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# Performance on a DRL Schedule as a Function of Deprivation Levels

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PERFORMANCE ON A DRL SCHEDULE AS A

FUNCTION OF DEPRIVATION LEVELS

(TITLE)

BY

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THESIS

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## ABSTRACT

Twelve male albino rats were divided into three groups that were exposed to a DRL-18 second schedule of reinforcement. Each group was maintained at 70%, 80%, and 90% ad lib weight respectively during 28 days of acquisition training. The 70% ad lib weight group demonstrated continued superior performance over the other two groups after the 10th day. The 80% and 90% groups evidenced little difference between each other until the 20th day when the 80% group showed slightly better performance. Performance was based on the mean time-response efficiency ratios  $\left[ \frac{(\text{reinforced responses} / \text{total responses}) + (\text{reinforced responses} / \text{total possible reinforced responses})}{2} \right]$ . The results were discussed in terms of activity and development of collateral behavior.

The four basic schedules of reinforcement most extensively used in experimentation since Skinner's The Behavior Of Organisms (1938) have been; fixed interval (FI), fixed ratio (FR), variable interval (VI), and variable ratio (VR). Another schedule mentioned in Skinner's book has recently come into wide usage. This schedule of reinforcement is known as the " differential reinforcement of low rates of responding " or the DRL schedule. Skinner alludes to this schedule in describing an experiment in which the response rates of rats were decreased by reinforcing responses which occurred only after a minimum time of 15 sec. of nonresponding had elapsed. This is also confirmed and extended by Wilson and Keller (1953) who found that as the DRL value ( minimum time of nonresponding necessary to gain a reinforcement ) was increased the response rate decreased.

Typically, in the DRL schedule, reinforcement is contingent upon a response which is made  $t$ -seconds after the previous response. The period of time elapsing between responses is known as an inter-response time (IRT). The DRL schedule differs from the VI schedule in that, if a response occurs before  $t$ -seconds has elapsed since the previous response, no reinforcement is given and a reinforcement will now only be available if a response occurs  $t$ -seconds after the previously unreinforced response. For example, when exposed to a DRL-18 sec. schedule the subject would be required to wait a minimum of 18 seconds after his pre-



vious response before making a response which would be reinforced. If the subject failed to wait 18 seconds before responding, no reinforcement would be received and a reinforced response could only occur after a minimum IRT of 18 sec. from the premature response.

Another contingency which may be imposed upon the DRL schedule is that of a limited hold (LH). Under this schedule the subject would not only have to delay responding for a specified period of  $t$ -seconds but would also have to make that response before an additional  $t'$ -seconds had elapsed in order to gain a reinforcement. The DRL and DRL-LH schedules may also be described in this manner:

DRL- $t$  sec.

$IRT > t \rightarrow$  reinforcement

$IRT < t \rightarrow$  nonreinforcement

DRL- $t$  sec. LH- $t'$  sec.

$t < IRT < t + t' \rightarrow$  reinforcement

$IRT < t \rightarrow$  nonreinforcement

$IRT > t + t' \rightarrow$  nonreinforcement

The experiments involving the DRL schedule have taken many directions. Some have directly studied the schedule and the behavior it generates while others have used it as a baseline to study various independent variables. One characteristic of the DRL schedule which has

received extensive study is that of bursts of responding.

Sidman (1956) defines "bursts" as any sequence of two or more responses in which no consecutive responses are separated by more than two seconds. In this same study a relationship between the probability of a burst and the length of the preceeding IRT was found. He used water deprived rats on a two-lever concurrent schedule of reinforcement. Responses on lever A were reinforced on a DRL-20 sec. LH-2 sec. schedule. Responses on lever B were reinforced on an FI-4 min. schedule. At the end of the four minutes a tone was presented signaling that the next response on lever B would produce a reinforcement. After 20 sessions the auditory stimulus was systematically manipulated so that it could now be turned on at any time during the delay period of a lever A response. Approximately once every four minutes, the auditory stimulus was presented after the animal had waited  $t$ -seconds without a barpress on lever A; various values of  $t$  were used. He found that the probability of a burst on lever A increased as the length of the preceeding IRT on that level increased.

Other investigators, however, have not been able to replicate this finding. Staddon (1965) used pigeons on food deprivation of 80% of their free feeding weight. Though he used extensive training on eight DRL levels, ranging from 5-30 seconds, he did not find a relationship between bursts and the preceeding IRT. He did find, however,

that the number of bursts decreased as training increased. Kramer and Rilling (1969) found essentially the opposite result the Sidman (1956) found. They used three pigeons held at 80% of their free feeding weight. Under a DRL-20 sec. and DRL-30 sec. schedule they found that the percentage of bursts became lower as the response rate increased across subjects. The precise nature of bursts to the preceeding IRT as yet appears unclear.

One possible explanation as to the nature of bursts comes from Blough (1963). He suggests that bursts are relatively insensitive to stimulus variations and possess a special character. Using pigeons on a tandem VI-60 sec. DRL-10 sec. schedule he found that, although differences in responding to various wavelengths occurred, short IRTs which peaked at about .1 and .4 seconds were relatively unaffected. In a later study, Blough (1966) used pigeons on a schedule in which the least frequent IRT was reinforced. IRTs of less than .8 seconds were never reinforced. This, therefore, should have generated an equal number of responses in each IRT category. Here again he feels that short IRTs have a special character that warrants special treatment. Though IRTs of .8 sec. were never reinforced, they still occurred with a high frequency; one animal emitting as many as 1000 in an 80 minute session. Also, while the behavior of all pigeons was quite similar under the various conditions, individual differences in the probability of IRTs less than .7 sec. were large.

Blough (1966) suggests that short IRTs are patterned in a way peculiar to the subject. If this is the case, bursts may best be considered a part of the animals response topography. He also states that these "double pecks" would be worthy of little attention were it not that they often constitute a large portion of the subjects output and can cause considerable variability across subjects from time to time.

Though Blough (1963, 1966) appears to be referring solely to pigeons, it would seem that other investigators have taken this theory and applied it to the rat. In several recent articles, the investigators simply ignored bursts in their analysis. Trumble, Switalski and Gilbard (1968) who were interested in behavior changes as a function of the distance from the primary reinforcement in a chain DRL schedule, simply dropped out all responses with an IRT of less than three seconds. Meltzer and Brahlek (1967), studying the effects of delay of reward on DRL performance, dropped out all responses in bin 1 ( 4 sec. or less ), attributing them to being mostly bursts and not under schedule control. Meltzer et al. (1965) in a similar study, used exactly the same procedure in their analysis of the results.

Another explanation for the possible cause of bursts comes from studies in the area of stimulus feedback. Kelleher et al. (1959), using rats on a DRL-15 sec.

schedule, provided them with an audible relay click each time the bar was depressed. Under these conditions he found very few bursts of responding. As a continuation of the study, a DRL-20 sec. LH-5 sec. schedule was presented for 120 hours. The same click was presented whenever the bar was depressed. The click was then removed for three of the animals. The result was an increase in bursts for all three animals. In another study examining the effects of stimulus feedback on bursts Topping and Pickering (1972) used shock as the stimulus feedback. Rats were trained on a DRL-20 sec. schedule and then divided into three groups; Control Group (no shock), Short-Shock Group (received shock for responses of two seconds or less), and the Long-Shock Group (received shock for responses of 2-20 sec.). The results showed that there was no significant difference in the amount of bursts between the Short-Shock Group and the Long-Shock Group. There was a significant difference between the Short-Shock Group and the Control Group and between the Long-Shock Group and the Control Group. They concluded that the particular band of IRT punished was not of importance as far as its effects upon bursts. The bursts decreased irregardless of which band was punished. It would appear that some sort of feedback information aids the subject to determine whether he has made a complete or a partial response.

Since a reinforced response is generally followed

by some sort of stimulus feedback information ( cue light on or off, relay click of the pellet dispenser ) a number of investigators have noted the relationship of reinforced responses to bursts. Kramer (1968) recorded a large percentage of bursts for pigeons trained on a DRL-20 sec. and DRL-30 sec. schedule. He found that virtually no bursts occurred after a reinforced response when the key light was out and the food magazine was presented. Sidman (1956) has also noted that few bursts occur after a reinforced response. A study by Bradley (1971) yielded a more detailed analysis of the relationship of bursts to reinforced responses and also nonreinforced responses. Using the records of two rats trained on a DRL-15 sec. LH-5 sec. schedule, he performed a sequential analysis of the IRT distribution and found that bursts: 1) did not occur after a reinforced response, 2) were more likely to follow a nonreinforced response if the latter was preceded by a reinforced response, 3) increased in probability after a nonreinforced response when the prior run of reinforced responses was greater than one, 4) decreased in probability as the last successfully timed response became more remote.

These studies suggest that bursts of responding may be due to lack of stimulus feedback. However, control does not necessarily imply causation. In these studies though the amount of bursts was reduced, it was never totally removed from the subjects behavior. Probably one

of the most definitive statements one could make concerning the relationship of stimulus feedback to bursts is that it is a means of partial control. At this time it appears that the best solution for handling burst-data would be to drop it from the analysis.

An intriguing aspect of the behavior of a subject trained on a DRL schedule is his ability to discriminate time. Studies concerned with this aspect of the schedule hinge on the question of whether or not the behavior occurring between responses is mediational in nature or simply collateral. Mediating behavior refers to that behavior which occurs between two instances of the responses being studied. In the case of DRL schedules, it would be the behavior occurring during an IRT, which is used by the organism as a controlling stimulus in subsequent behavior (Ferster & Skinner, 1957). Collateral behavior, however, also refers to the behavior occurring during an IRT but does not take on the functional significance such as is attributed to mediating behavior.

Wilson and Keller (1953) were one of the first to note the organism's behavior during inter-response times. " Although no quantitative records were made of the behavior which occurred between barpresses, in the case of each animal there developed an easily recognizable and predictable form of collateral behavior p. 192 ." They argue that the behavior occurring directly before a reinforced response becomes conditioned and increases the probability of it occurring

again. Should this behavior occur long enough in the DRL situation, it will be followed by a reinforced response. This will develop into a response chain, increasing the subject's efficiency of responding. Others have also noted the development of well defined response chains (Holz et al., 1963, Kramer & Rilling, 1969).

Bruner and Revusky (1961) using four human subjects, exposed them to four telegraph keys. Three of the keys were irrelevant. The fourth key produced reinforcement on a DRL-8.2 LH-2.25 schedule. At the end of the experiment the subjects were given a 5¢ reward for every reinforced response made during the experiment. The study was composed of three phases; a) operant level- 30 min. during which no responses were reinforced, b) DRL schedule for 80 reinforcements and c) 2 hour extinction. Very erratic responding occurred during phases a and c, while during the DRL phase, a systematic approach developed. In post experimental interviews, all subjects expressed the view that reinforcements could only be obtained by a pattern of responding on at least one of the other irrelevant keys in order to set up the reinforced key. None of the subjects expressed the opinion that reinforcement depended in any way upon the passage of time. These findings tend to lend support to the development of chained responding as described by Wilson and Keller (1963).

One explanation for the development of chained responding comes from Skinner (1948) when he describes what is



called superstitious behavior. " The conditioning process is usually obvious. The bird happens to be executing some response as the hopper appears; as a result it tends to be repeated. If the interval before the next presentation is not so great that extinction takes place, a secondary contingency is probable. It is true that some responses go unreinforced and that some reinforcements appear when the response has not been made, but the net result is the development of a considerable state of strength p. 168-69 . "

Anger (1963), however, points to the fact that the behavior, though it occurs, may not be necessary for the temporal discrimination to occur. A number of studies have attempted to shed some light on the possible functions of collateral behavior. Laties, Weiss, Clark and Reynolds (1965) noted, while training rats on a multiple schedule, That one animal had developed a good overt response chain on the DRL-22 sec. component. " The rat appeared to be biting his tail and moving his mouth over the surface from one end to the other while holding his tail in his front paws p. 108 ". Following this up, they examined the relationship between mouth-tail contacts and DRL performance using four procedures; a) extinction, b) presence or absence of the lever, c) suppression of mouth-tail contacts by coating the tail with cycloheximide (a substance which dissuades a rat from chewing things that are covered with it), d) through amphetimine injections. During control periods they found that less than 10% of those

responses occurring without prior tail nibbling of 20 sec. or longer were reinforced. Extinction or removal of the lever for the purpose of disrupting the temporal discrimination also led to a cessation of the collateral behavior. The application of cycloheximide to the tail in order to suppress the collateral behavior led to a disruption of the temporal discrimination. The authors concluded that the collateral behavior was operant in nature, lending support to the explanations put forth by Wilson and Keller (1953) and Skinner (1948). Extending their findings, Laties et al. (1969) exposed five rats to a DRL-18 sec. schedule. A standard size operant chamber made of wood was used with doors cut in the two side walls. The doors were connected by a 7" X 7" alley surrounding the chamber on three sides. It was hoped that the rats would pass through the alley as a mediating behavior. Instead, however, two of the rats began nibbling at the door of the alley, one developed a response of licking the front bar of the grid floor, and the other two developed no consistent response chain. These last two were given a block of wood, wedged in the back of the chamber, which after a few sessions they began to nibble. As soon as these behaviors became established, all the rats were prevented from emitting them through some manipulation (adding barriers, removing wood, false floor). When these behaviors had originally been established the reinforcement rate had increased considerably. When they were prevented from occurring, however, the

reinforcement rate dropped. When these behaviors were allowed to be emitted again the reinforcement rate increased again. The two rats who nibbled the blocks of wood were then put on extinction. By the fourth session wood chewing had decreased to near zero. Also, by collecting the wood chips that had been chewed off and weighing them they obtained an operational measure of the amount of wood chewed. A Spearman Rank Difference Correlation between the amount of wood chewed and the number of reinforcements received ranged from .63 to .89.

It would appear from previous studies that the behavior occurring during an IRT is closely related to performance on a DRL schedule. When it occurs, responding tends to be more efficient than when it does not. Though, once established, the behavior appears to be necessary for continued efficient responding of the organism, it is still uncertain as to whether the behavior is necessary for the learning of the schedule. Whether or not the behavior is mediational or collateral is also uncertain.

Employing the schedule as a dependent variable has been found to be a useful research approach. In the little studied area of the effects of deprivation upon responding during DRL schedules this approach is used. Conrad, Sidman and Herrnstein (1958) were the first to study the effects of deprivation on DRL responding. In the first part of this study, one rat and one monkey were trained on a DRL-20 sec. schedule till the response rates were stabilized. They were then tested

once a week in a two hour session. The levels of deprivation for the rat were; 9.0, 21.5, 45.5, 69.5 hours. For the monkey the levels of deprivation were 0, 3, 7, 24 hours. Both animals were water deprived. Reinforcement for the rat was a drop of water and for the monkey, 1ml of orange juice. The results showed that the only noticeable effects were at the lower levels of deprivation. Up to 20 hours of deprivation there is a sharp increase in the overall response rate. From 20-70 hours of deprivation there is only a slight increase in the response rate. In the second part of the experiment the procedure was changed to determine whether the results from the previous method would be confirmed. Two rats were water deprived for approximately 69.5 hours. They were then given a 10 hour test session with the hope that at the end of the session they would be satiated. The result was a large drop in the response rate late in the session. It appears that deprivation has its most noticeable effect upon the response rate when the degree of deprivation is low or the organism is near satiation. Another study which examined the effects of gradual satiation upon the response rate was done by Holz and Azrin (1963). Four pigeons were maintained at 80% of their free-feeding weights while being trained on a DRL-30 sec. schedule. The animals were given a minimum of 60 hours training until performance had stabilized. The animals were then satiated by providing extra grain in their home cages after each session. The extra grain was increased

by small amounts during the experiment until the amount was too great to be consumed during the time between sessions. The findings were similar to those of Conrad et al. (1958). No immediate effect occurred until the animals body weight had reached 95% of its free-feeding weight. At this point the response rate had been decreased by only 10%. To decrease the response rate by 50% and increase to 99% of the free-feeding weight was necessary. Satiation did not occur until the animals had reached 109% of their original body weight. Reynolds (1964), using a procedure for satiation similar to that used by Holz and Azrin (1963), found that increases in body weight resulted in decreases in the rate of responding. The magnitude of these changes corresponding with those found by Holz and Azrin (1963).

Using a method which allows separate analysis of the post reinforcement pause (PRP) and IRT, Mechner and Guevrekian (1962) arrived at a different conclusion. Four rats served as subjects run on an FMI-5 sec. schedule ( fixed minimum interval of 5 sec. ). This schedule is the equivalent of a DRL-5 sec. schedule. In their procedure two bars were used. The animals were required to depress bar A to start the schedule. After a minimum of 5 sec. they could obtain reinforcement by a response on bar B. If a response was made before five seconds had elapsed, reinforcement was withheld and a response on bar A would be necessary to start the sequence again. Using this procedure, the PRP ( time from a

response on lever B to a response on lever A ) could be separated from the timing required by the schedule ( time from a response on lever A to a response on lever B ). The rats were tested at water deprivation levels ranging from 8-56 hours. Each animal was tested under every level three times. The order of presentation was random. The results showed that the mean IRT gradually decreased in length as the deprivation levels increased. The mean PRP also decreased, though it was less gradual, with increased levels of deprivation. The authors concluded from their findings that the IRTs are only minimally affected by deprivation while it is the PRP which is greatly affected by deprivation. As Nevin (1973) sums it up, ".... the rate of responding is not sensitive to deprivation or satiation. Only the tendency to initiate responding varies with deprivation p. 231 ".

The evidence on the effects of deprivation upon DRL responding is not as clearcut as it may seem. First of all, in the studies by Holz and Azrin (1963) and Reynolds (1964) pigeons were used. These and other investigators ( Kramer & Rilling, 1969) have noted that the percentage of reinforced responses seldom, if ever, exceeds 2% on a DRL-20 or DRL-30 sec. schedule. This is decidedly poor when compared to the performance of rats, monkeys or humans ( Conrad, Sidman & Herstein 1958, Wilson & Keller, 1953, Weiss et al. 1966, Bruner & Revusky, 1961 ). Only in the Mechner and Guevrkian (1962) study is the efficiency even somewhat examined. It

would seem that the effects of deprivation upon the subjects efficiency would be a more informative factor. It is also of interest to note that in this same study deprivation levels did, in fact, have a significant effect upon IRTs even though a DRL-5 sec. schedule (a relatively easy time discrimination by comparison) was used. It simply did not have as great an effect as it did on the PRP.

If one looks at increasing deprivation from the standpoint of increasing the probability of a response, the Beers and Trumble (1965) study adds more evidence for an effect of deprivation upon performance. Using the double bar procedure that Mechner and Guevrkian (1962) used, they studied the effects of various magnitudes of reward. Using one, two, or four .045 gm. food pellets as reinforcement they trained rats on a DRL-18 sec. schedule, randomly presenting each reinforcement condition. The results clearly showed a negative linear relationship between the size of the reinforcement and the efficiency ratio (reinforced responses/ total responses). In other words, as the size of the reinforcement increased (and therefore the probability of a response) the efficiency of responding decreased. A conclusive statement based on the present information is difficult due to its' conflicting nature. It would appear, however, that low deprivation yields low response rates; compatible with the DRL requirements while high deprivation yields high response rates that interfere with performance on a DRL schedule.

The present study examines the effects of deprivation

upon the acquisition of a DRL schedule. It is hypothesized that three groups of animals trained on a DRL schedule while maintained at three distinct levels of deprivation will show significant differences in their rate of acquisition (based on efficiency). The direction of these differences showing more rapid acquisition for the low deprivation group; acquisition becoming slower with increased deprivation. The highest deprivation group showing the slowest acquisition.



## METHOD

### Subjects

Twelve male Holtzman albino rats served as subjects during the experiment. Ss were 120 days old at the beginning of the experiment.

### Apparatus

Four standard Gerbrands operant chambers (Model C) were used to train the Ss on the DRL-18 sec. schedule. The operant chambers were housed in sound attenuating chambers fitted with exhaust fans that provided some masking noise. The chambers were located in a separate room from the relay apparatus.

The relay control apparatus was programmed to deliver reinforcement only if a barpress was separated from a previous barpress by a minimum of 18 sec. Each barpress was recorded on one of 10 electromechanical counters, the counter being determined by the length of the IRT. The counters were arranged in a cumulative progression with each counter representing three seconds. Thus an IRT of six to nine seconds was recorded on counter three. All interresponse times of 27 sec. or greater were recorded on counter 10.

### Procedure

A matched groups design was employed to assign subjects, by weights, to their respective groups. Three groups were

used composed of four animals each. The groups were randomly assigned to one of three deprivation levels. The deprivation levels used were; 70%, 80% and 90% of the animals free-feeding weight.

The three groups were first brought to 80% of their free-feeding weights and bar-trained on a CRF schedule. This condition was maintained until each animal had recieved 500 .045gm. pellets. At this point the groups were returned to their home cages and their weights gradually brought to their respective experimental levels. When all animals had reached their proper weights, daily 90 min. sessions were started. Their were three sessions per a day consisting of four animals each. Assignment to each session was random with the restriction that at least one animal from each deprivation proup be included in each session. The animals were trained during these sessions on a DRL-18 sec. schedule.

RESULTS

Response efficiency (RE) ratios (reinforced responses/total responses), time efficiency (TE) ratios (reinforced responses/ optimal reinforced responses) and time-response efficiency (TRE) ratios ( $RE + TE/2$ ) were computed for each of the deprivation groups. The commonly used RE ratio was found to be insufficient in describing a subjects performance. The RE ratio accounts only for the efficiency of the reinforced responses relative to the total responses. Since this ratio does not account for how efficiently a subject uses available time (an important factor of the DRL schedule) the TE ratio was developed. The TRE ratio is an average of the TE and RE ratios and yields a more complete analysis of a subject's performance.

Figure 1 shows the changes in the mean TRE during acquisition of the DRL-18 sec. schedule for the 70%, 80% and 90% deprivation groups. The old 70% groups mean TRE (before dropping two animals, who did not acquire the schedule, from the analysis) is also presented. The difference between the three groups are minimal during the first five days of acquisition with the 90% group being slightly more efficient than the 80% group and the 70% group slightly less efficient than the 80% group. It can be seen, however, that the 70% group increases its efficiency rapidly over the next five days while the 80% and 90% groups show only gradual increases

in efficiency. By the 14th day the 80% and 90% groups are showing much steeper increases in efficiency while the 70% group evidences much more slight increases. By day 28 the 80% and 90% groups have continued to increase their efficiency until the differences between the three groups are again minimal.

Figures 2 and 3 show the changes in response efficiency and time efficiency, respectively, for each of the three groups. The trends during acquisition of these two performances measures are the same as those of the TRE. Figure 4 shows the reinforcement rates for each animal and Table 1 shows the mean reinforcements for each group on days 5, 15 and 28. Figure 5 shows the response rates for each animal and Table 2 shows the mean responses for each group on days 5, 15 and 28.

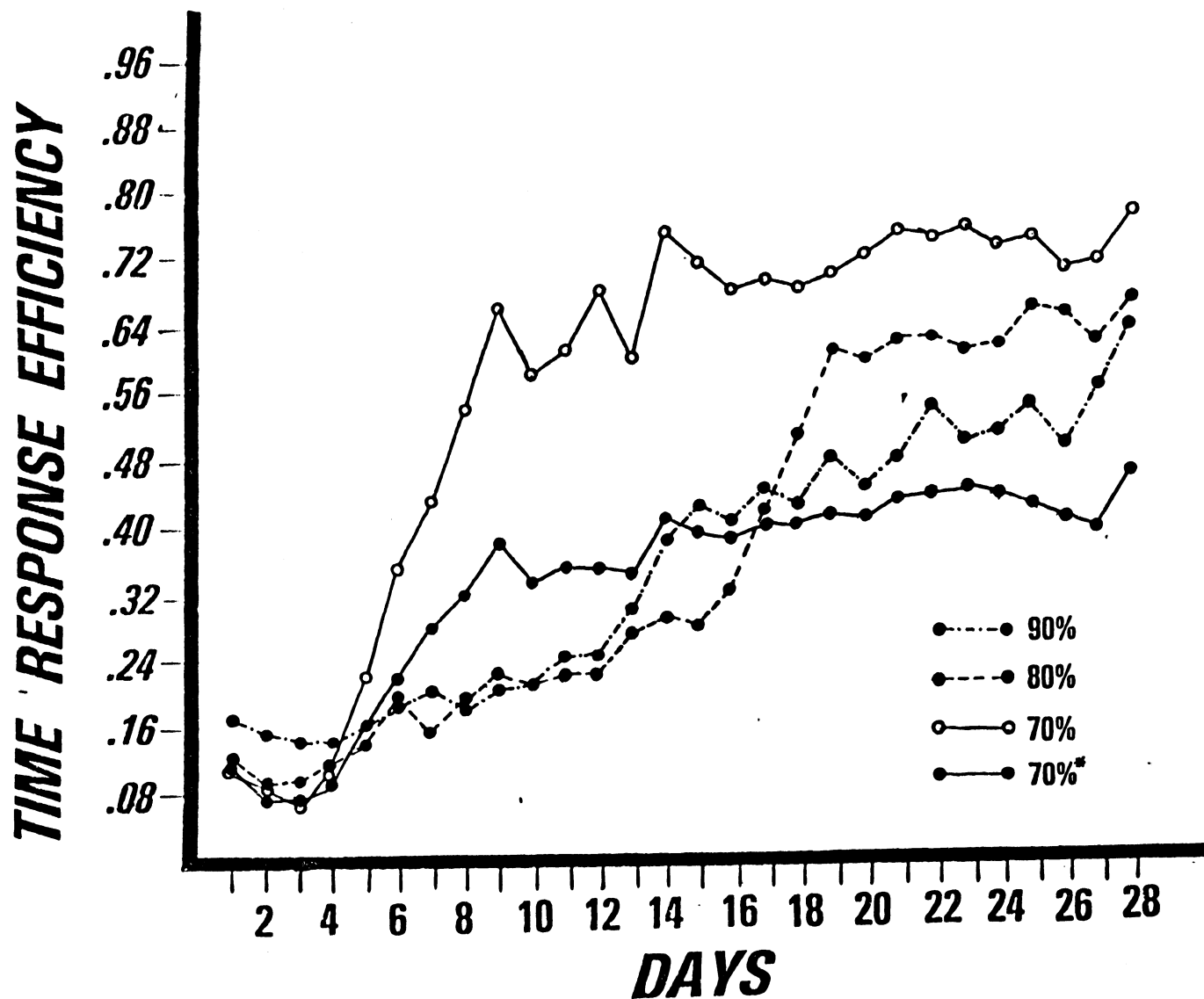


Figure 1

Graphical Representation of The  
Mean TRE Ratios For All Three Groups

\* 70% group containing all four animals

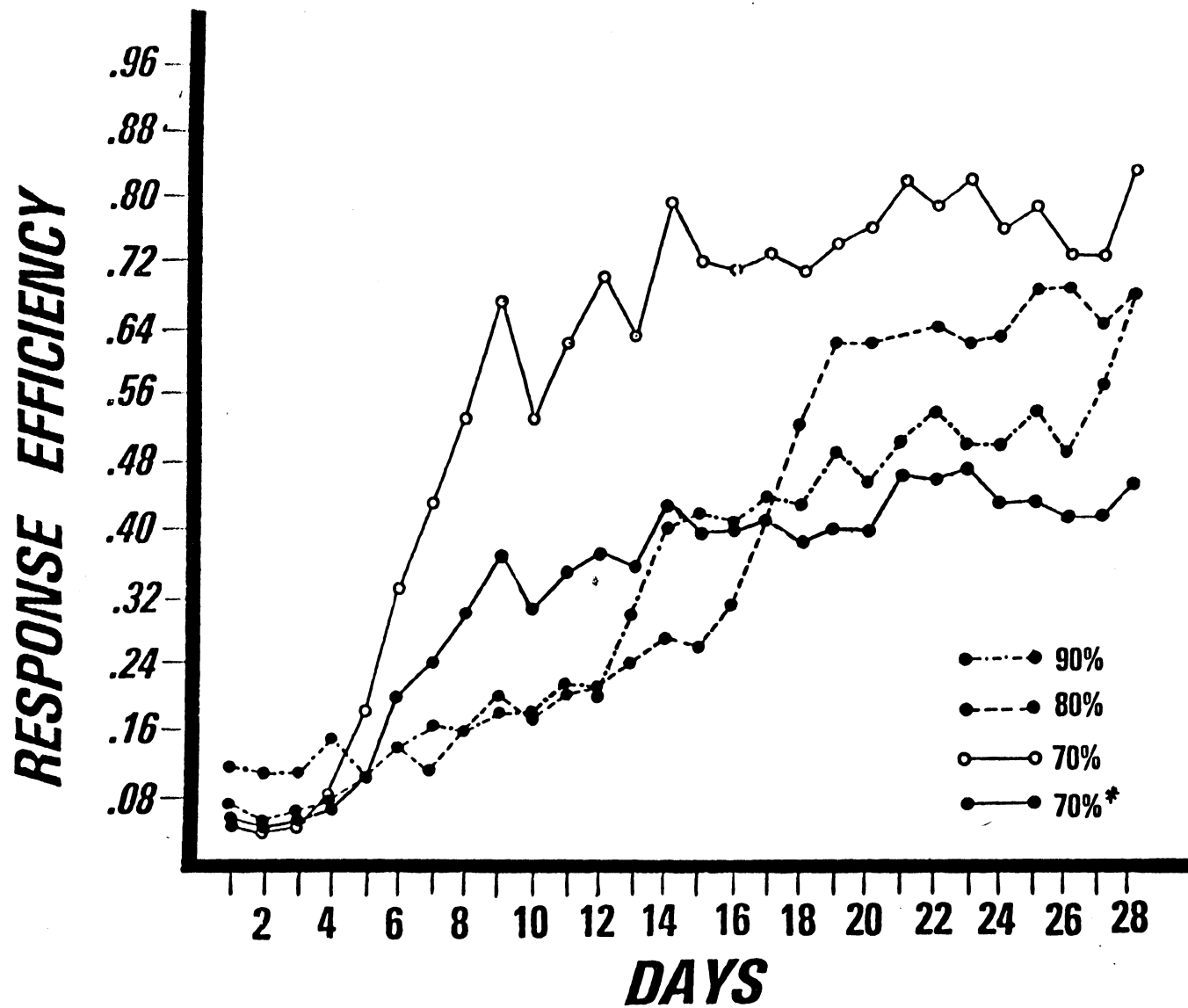


Figure 2

Graphical Representation of The  
Mean RE Ratios For All Three Groups

\* 70% group containing all four animals

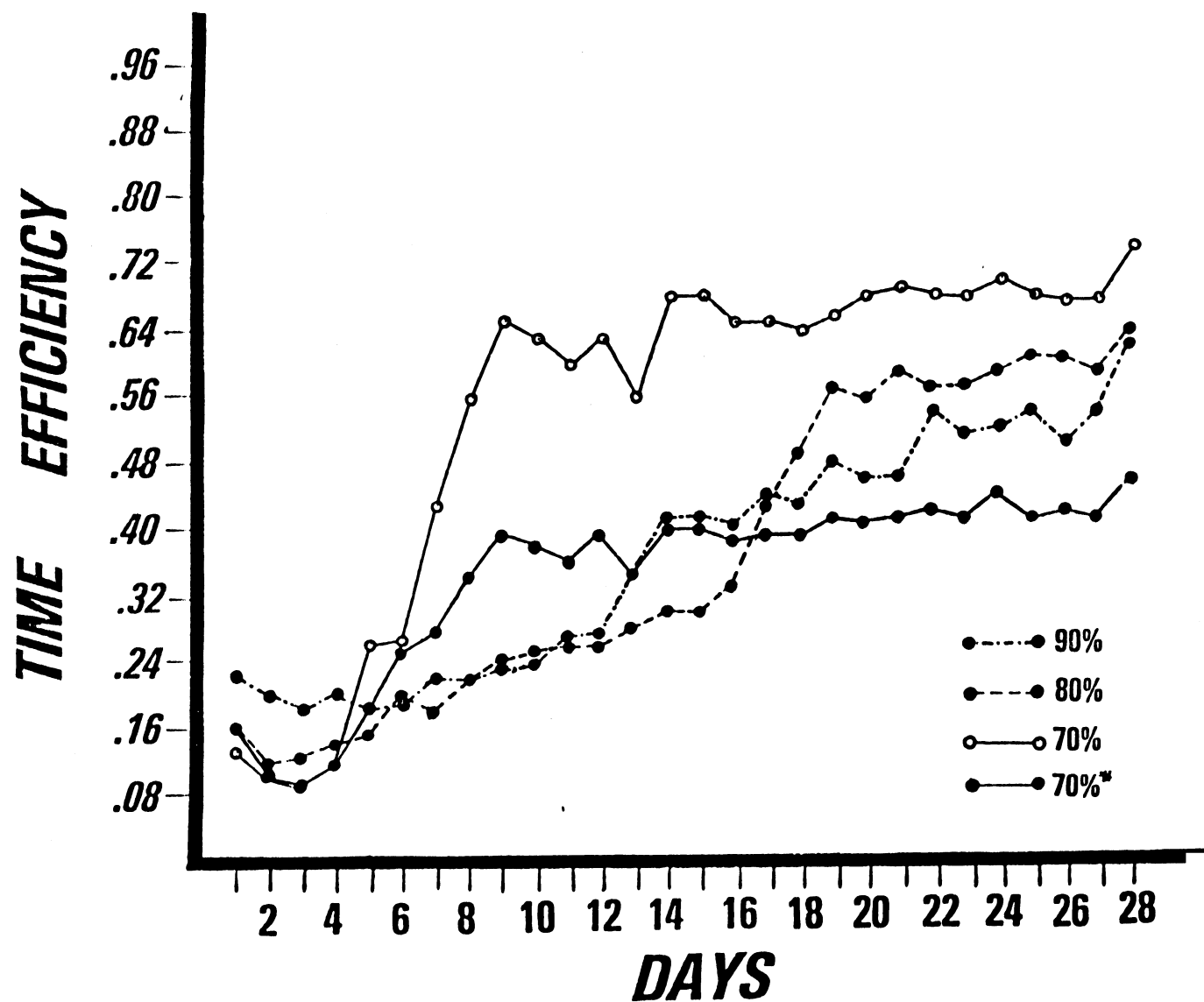


Figure 3  
 Graphical Representation of The  
 Mean TE Ratios For All Three Groups  
 \* 70% group containing all four animals

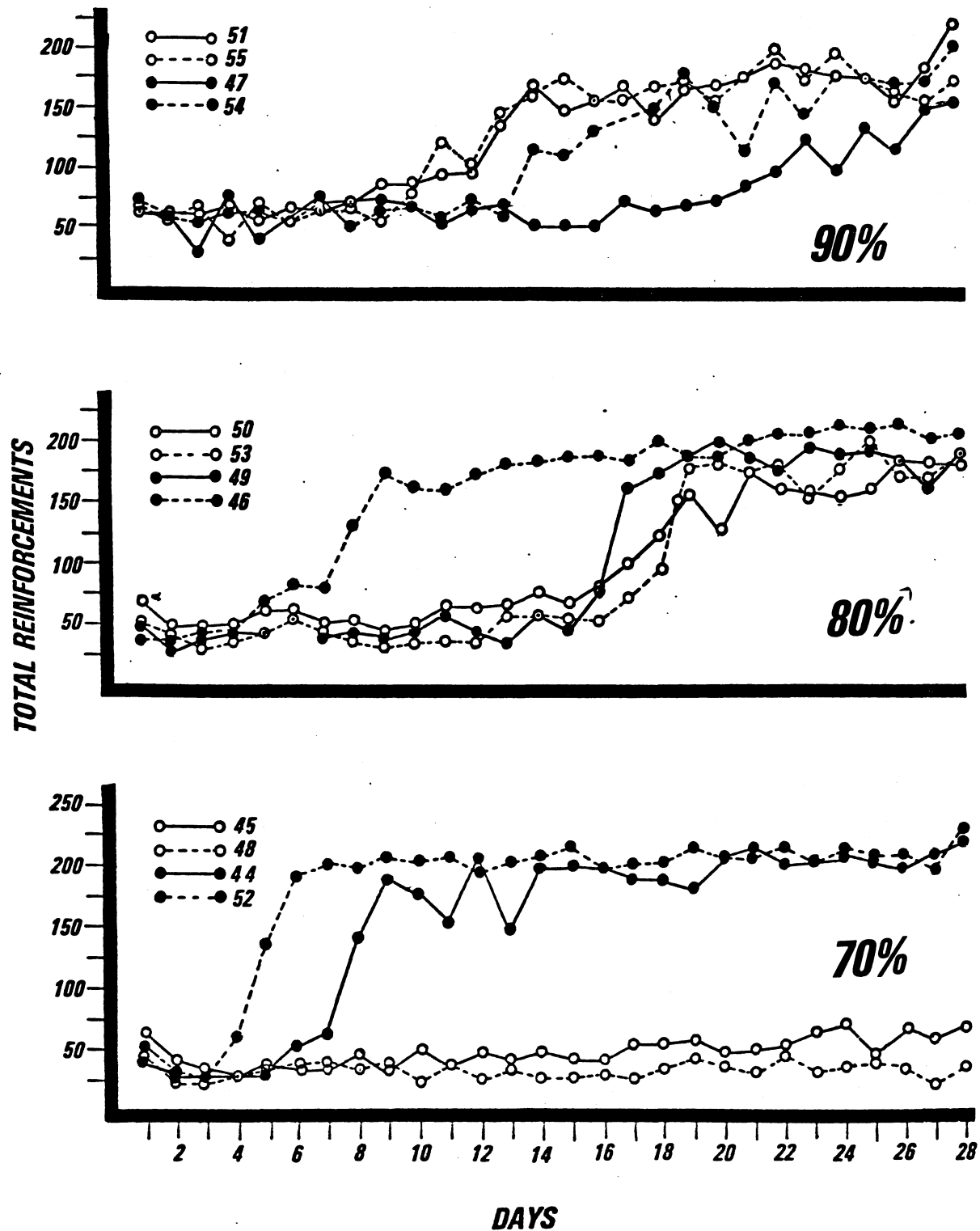


Figure 4  
Graphical Representation of The  
Reinforcement Rates for Each Animal of Each Group



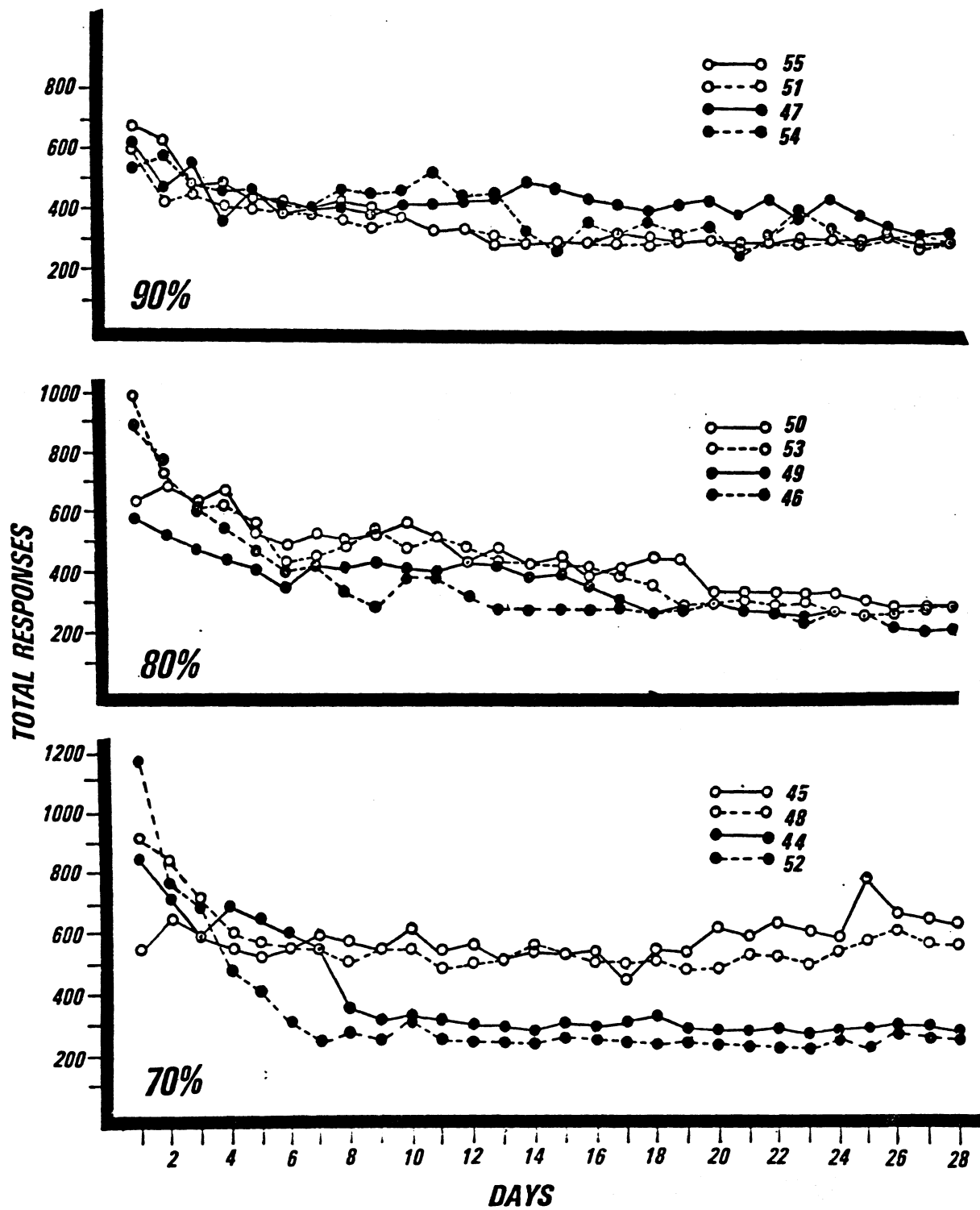


Figure 5  
Graphical Representation of the  
Response Rates For Each Animal of Each Group

TABLE 1

Mean Reinforcements For Each Group  
At Three Points During Acquisition

GROUPS			
DAY	70%	80%	90%
5	80	51.75	56
15	207	87.5	124
28	223.5	191.5	187.2

TABLE 1

Mean Responses For Each Group At  
Three Points During Acquisition

GROUPS			
DAY	70%	80%	90%
5	536	494	440
15	288	387	327
28	267	282	290

DISCUSSION

In studying the effects of deprivation upon acquisition of the DRL schedule, efficiency appeared to be the best indicator of a subject's performance (and therefore acquisition rate). The commonly used efficiency ratio (reinforced responses/ total responses), however, does not account for one important factor related to DRL schedules; how efficiently the subject used the available time. The DRL schedule requires that the subject respond only after a certain period of time has elapsed in order to gain a reinforcement. If he responded too soon he has lost that time. Also, if he waits longer than is necessary to respond he has again lost "valuable time". In order to maximize his total reinforcements during a session, the subject must respond precisely after the specified period of time has elapsed. The present study used a DRL-18 sec. schedule and 90 min. sessions. Under these conditions the animal could receive a maximum of 300 reinforcements if he made one response exactly every 18 sec. If he waits less than 18 sec. or longer than 18 sec. he has lost some of the time available to him and, therefore, reinforcements.

To take into account the subject's use of time during a session a second measure was developed; the TE ratio. This ratio is computed by dividing the number of reinforced responses by the maximum possible number of reinforcements in a session.

The importance of such a ratio becomes more apparent if we look at the hypothetical performance of two animals who would be considered equally efficient using the standard efficiency ratio (RE). Animal A receives 50 reinforcements and makes a total of 100 responses during a 90 min. session of DRL-18 sec. training. Animal B, under the same conditions, receives 100 reinforcements while making 200 responses. Their efficiency ratios, when computed, would each equal .500 and they would be considered equally efficient based on this information alone. Animal B, however, has gained twice as many reinforcements as animal A. Obviously, the performance of the two animals is not equal, as is evidenced if the TE ratios are computed. Animal A now has an efficiency ratio of .165 and animal B has an efficiency ratio of .333. To use the TE ratio only would also result in a biased measure of performance. Both components are necessary to get an overall view of the subjects performance in the DRL situation. To achieve an overall view an average of the two measures is computed  $(RE + TE / 2)$ . The resulting ratio is therefore a time-response efficiency (TRE) ratio.

In Figures 1, 2, and 3 we can see that the three ratios are generally the same in this study. Response efficiency does appear to fluctuate more than does time efficiency. A procedure in which TRE might prove a more valuable source of data is that of satiation. Reynolds (1964) found that as the subject's weight increases the response rate decreases, leading

to what he interprets as a finer temporal discrimination. He also states that the resulting changes in the IRT distribution are much the same as those of Holz and Azrin (1963) who used a satiation procedure. They, however, show a graphic representation of the changes in the IRT distributions. These distributions reveal that although the percent responses being reinforced is increasing, a large percentage of these reinforced responses are being recorded in the last bin. In other words, the animal is waiting much longer than is necessary to gain reinforcement. With an increased percentage of reinforced responses the subject's RE ratio will also increase. However, the decrease in responding may also have resulted in fewer total reinforcements. The TE ratio would, therefore, be decreasing with increasing satiation. This statistical discrepancy would probably be most evident at high satiation levels. The TRE ratio would, in this case, compensate for bias in the RE ratio.

By the final day of the present study two animals had still not adapted to the requirements of the schedule. Both these animals which were in the 70% group were dropped from the analysis. Looking at Figure 4, it can be seen that while all other animals showed marked increases in their reinforcement rates, animals #45 and #48 evidenced very little increase. The data presented in Figure 5 supports this position also. While all other animals show similar decreases in responding,

animals #45 and #48 evidence little decrease after day 3 and show a much higher and less adaptable response rate than the other two 70% animals.

Reasons for these two animals' lack of acquisition can only be guessed at. It should be noted, however, that while all other animals developed obvious collateral behaviors (chewing grid floor, sniffing top of chamber) coinciding with marked increases in their TRE, animals #45 and #48 did not appear to have developed any consistent collateral behaviors. (45 min. observations of the animal during a session were made the following day after a marked increase in reinforcements). This tends to support Laties et al. (1969) who also found that when collateral behavior is established the reinforcement rate increases markedly. It should also be noted that in this same study only three of five animals trained on a DRL-18 sec schedule developed collateral behaviors. The remaining two rats were given "artificial" collaterals (blocks of wood to nibble were placed in the chambers during the sessions).

It was observed during the present study that the feeder click in one of the experimental chambers was quieter than in any of the other chambers. Animals #45, #48 and #52 were run in this chamber. Although animals #45 and #52 appeared to be unaffected, the pellet dispenser was replaced with one more comparable to those in other chambers. Animal #48 was then

run two more days. The more audible relay click had no appreciable effect upon the animals performance. It did, however, decrease the number of responses in bin 1 by nearly 50% of what it had been on previous days. Apparently a more audible relay click increased the secondary reinforcing properties of the reinforcer and made reinforcement delivery more obvious. This lends support to the findings of Kramer (1968) and Sidman (1956) that few bursts occur after a reinforced response.

The hypothesis of the present study was not supported by the data. In fact, the rate of acquisition is somewhat opposite that predicted. Although the 80% and 90% groups do not differ markedly, the 70% group reached and maintained a high efficiency of responding much quicker than the other two groups. The fact that deprivation effects were studied during acquisition rather than after stabilization of responding may be important in analyzing this discrepancy with other research.

A possible approach to further research may involve the development of collateral behaviors and their relationship to activity levels. A number of researchers have noted that increased food deprivation resulted in increased activity (Richter, 1922; Siegel and Steinberg, 1949; Teitlebaum, 1957). This increase in restless activity should result in increased exploratory behavior. If this keeps the animal away from the bar long enough he will eventually make a reinforced

response. This is the same process for the development of collateral behavior as described by Wilson and Keller (1953).

Also, in most studies of the effects of deprivation on DRL responding, the deprivation levels are not altered until after responding has stabilized. Collateral behaviors are likely to have already developed if responding is truly stable. The degree to which the deprivation state is altered possible determines the degree to which it will affect this response chain. However, if the deprivation state is held constant then its effect should also be constant and if the deprivation condition is applied during acquisition of the DRL schedule then it is the acquisition of the collateral behavior that is affected. It may be concluded, therefore, that due to these conditions the 70% group of the present study showed quicker acquisition than did the other two lower deprivation groups.

Admittedly, the evidence for such a conclusion is not overwhelming. Most of the support for such a conclusion is observational in nature. None the less, a discrepancy between the results of this study and those of previous research exists. The approach suggested here would at least provide a starting point for further research.



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