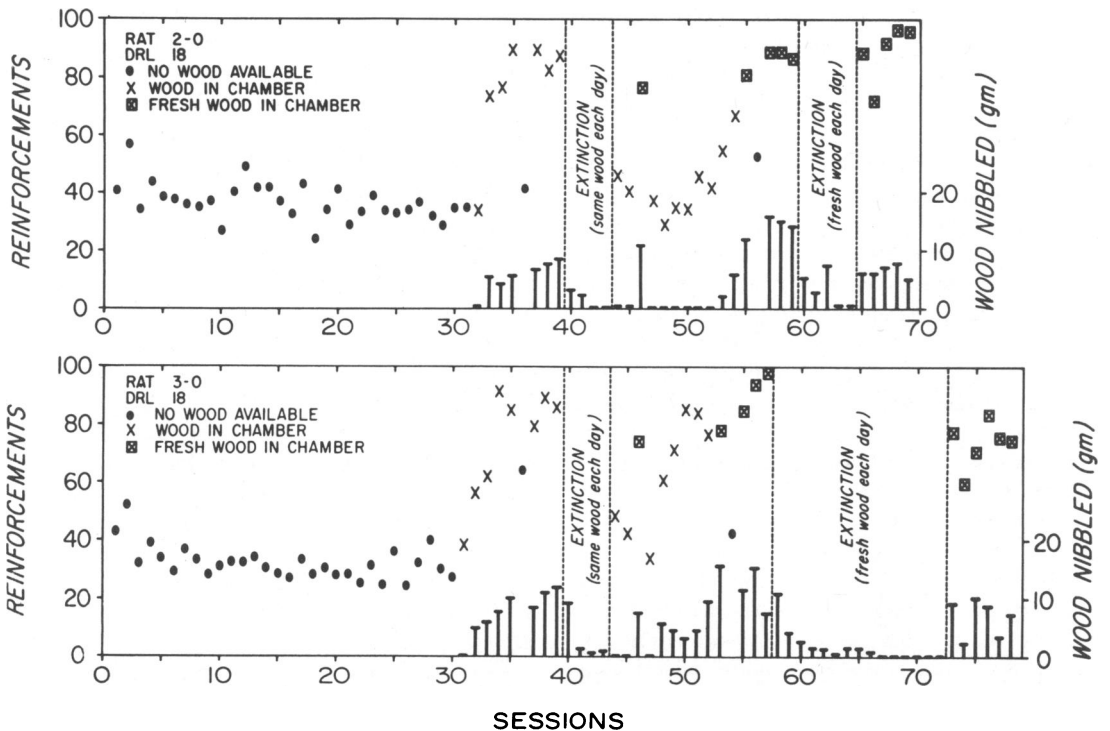

Fig. 4. Reinforcements earned and amount of wood nibbled (vertical bars) during 1-hr sessions by Rat 2-0 (top) and Rat 3-0 (bottom) as a function of various experimental manipulations.

dipper continued to operate.) Each rat had its own piece of wood wedged into the chamber at the beginning of each session, as before. Over four extinction sessions the amount of wood nibbled decreased, in both cases, to less than 1 g per session (Fig. 4). During the fourth session, Rat 2-0 made 70 responses (*vs.* 148 during the last pre-extinction session), while Rat 3-0 made 30 (*vs.* 129). In each case the subject made very few responses during the last half of the fourth session, lying on the floor most of the time. Thus, gnawing ceased before lever pressing, confirming the extinction results of the single tail-nibbling rat of Laties *et al.* (1965) and demonstrating again the status of the collateral behavior as a member of a heterogeneous chain. This disappearance of wood nibbling also argues against any interpretation of it as merely competing behavior which would keep the rat away from the lever in the way that running did in the Skinner and Morse (1957) study of fixed-interval performance.

We expected the rats to resume gnawing wood during the first reconditioning session. Instead, both rats ignored the wood during this and the succeeding session. The number of reinforcements earned was appropriate to the previous no-wood sessions. It seemed possible that extinction of wood nibbling may have been specific to the particular piece of wood present during the extinction sessions. When a fresh piece of wood was used for each rat during Session 46, both subjects gnawed vigorously and earned many more reinforcements than during the two prior sessions. The pieces of wood present during extinction were returned before the next session and neither animal gnawed. Reinforcement frequency halved. Further sessions were then conducted with the original wood present to see if and when the rats would resume gnawing. Rat 2-0 ignored the wood until its ninth session with the original wood. Rat 3-0 started to gnaw during the fourth session.

After the rats were gnawing the original wood regularly, they both were switched to a regimen of a fresh piece of wood each day. When the wood piece was again withdrawn, reinforcement frequency declined substantially (Session 56 for Rat 2-0, Session 54 for Rat 3-0). Extinction was now tried once more, this time with a fresh piece of wood available each day, to test whether or not gnawing had, indeed, previously come under the discriminative control of the particular piece of wood present during extinction. (Each rat was first given three sessions, each with new wood, before the milk was withdrawn for the extinction sessions.) Rat 2-0 had five extinction sessions; at the end of these it was once more responding at a very low rate and nibbling very little wood. When the milk was replaced for Session 65, the rat immediately began to gnaw the wood, although only half as much as before extinction. Rat 3-0 was given 15 extinction sessions, each with fresh wood available. During its last session it made only a few responses and gnawed only 0.05 g of wood. After milk was returned for the next session, it nibbled 9.3 g of a fresh piece of wood. It seems clear that regular changing of the wood present during extinction prevented the build-up of discriminative properties.

Effect on Collateral Behavior of Adding a Limited Hold

If an upper bound is added to the inter-response times required by the DRL schedule, a DRL with limited hold (DRL LH) results. Kelleher, Fry, and Cook (1959) suggested that "the development of chains of behavior should be less probable [on such a schedule], since the animal must discriminate a discrete point on the temporal continuum. The time occupied by overt behavior other than lever pressing could occupy enough time to enable the animal to meet the minimum requirement; but this chain of responses would be unreinforced whenever it extended beyond the maximum requirement." In fact, they found no overt chaining in animals they trained on DRL with limited holds.

In order to see what the addition of a limited hold would do to the collateral behavior that had already developed, two animals with stable collateral behavior were shifted from DRL 18 to DRL 18 LH 3; *i.e.*, only responses at least 18 sec but no more than 21 sec since the previous response were reinforced.

Rat 2-1's last 1-hr session on DRL 18 is shown in the upper portion of Fig. 5. This subject, which usually nibbled on the front bar of the grid floor, was then shifted to the 3-sec limited-hold contingency and maintained

on that regimen for 26 one-hour sessions. The first effect of the shift was to abolish nibbling of the front bar and increase markedly the amount of time the animal spent out in the alley. (The doors were open throughout for this rat.) Some licking of the front wall was seen during the second and third sessions. By the fourth session, however, the rat was back to bar nibbling, and it remained at that task between lever presses throughout the rest of the limited-hold sessions. The numbers of reinforced responses were 11, 23, 27, 38, 27, and 31, respectively, for the last six. The cumulative record from Session 50 is shown in Fig. 5 (bottom). Notice especially the increased density of the marks made by the pen that monitored contacts with the first bar, reflecting an increase in bar nibbling.

The responding of Rat 3-1, the subject that usually gnawed the wooden stanchions in the alley, was placed on a limited hold immediately after the last session shown in Fig. 2 and kept on it for ten 1-hr sessions. It did not gnaw the stanchions during the first session and earned 20 reinforcements. It then returned to gnawing the wooden posts. The amount chewed was not measured but it appeared to remain fairly constant during the course of the 10 sessions on limited hold. Reinforcements varied between 18 and 30.

We conclude that the imposition of a limited hold with rats that had already developed stable collateral behavior does not lead to the extinction of the collateral behavior. Instead, it appears that reinforcements received on a limited-hold schedule are sufficient to keep the collateral behavior in full strength.

Effect of Adding Collateral Behavior to Stable Behavior on DRL 18-sec LH 3-sec

We also examined whether or not the opportunity to gnaw wood for a rat with a history of wood nibbling would modify its behavior on the limited-hold version of the DRL schedule. Rat 2-0 was given five 2-hr sessions on DRL 18 LH 3 with no wood available. During these sessions, with no systematic collateral behavior visible, it produced 56, 76, 64, 51, and 41 reinforcements, respectively.
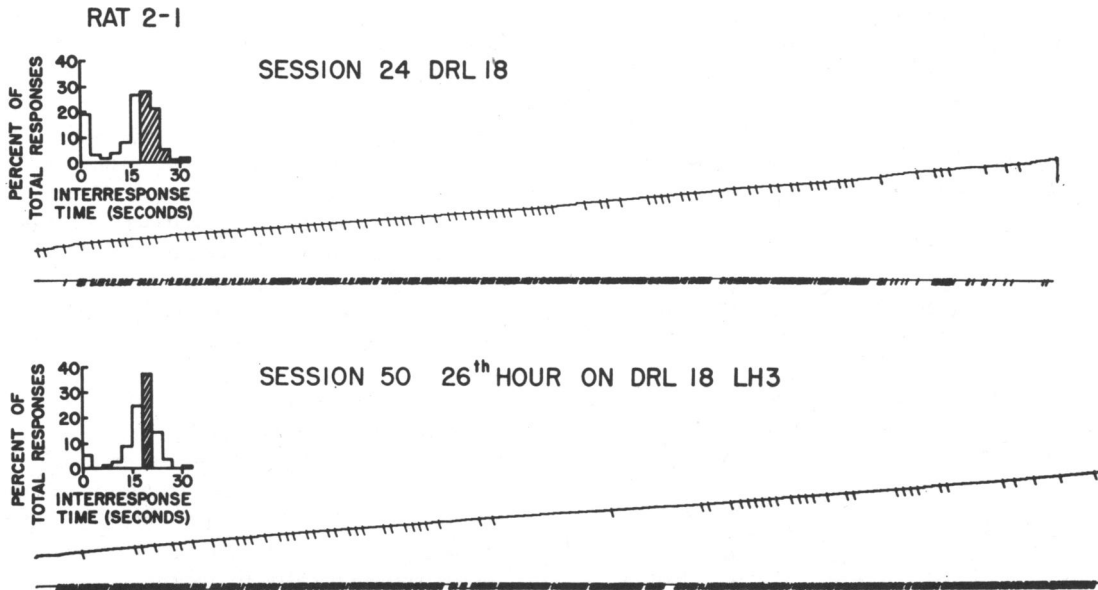

Fig. 5. Effects on nibbling front bar of grid floor by Rat 2-1 of adding a 3-sec limited hold to DRL 18-sec. Downward deflections of the operations pen (bottom line of each pair of records) denote contacts with front bar. A Lehigh Valley Electronics drinkometer was used to monitor contacts with the front bar, with the sensitivity set so that only juxtaposition of wet mouth and the bar produced these deflections. The oblique pips on the cumulative records represent reinforcements which, for the top record, occurred whenever the subject responded at least 18 sec after the last response and, for the bottom record, whenever the subject had paused between 18 and 21 sec before making a response. The shaded portions of the interresponse-time graphs also indicate reinforced responses. The recorder did not run during the reinforcement cycle. The rat made 183 responses during Session 24, 100 during Session 50.

Before the beginning of the next session a fresh piece of wood was introduced, and this procedure was followed for four more sessions. During these sessions it produced 82, 75, 100, 104, and 102 reinforcements, respectively, and the amount of wood gnawed varied between 2.8 and 6.0 g, with no correlation apparent between amount nibbled and number of reinforcements (see below for more data on such correlations). Figure 6 (bottom) displays the interresponse-time distributions derived from the last two sessions under each condition. The shift of the distribution is similar to that seen on a regular DRL. That more than a simple shift of the distribution is involved is shown by the conditional probability function (Fig. 6, top). Clearly, the rat showed a more precise discrimination when it spent its time between responses gnawing wood. An attempt to recapture the "no-wood" performance proved only partially successful: the rat started nibbling on one of the bars of the grid floor part way through the first session without wood and continued to do so through two more sessions. The conditional probabil-
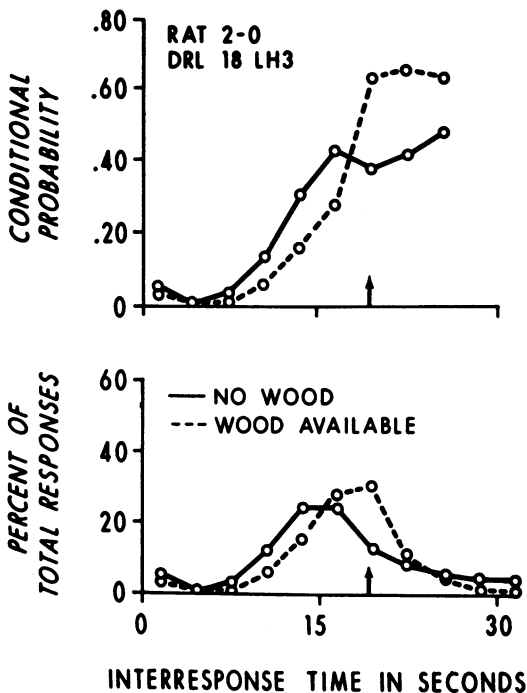

Fig. 6. Effects of collateral behavior on the interresponse distribution (bottom) and conditional probability function (top) of Rat 2-0 when it worked with a 3-sec limited-hold requirement added to the DRL 18-sec schedule.

ity curve from the first session fell neatly between the two curves plotted in Fig. 6, top.

Comparison of Two Varieties of Collateral Behavior in the Same Rat

Several rats were seen to change from one type of collateral behavior to another. For example, Rat 2-1 (see above) was seen to lick the front wall when prevented from nibbling on the bars of the grid floor. Two rats developed collateral behaviors that allowed comparison of the DRL performances associated with each.

Rat 3-2. Directly after the experiment summarized in Fig. 3, this rat was used in a drug experiment. The effects of amphetamine were assessed as a function of the opportunity to gnaw the pressed wood projecting into the chamber (Weiss and Laties, 1966). Data from control sessions (two of every four) are summarized in Fig. 7. Gnawing occurred with great regularity during sessions in which the rat was permitted access to the wood and the interresponse-time distributions consistently peaked in the 18- to 21-sec bin. At first, preventing access to the pressed wood with Plexiglas barriers led to a marked shift toward lower interresponse-time values. This regularity broke down at approximately the fiftieth session. From then on, behavior with and without barriers in place became progressively more similar, the rat producing almost as many reinforcements with barriers in place as not. The reason for this seems clear: whenever it was denied access to the pressed wood, it gnawed its tail. This nibbling was not as systematic as the wood nibbling and obviously was a poor substitute for the latter, for whenever the barriers were removed, the rat went back to nibbling wood.

Rat 3-0. This rat was exposed to DRL 18 LH 3 (no wood available) to replicate the experiment with Rat 2-0 (see above). However, during one of its first few 2-hr sessions, it began systematically to nibble its tail (the exact time was not noted). After seven sessions, wood was placed in the chamber to determine if wood nibbling would now displace tail nibbling (Fig. 8). It did so, briefly. During the first of these sessions, the animal gnawed 4.4 g of wood and also nibbled its tail frequently. During the next four sessions, it gnawed less and less wood, dropping finally
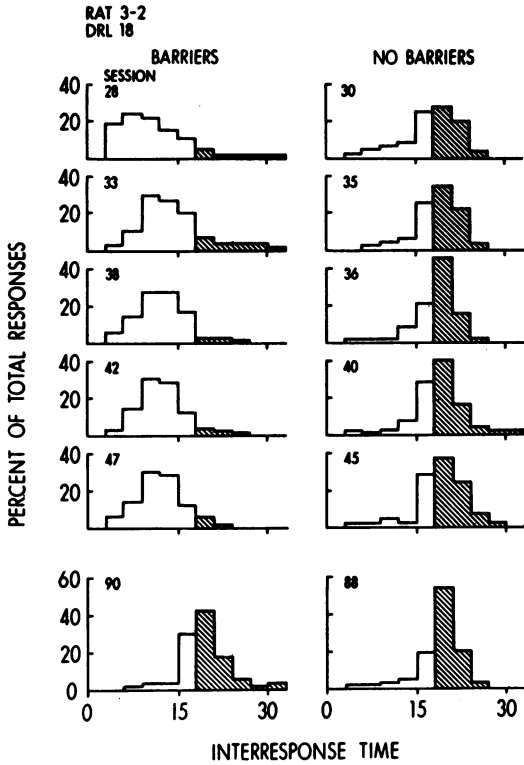
RAT 3-2
DRL 18

Fig. 7. Performance of Rat 3-2 during 1-hr sessions with (right) and without (left) access to the pressed wood that it nibbled between lever presses. Interresponse times shorter than 3 sec have been ignored in casting up these distributions (see Hodos, 1963).

to 0.1 g, and spent more and more of the time between lever presses with tail in mouth. Reinforcements rose with tail nibbling. Next, the tail was painted with a substance used to dissuade rats from gnawing wires, a 1.0% solution of cycloheximide (Weeks, 1962; Laties et al., 1965), in order to see if the rat would go back to wood nibbling when tail nibbling was made less likely. This procedure did abolish tail nibbling and reinforcements decreased to 23 during the first such session. The rat did not immediately resume chewing wood, nibbling only 0.4 g, and it spent a great deal of time grabbing its tail and dropping it after touching it to its mouth. For five more 2-hr sessions, the tail was painted before the session and wood was made available to the animal. During these sessions the rat ignored its tail, nibbled amounts of wood varying from 0.9 to 3.2 g, and spent much time with its nose near the dipper hole in a manner reminiscent of the original descriptions of sus-

pected mediating behavior during DRL (Wilson and Keller, 1953) and of the "active employment" near the dipper described by Azzi, Fix, Keller, and Rocha e Silva (1964) for a delayed reinforcement procedure. Reinforcements had reached 101 when the experiments had to be discontinued.

This rat obviously favored tail nibbling to the previously quite strong wood nibbling, and interfering with the former markedly reduced reinforcements. This animal had shown tail nibbling once before when wood was withdrawn earlier in its experimental history (see above). But at that time the tail nibbling disappeared as soon as wood was again made available.

Collateral Behavior at Higher DRL Values

A single subject, Rat 3-1, was used to see whether or not wood nibbling would continue to serve a mediating function at values of the minimum reinforced interresponse time higher than 18 sec. This rat, which previously had worked on DRL 18 LH 3 with the alley doors open, was placed on DRL 18 with the
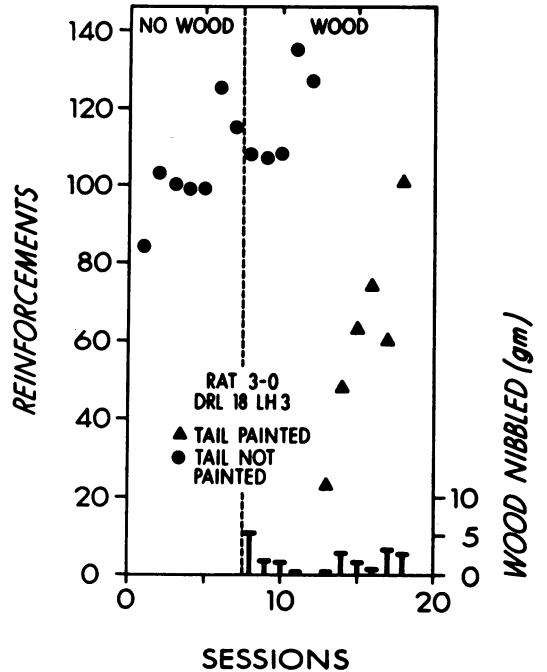

Fig. 8. Performance of Rat 3-0 on DRL 18-sec LH 3 without and with wood available to it. Vertical bars indicate amount of wood nibbled. Tail nibbling developed sometime before the fourth session. Tail nibbling was disrupted when wood was first returned and was suppressed completely by the cycloheximide.

limited-hold contingency removed, and with the doors to the alley closed. A piece of wood similar to that used successfully with Rat 2-0 and Rat 3-0 was then wedged in the chamber. Within three 1-hr sessions the rat was gnawing consistently between bar presses. After about 10 hr more of training, the minimum required pause for reinforcement was raised to 24 sec for three sessions, to 30 sec for three sessions, and then to 36 sec for 17 sessions. Figure 9 shows the development of the latter performance to the point where the rat was earning about 40 reinforcements and was making approximately 90 responses per hour. It nibbled 4.1 g of wood during the seventeenth session with wood available to it. When the wood was removed, responses rose sharply to 129. Reinforcements obtained correspondingly decreased to 15. Seven more sessions without wood did not materially change the IRT distribution, and no other regular pattern of overt behavior was seen. Responses totaled 136 and reinforcements 12 during the twenty-fifth session on DRL 36. The minimum required pause length was then increased to 48 sec and the wood replaced. During the last of eight such sessions the rat made 82 responses, 34 of which were reinforced. It nibbled 5.4 g of wood. The wood was then removed, again with dramatic effect: responses increased to 145 and reinforcements earned decreased to five. During the eighth session without wood the rat made 171 responses and received only three reinforcements. It had developed no substitute overt

collateral behavior during that time. Replacement of the wood quickly reversed matters; during the first session the rat made 127 responses, 20 of which were reinforced, and gnawed 5.1 g of wood. During the third such session, the rat made only 73 responses and earned 37 reinforcements, while gnawing 7.9 g of wood. The opportunity to gnaw wood clearly has effects that are not limited to a minimum pause of 18 sec.

Correlation Between Amount of Wood Nibbled and Number of Reinforcements

It is possible to examine some of the data already discussed to see how closely amount of collateral behavior covaried with the number of reinforcements earned. This has been done for three instances where extensive wood nibbling data are available. Figure 10 summarizes these data for Rat 2-0 and Rat 3-0. In both cases the scatter diagrams contain data collected on all the occasions shown in Fig. 4 when wood was available to the subject. Shown as well in each case are results from the session immediately before wood was introduced and the two test sessions for which wood had been removed from the box. When no wood was available, number of reinforcements was low; when wood was available but not nibbled, reinforcements remained low; and, as amount of wood nibbled increased, so did number of reinforcements. The Spearman rank-difference correlation coefficients for sessions with wood present are 0.73 for Rat 2-0 and 0.68 for Rat 3-0.
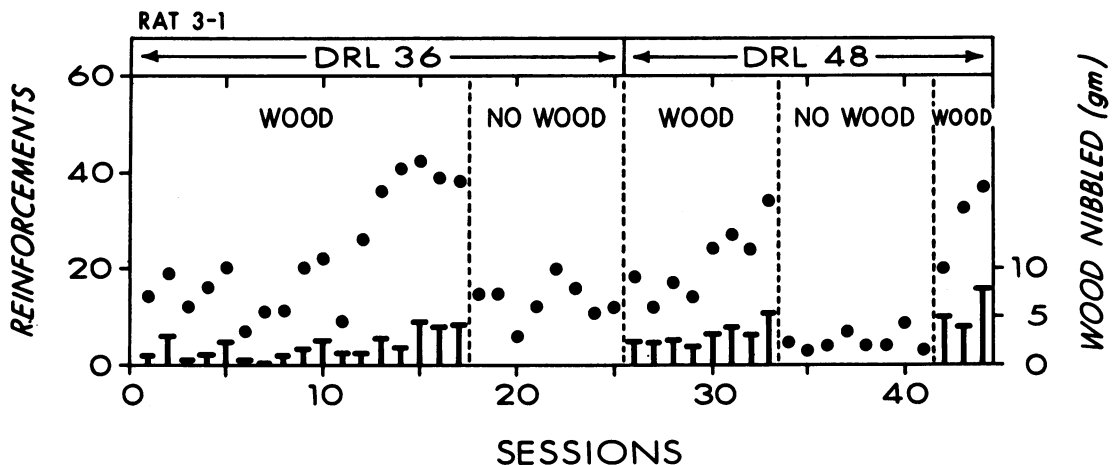

Fig. 9. Performance of Rat 3-1 with and without wood available at higher values of the minimum reinforced interresponse time. Vertical bars indicate amount of wood nibbled.
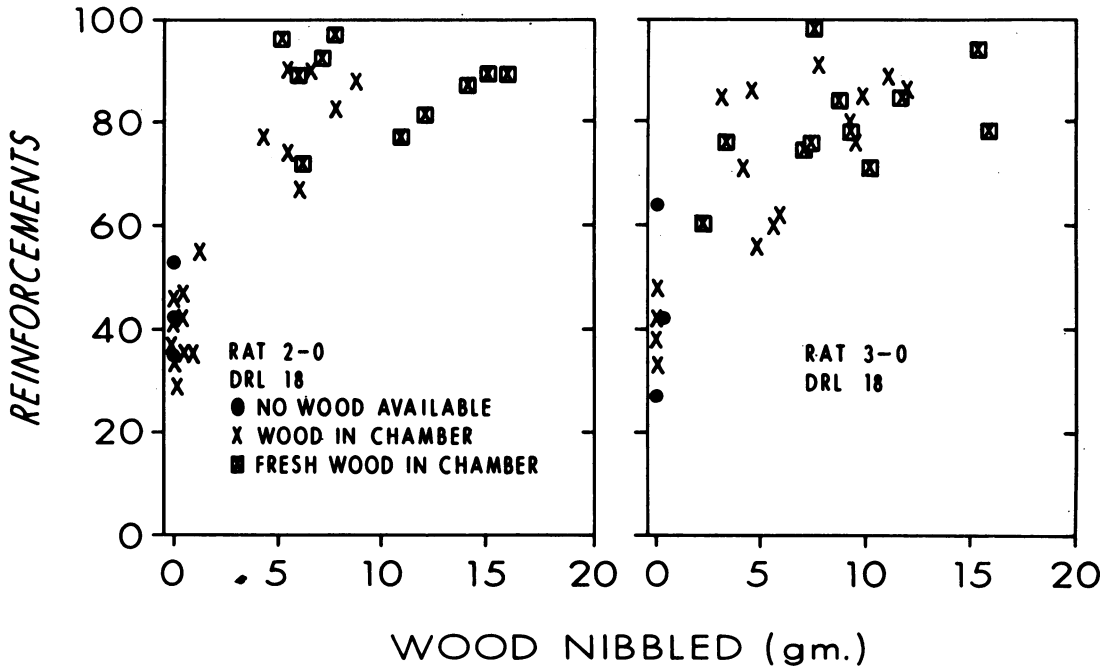
Fig. 10. Covariation of amount of wood nibbled and number of reinforcements for Rat 2-0 and Rat 3-0. Data from all sessions with wood available have been plotted (see Fig. 4). These started with Session 32 for Rat 2-0, with Session 31 for Rat 3-0. In addition, three occasions on which no wood was available have been included for each rat—the one just before the first wood-available session, and the two sessions that were interpolated among the wood-available sessions. Extinction sessions, during which reinforcements were, of course, not present, have been excluded.

A similar analysis of the data from Fig. 9 of Rat 3-1 is displayed in Fig. 11. Here, the correlations are higher, with rho = 0.82 for the DRL 36 data and 0.89 for the DRL 48 data. Given the crude nature of the measure of collateral behavior—the weight of wood chips gnawed from a bar of pine—these correlation coefficients, which (assuming causality) can be interpreted as indicating that between 45 and 80% of the variance has been accounted for, are heartening. But the coefficients are not unity, a fact that suggests that the collateral behavior studied here, when present, is not the only factor controlling lever-pressing behavior. Also, any lines fitted to the plotted points would intersect the ordinate far above zero: the rats did space a substantial number of their responses far enough apart for reinforcement even in the absence of wood nibbling.

DISCUSSION

The wood nibbling and other collateral behaviors that developed between lever presses on the DRL schedule appear to have been re-

lated to the frequency with which rats refrained from lever pressing long enough to insure reinforcement. It proved possible to vary this frequency by varying the opportunity to engage in nibbling behavior, either by preventing the rats from using the object nibbled or by extinguishing nibbling. In general, when collateral behavior was present, large amounts of such behavior were correlated with large numbers of reinforcements, while small amounts were correlated with small numbers of reinforcements. And fewest reinforcements were earned when the animals did not show any collateral behavior at all. This relationship held even when a limited hold was in effect, evidence that the collateral behavior was more than merely competing with lever pressing, keeping the rat away from the lever long enough for the minimum interval to have elapsed. Further evidence that the collateral behavior had a mediating function comes from the sharpening of the discrimination in the single case when the opportunity to nibble wood was given a rat on a limited-hold schedule (Fig. 6).
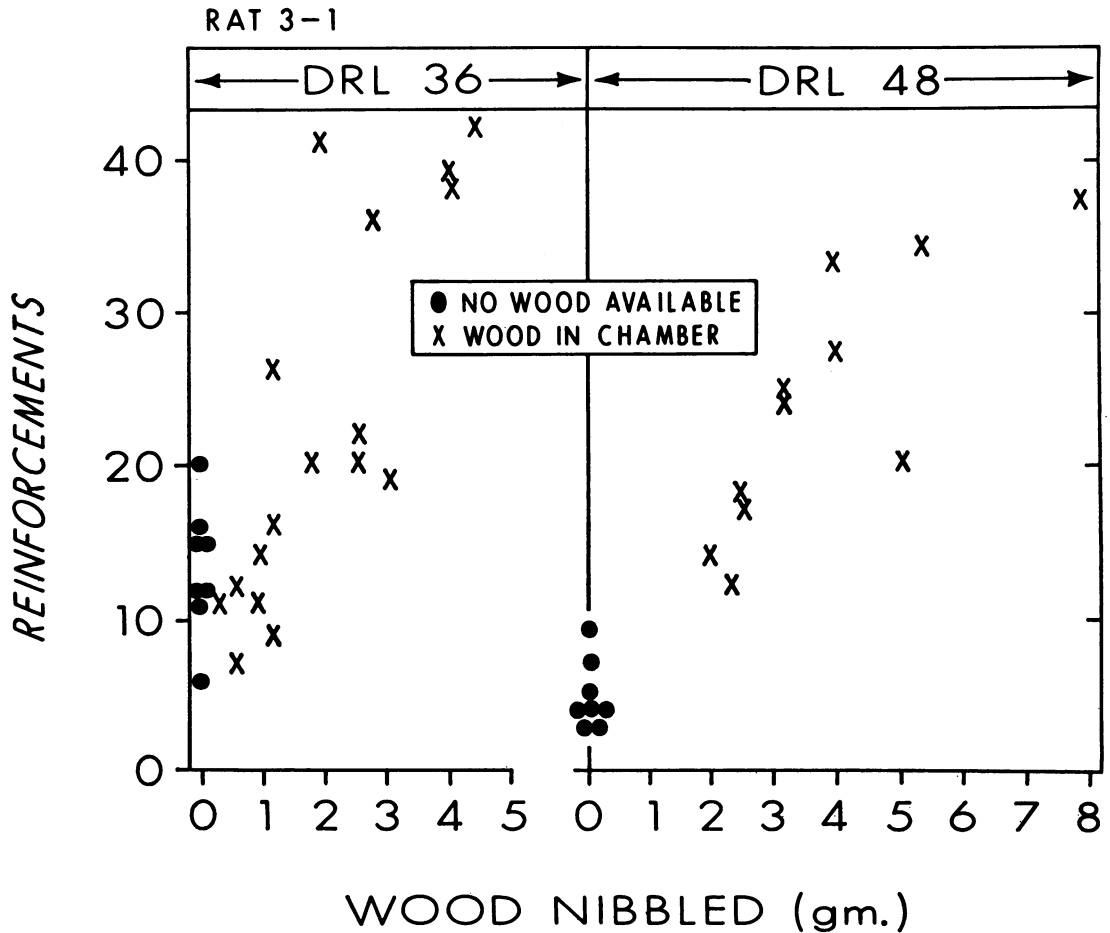
Fig. 11. Covariation of amount of wood nibbled and number of reinforcements for Rat 3-1 on DRL 36 and on DRL 48. Data from all sessions with wood available have been plotted (see Fig. 9). In addition, the number of reinforcements for those occasions on which no wood was available has been indicated.

Anger (1963, p. 479) took as the cornerstone of his analysis of temporal discrimination the proposition "that animals have available some events, either internal *or in their behavior,* that change in a consistent way with time after the last response, reinforcement, *etc.* These events function like external stimuli, at least to the extent that differences in responding can be conditioned to these organism differences." (Italics ours.) The data from both this and our preceding paper on overt "mediating" behavior (Laties *et al.,* 1965) are consistent with this analysis. But what are the "events"? At least some seem to be overt activities, the manipulation of which can change profoundly the distribution of responses in time. Under the conditions of the present experiments, both stimuli from inter-

nal physiological events and stimuli from unobservable behavior appear to be of little importance. In particular, discriminative stimuli arising from non-behavioral activity, such as heart rate, are unlikely to play much of a role in controlling the spacing in time of the rat's responses on the lever. Although such internal events may "change in a consistent way with time", they would presumably be undisturbed by such procedures as introducing a piece of wood into the experimental chamber. If anything, they would become less, rather than more, regular. The assumption that they are important, therefore, seems gratuitous. But in what way does behavior such as wood nibbling "change" with time? We have not seen long chains of topographically distinct responses, each response setting the

occasion for the next; *i.e.*, heterogeneous response chains.[2] If these were present, the discrimination of time would reduce to the simple discrimination of the last member of the chain, since the probability of reinforcement would be greatest at the time of its emission. Instead, behavior develops that possesses great apparent homogeneity, resembling response sequences rather than response chains (Kelleher, 1966, p. 163). Some physical property of this activity taken as a whole must therefore come to exert discriminative control over responding.

The fact that the behavior of the rat can readily be brought under the discriminative control of a particular amount of its own behavior is documented by much prior work; *e.g.*, Ferster and Skinner, 1957, p. 590; Hurwitz, 1963; Keehn, 1965; Mechner and Guevrekian, 1962; Notterman and Mintz, 1965; Schlosberg and Katz, 1943; Solomon, 1949; Weissman, 1960).[3] Although many of the preceding references confound number (or amount) and duration, the Mechner and Guevrekian (1962) experiment strongly suggests that the discrimination may well be primarily of amount rather than duration. Rats trained to emit four or more responses on one lever before switching to a second lever that then, and only then, produced reinforcement continued to emit the same mean number of responses even when the response rate was markedly slowed by a low condition of deprivation.

Another possible discriminative property of a homogeneous chain, one about which even less is known, may lie in sequential dependencies among members of the chain. It is known that a long series of lever presses exhibits such properties (*cf.*, Weiss, Laties, Siegel, and Goldstein, 1966; Weiss, in press). We should not be surprised to find similar proper-

ties in long chains of nibbles, licks, sniffs, *etc.*, after appropriate techniques have been developed to measure the intensive and temporal characteristics of these behaviors.

The precise topography of the collateral behavior that may appear in a subject maintained on a DRL schedule depends, of course, on the behavioral predilections of the subject and the experimental environment. Gnawing probably arose here because oral activity predominated in our rats, as it does in all rats. The mouth area is known to have extensive representation in the rat's somatosensory cortex (Woolsey, 1958), a fact reflecting, in part, this organ's acuity in tactile discrimination and the role it plays in the rat's behavior (Rose and Mountcastle, 1959, p. 402). One would thus expect the rat to be able to discriminate amount of gnawing with fair precision. If the environment of rats on DRL schedules includes objects that lend themselves to oral activity, such activity will have a high operant level and a substantial probability of being reinforced adventitiously.

Although the activity studied here seems to serve as "mediating" behavior, it is unlikely that all overt behavior emitted between lever responses on the DRL schedule does so. For instance, the drinking of great quantities of water between lever presses by rats working for dry food apparently sometimes does and sometimes does not serve as mediating behavior (Clark, 1962; Deadwyler and Segal, 1965; Falk, 1961; Segal, 1965; Segal and Deadwyler, 1964, 1965a, 1965b; Segal and Holloway, 1963; Segal and Oden, 1965; Stein, 1964). It is also necessary to recall that, as Morse (1966, p. 91) has pointed out: ". . . the temporal correlation of a response with a reinforcer has inherent effects that will necessarily be operating in any situation in which temporal discriminations may be operating. Since these inherent dynamic factors control patterns of responding in time, the continued appeal to temporal discriminations and timing as 'pure' stimulus events obverts progress in the analysis of temporally patterned responding." It thus is particularly important that the precise stimulus function of each example of collateral behavior be established independently.

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[2] We are here attending only to the collateral behavior itself. If the lever press is also considered, the entire chain is, of course, heterogeneous. And we also are defining homogeneity in terms of our own, rather than the rat's discriminative capacities; while a sequence of nibbles may look alike to us, they may constitute a very heterogeneous chain to the rat.

[3] That other animals can discriminate amount of emitted behavior is suggested by, *e.g.*, Pliskoff and Goldiamond (1966) and Rilling and McDiarmid (1968) for the pigeon, and Laties and Weiss (1963) for man. See Kelleher (1966) for a recent analysis of much of this work.

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