Selective punishment of temporally spaced responding

George Howard Davol

The University of Montana

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SELECTIVE PUNISHMENT OF TEMPORALLY
SPACED RESPONDING

By
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B.A. Cal. State University at Humboldt, 1971

A committee draft submitted in partial fulfillment of the requirements for the
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UNIVERSITY OF MONTANA
1973

Approved by:

[Signatures]
Chairman, Board of Examiners
Dean, Graduate School
Date
Dec. 8, 1974
ACKNOWLEDGMENTS

I wish to extend my appreciation to my committee chairman, Dr. Andrew Lee for his patience, timely comments, and critical reviews. I would also like to thank my committee members, Drs. Francis Hill, Charles Allen and Evan Jordon for their comments and time devoted to this thesis.
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CHAPTER I

INTRODUCTION

Ferster and Skinner (1957) used the term differential reinforcement of low rates (DRL) to designate a schedule requirement of a long inter-response time (IRT), which is the time interval between successive responses. Skinner (1938) has shown that by reinforcing a single relatively long IRT on a fixed interval schedule of reinforcement, the effect of reinforcement is to decrease the rate of response. Wilson and Keller (1953) manipulated the length of a reinforced IRT and found it to be inversely related to the rate of responding. That is to say, as the length of the reinforced IRT increases, the rate of responding decreases.

The DRL schedule is commonly programmed in the following manner. All IRTs must be of a minimum specified duration in order to be reinforced. IRTs that fall short of this minimum time duration reset the timing contingencies. Thus all IRTs greater than or equal to \( t \)-seconds yield reinforcement and likewise all IRTs less than \( t \)-seconds yield non-reinforcement. Kramer and Rilling (1969) described \( t \) as being normally measured from either the last response, the last reinforcement, or the start of the session, whichever had occurred most recently. The frequency of reinforcement is thus a function of the number of times the organism emits IRTs of \( t \) seconds or greater over the total session time. If an organism fails to emit any IRTs greater than \( t \), his frequency of reinforcement will be zero.
DRL behavior is customarily recorded and analyzed in the following manner. The time intervals between successive responses, IRTs, are recorded in class intervals called bins. For instance we may group all IRTs from 0-2 seconds in the first bin, 2-4 seconds in the second bin, and so forth until there are enough bins such that each IRT must necessarily fall into a bin. A "dump" bin is usually employed for IRTs that far exceed the minimum specified IRT for reinforcement. A first order probability density distribution, better known as an interval histogram may be derived from the frequency counts in each IRT bin. In a distribution of this nature IRT bins are plotted on the abscissa with either frequency or probability as the ordinate. This distribution may also be referred to as an IRT frequency distribution.

A characteristic of DRL responding is a large number of short IRTs less than two seconds in length. Sidman (1956) termed these short IRTs, "bursting". Typically the relative frequency distribution of IRTs for an organism stabilized on a DRL schedule is bimodal with the first mode occurring in the first bin (0-2 sec), and a second mode occurring just prior to the reinforced IRT. Between these two modes, the relative frequency is near zero. A limited-hold contingency (LH) may be imposed on the DRL schedule. The limited-hold contingency imposes an upper limit on the IRTs which will be reinforced. Thus the response requirement requires the organism to delay responding for \( t \) sec but not for more than \( t + t' \) sec from the previous response to obtain reinforcement. Laties,
Weiss, and Weiss (1969) have demonstrated that the limited-hold contingency seems to increase the probability of responding for a reinforced IRT and leads to a decrease in IRTs too short for reinforcement.

Discrimination between stimuli is inferred if there is a greater probability of responding to one stimulus than to another. In the DRL schedule the stimulus to respond is presumably time itself. Temporal discrimination was defined by Kramer and Rilling (1969) to be an increased probability of responding only at such time when the probability of reinforcement is likewise high. The organism that has not formed a temporal discrimination will not show an increased probability of responding at the reinforced IRT.

A second type of distribution, more sensitive to temporal discrimination than the IRT frequency distribution, is the distribution Shimp (1967) referred to as "dwell time". The dwell time distribution is a transformation of the IRT frequency distribution calculated by multiplying the number of entries in a bin by the midpoint of the bin. Weiss (1970) points out that the dwell time distribution is a more revealing index of DRL discrimination than the frequency distribution because early bursting responses are discounted due to the time factor involved in weighting the distribution. In calculating a dwell time distribution from a bimodal IRT frequency distribution, the bimodality of the derived distributions is less obvious. Even though the dwell time distribution is bimodal, temporal discrimination is reflected to a greater degree since typically the probability
of a bursting response is much lower than that of a response occurring near the reinforced IRT. This occurs because of the time weighting given to long IRTs in the dwell time distribution.

When compared with rats, monkeys, and humans, pigeons for the most part perform poorly on DRL schedules. Reynolds (1964 a, b) has pointed out that pigeons maintain a rate of responding far higher than that required by the schedule. Pigeons normally pick up less than 2 per cent of the programmed reinforcement on a DRL 20-sec or DRL 30-sec schedule, (Holz & Azrin, 1963; Holz, Azrin & Ulrich, 1963; Kramer & Rilling, 1969).

Kramer and Rilling (1969) stated that only a very few of the many studies involving DRL have attempted to investigate this observed deficiency in responding on a DRL 20-sec or 30-sec schedule with a pigeon. Kramer and Rilling (1969) believed pigeons to be able to form long temporal discriminations, citing the works of Rilling (1967), Stubbs (1968) and Reynolds and Catania (1962) as evidence. Reynolds and Catania (1962) found that pigeons were able to discriminate 27 from 30 seconds in responding to a lighted key. Pigeons were reinforced for pecking a lighted key on a VI 20-sec schedule only if that key had been dark for 30 seconds, however they were not reinforced if the key had been dark for 27 seconds. Rates of responding were found to be much higher after 30 seconds than after 27 seconds, demonstrating temporal discrimination. Kramer and Rilling (1969) felt that since pigeons are a widely used experimental animal, some attempt should be made to investigate the observed inefficiency of the pigeon's DRL behavior, and to determine whether this
inefficiency is truly characteristic of this organism. One possible mode of investigation is through the use of punishment.

**Punishment of DRL Responding**

Azrin and Holz (1966) defined punishment to be a reduction of the future probability of a response as a result of the immediate delivery of a stimulus for that response. In most schedules of reinforcement punishment decreases the probability of reinforcement by decreasing the rate of responding. Typically, when punishment is no longer contingent upon responding, the frequency of reinforcement returns to its pre-punished level.

Since punishment decreases the probability of a response, thus lengthening IRTs, DRL behavior should improve as a result of punishment. Holz, Azrin and Ulrich (1963) punished all responses on a DRL 30-sec Appetitive Reinforcement schedule with electric shock. They demonstrated that rate of responding to be inversely related to shock intensity with frequency of reinforcement reaching a maximum value and then decreasing at the highest intensities of shock. Holz, Azrin and Ulrich (1963) found that the increased frequency of reinforcement due to a lowered response rate was not maintained after punishment was removed. It was also noted in this study that the IRT frequency distribution did not change uniformly as a function of shock but rather that the number of short IRTs (bursts) was greatly reduced.

Holz and Azrin (1963) conducted a second experiment along these same lines, comparing the suppressive effects of punishment, satiation, extinction, and stimulus change, on responding in a DRL 30-sec appetitive
paradigm. Punishment, in this case shock, was found to be a more immediate and long lasting suppressor than either of the other three. Holz and Azrin (1963) noted that punishment had its greatest effect on the least relevant responses to the overall frequency of reinforcement. That is to say bursting responses are the least relevant since their elimination does not greatly effect the overall frequency of reinforcement. Holz and Azrin (1963) state that "since their elimination does not reduce the rate of reinforcement, they appear to be relatively more sensitive to punishment." Thus punishment produced a temporal response pattern that allowed a large reduction of punishments as evidenced by the examination of the IRT frequency distribution which shows a large reduction in short IRTs with the median IRT moving toward one of a progressively longer duration. Kramer and Rilling (1969) confirmed Holz and Azrin's findings using blackout as punishment instead of shock.

Leitenberg (1965) reviewed the literature on blackout and found it to have aversive properties yielding behavioral results much like shock. Kramer and Rilling (1969) ran a DRL 20-sec schedule with blackout as punishment for all IRTs shorter than 20 seconds and similarly found rate to be suppressed, with an initial increase in the frequency of reinforcement. However, IRT distributions returned to pre-punished levels when blackout was removed. Kramer and Rilling (1969) found as did Holz and Azrin (1963) that the shortest IRTs were virtually eliminated under the punished condition.
The Experiment

Kramer and Rilling (1969), Holz, Azrin, and Ulrich (1963) and Holz and Azrin (1963) in punishing DRL responding punished all responses. The proposed experiment, however, punished responses based on select IRT categories. The experiment was unlike previous studies in that IRT classes were punished separately and an index of response suppression was employed to measure the varying sensitivities of the different IRT classes to punishment. Holz (1963) concluded that bursting responses were less relevant responses for reinforcement, thus more sensitive thereby accounting for their rapid elimination. The implication of this statement is that punishment differentially effects different IRT classes depending upon their relevancy which Holz and Azrin (1963) defined as reduction of reinforcement frequency. However, their paradigms did not specifically examine the varying sensitivity of IRT classes to punishment. The experiments of Kramer and Rilling (1969), Holz, Azrin and Ulrich (1963) and Holz and Azrin (1963) though seemingly demonstrating differential effects of punishment on different IRT classes, did not actually differentially punish various IRT classes.

The present study examined the effects of punishment on an IRT class as evidenced by the latency of post blackout responses. In the present study the post blackout latency distribution is a frequency distribution composed only of those IRTs that follow punishment. Post blackout response rates and efficiency ratios can be derived from the post blackout latency distribution, and as such serve as an index of
response suppression. Neuringer and Schneider (1968) employed a post blackout latency distribution as an index of response strength. The post blackout latency distribution revealed response latencies to be linearly related to interreinforcement time on both an FR and FI schedule, whereas they were not correlated with the number of interreinforcement responses. Staddon and Innis (1969) in studying reinforcement omission found that as blackout duration increased post blackout latency decreased on an FI 2 min schedule. Both of the above mentioned studies employed post blackout latency as a measure of response strength. The present study employed the post blackout latency distribution of responses following punishment as an index of suppression. One of the experimental objectives was the comparison of the post blackout response rates and efficiency ratios between punished bursting responses, and the punished modal point of the pre-punished IRT frequency distribution. This technique of comparing post blackout response rates and efficiency ratios for the two different classes of punished responses should reflect the sensitivity of that particular IRT class to punishment. Sensitivity to punishment is to the extent to which responding is suppressed. If one class is more sensitive to punishment than another the post blackout response rate should be lower for that class and likewise efficiency should be greater. If, however, there appears to be no differences between the post blackout rates we may conclude that Holz and Azrin (1963) were unjustified in claiming the rapid elimination of bursting responses was a function of their sensitivity, but rather that: (1) punishment may have
served as feedback for the bursting response, or (2) bursting responses are emitted more frequently and thus have a higher frequency of punishment. Thus a decrease in the large number of short IRTs will lead to a large reduction of punishment.
CHAPTER II

METHOD

Subjects

The subjects were three experimentally naive adult white Carneaux pigeons, maintained at 80 per cent of their free feeding weight.

Apparatus

A Lehigh Valley Electronics three-key pigeon chamber was employed. The chamber measured 31 x 34 x 34 cm. The response keys, 2.5 cm in diameter, were mounted 20 cm. from the floor and 10 cm. above the top of the feeder aperture. Reinforcement was 6 seconds access to grain, obtained through a 4 by 6 cm. feeder aperture, located 6 cm. above the floor. Exteraneous noise was controlled with a Lehigh Valley Electronics attenuation shell and a Grason-Stadler white noise generator, model 455C. Solid state digital logic was used to program all experimental events. Responses and reinforcements were recorded on electromagnetic counters. Post blackout latency response intervals were taken on a print-out-counter (Moduprint-Model MMP-6), manufactured by Practical Automation, Inc. The programming circuitry and the pigeon chamber were housed in adjacent rooms.

Procedure

Kramer and Rillings' (1969) procedure of conditioning DRL behavior
was employed. During the first few sessions pecks on the center key were conditioned. The reinforcement schedule employed was CRF and the sessions were terminated after 25 reinforcements were delivered. The house lights were on continuously as well as the lighted center key, except during the delivery of a reinforcement, at which time the grain hopper reinforcement light was turned on and the house light and center key light were darkened. Once stable CRF behavior was conditioned the subjects were placed on DRL (t) second schedule. In this case (t) was measured from either the last reinforcement, the beginning of the session, or the last response which ever had occurred most recently. The initial value of (t) was one second. On each succeeding day (t) was increased by one second, if the behavior of the subject allowed, until a DRL 20-sec schedule was in effect. The subjects were maintained on a DRL 20-sec schedule until stability was achieved. This was the initial baseline condition (B₁). Stability was evidenced by a stable efficiency ratio for a period of five days in addition to a stable frequency distribution for a period of five days. The efficiency ratio is derived by dividing the total number of responses by the total number of reinforcements. Daily sessions for each pigeon were either terminated by 25 reinforcements or 1 hour of running time.

The experiment consisted of four phases once DRL behavior was conditioned. In the first phase, punishment of short IRTs (Pₛ), all IRTs less than two seconds were punished by a ten second blackout at which time the house light, and key light were darkened and further responding
had no consequences. Time \( t \) was now measured from either the last reinforcement, the start of the session, the last response, or the end of blackout, whichever had occurred most recently. Phase one was in effect until stability of responding was recorded for 5 days, as evidenced by the subjects' efficiency ratio and frequency distributions. During the second phase, punishment was no longer delivered for IRTs shorter than 2 seconds. This baseline phase \( B_2 \) was employed to recover a stable baseline performance and was continued until stability was achieved.

In the third phase, long IRT punishment \( P_L \), the modal IRT category closest to the DRL criterion was punished for each pigeon. The 16-20 sec IRT category was punished for pigeon #1134 since the majority of IRTs terminated by this pigeon during stable DRL 20 sec responding fell into the 16-20 sec IRT category bin. For pigeon #533 the 8-12 sec IRT category contained the majority of IRTs emitted during initial DRL 20 sec responding and were thus punished. The 4-8 second category contained the majority of IRTs for pigeon #5992. However the 8-12 sec category was punished for pigeon #5992 since the difference between the 4-8 sec and 8-12 sec category was small and the 8-12 sec category was closer to the DRL criterion. Phase three was continued until stability was achieved.

The fourth phase consisted of another baseline recovery phase \( B_3 \) in which punishment was removed and behavior was allowed to stabilize. The procedure table outlines the experimental phases and their order of occurrence for each pigeon:
**EXPERIMENTAL ORDER OF PHASE**

Pigeon

<table>
<thead>
<tr>
<th></th>
<th>B1</th>
<th>P_L</th>
<th>B2</th>
<th>P_s</th>
<th>B3</th>
</tr>
</thead>
<tbody>
<tr>
<td>#1134</td>
<td>B1</td>
<td>P_L</td>
<td>B2</td>
<td>P_s</td>
<td>B3</td>
</tr>
<tr>
<td>#533</td>
<td>B1</td>
<td>P_L</td>
<td>B2</td>
<td>P_s</td>
<td>B3</td>
</tr>
<tr>
<td>#5992</td>
<td>B1</td>
<td>P_s</td>
<td>B2</td>
<td>P_L</td>
<td>B3</td>
</tr>
</tbody>
</table>

B_1 - initial DRL 20 sec responding

P_L - punishment of long IRTs

P_s - punishment of burst responses

B_2 - recovery baseline

B_3 - recovery baseline
CHAPTER 3

RESULTS

Figure 1 shows the effects of punishment on the percentage of bursting responses. Each value represents the average percentage of bursting responses that occurred during the last five days in each condition. Figure 1 shows that burst responding was facilitated by burst punishment whereas bursting occurred less frequently during 16-20 sec and 8-12 sec punishment. Thus the response rate increases and decreased efficiency present during burst punishment occurred concurrently with large increases in the frequency of response bursting. Figure 1 shows that roughly half the IRTs emitted during the burst punishment phase by pigeons #533 and #5992 were bursting responses.

The effects of punishment on 8-12 and 16-20 sec IRTs are shown in Figure 2. Each value shown represents an average of the last five days in each condition. Pigeons #1134 and #533 showed suppression of 16-20 and 8-12 sec IRTs, over preceding stable DRL 20 sec responding, when punishment was contingent upon their emission. However pigeon #5992 showed a slight increase in 8-12 sec IRT emission, over the preceding stable DRL 20-sec responding, when punishment was contingent upon emission of 8-12 sec IRTs. This increase may be attributed to the
FIGURE 1
THE EFFECT OF PUNISHMENT ON THE PERCENTAGE OF BURSTING RESPONSES

EXPERIMENTAL PHASES ARE PRESENTED IN ORDER OF OCCURRENCE.
EACH VALUE REPRESENTS AN AVERAGE OF THE LAST FIVE DAYS IN EACH CONDITION.

**Pigeon**

<table>
<thead>
<tr>
<th></th>
<th>Initial 20 sec DRL</th>
<th>16-20 sec 1st pun.</th>
<th>Burst pun.</th>
<th>Final recovery</th>
</tr>
</thead>
<tbody>
<tr>
<td>1134</td>
<td>14.9%</td>
<td>6.4%</td>
<td>25.2%</td>
<td>14.4%</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Initial 20 sec DRL</th>
<th>8-12 sec 1st pun.</th>
<th>Burst pun.</th>
<th>Final recovery</th>
</tr>
</thead>
<tbody>
<tr>
<td>533</td>
<td>7.1%</td>
<td>10.7%</td>
<td>51.7%</td>
<td>19.7%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Initial 20 sec DRL</th>
<th>8-12 sec 1st pun.</th>
<th>Burst pun.</th>
<th>Final recovery</th>
</tr>
</thead>
<tbody>
<tr>
<td>5992</td>
<td>18.6%</td>
<td>5.6%</td>
<td>47.8%</td>
<td>9.6%</td>
</tr>
</tbody>
</table>
FIGURE 2
THE EFFECTS OF PUNISHMENT ON 8-12 AND 16-20 SECOND IRT'S.

EACH VALUE REPRESENTS AN AVERAGE OF LAST FIVE DAYS IN EACH CONDITION

pigeon

1134

<table>
<thead>
<tr>
<th></th>
<th>Initial 20 sec. drl</th>
<th>16 - 20 sec. lrt pun.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percentage</td>
<td>27.7%</td>
<td>15.3%</td>
</tr>
</tbody>
</table>

533

<table>
<thead>
<tr>
<th></th>
<th>Initial 20 sec. drl</th>
<th>8-12 sec. lrt pun.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percentage</td>
<td>34.0%</td>
<td>22.1%</td>
</tr>
</tbody>
</table>

5992

<table>
<thead>
<tr>
<th></th>
<th>Initial 20 sec. drl</th>
<th>8-12 sec. lrt pun.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percentage</td>
<td>26.1%</td>
<td>28.7%</td>
</tr>
</tbody>
</table>
finding that 8-12 sec punishment for pigeon #5992 resulted in an increased emission of IRTs relatively longer than those emitted during stable DRL responding.

Figure 3 shows the effects of punishment on IRTs. Four experimental phases are shown for each bird going from top to bottom. The phases from top to bottom in order are: initial 20 sec DRL responding, either 16-20 or 8-12 sec IRT punishment, burst punishment, and the final recovery phase. The IRT categories are in 4-sec intervals with the reinforced IRTs indicated by dotted bars. It is evident from Figure 3 that the effect of 16-20 and 8-12 sec IRT punishment was to shift the distribution toward longer IRTs. The effect of burst punishment was to shift the distributions toward shorter IRTs. The distributions marked final recovery indicate that after removal of all punishment contingencies the distributions shifted back in the direction of initial values.

Dwell time (Shimp, 1967) was chosen as an index of temporal discrimination. Weiss (1970) points out that dwell time is the most revealing index of temporal discrimination because early bursting responses are discounted due to the time factor involved in weighting the distribution. Figures 4, 5, and 6 are dwell time distributions for the three experimental pigeons. In order to facilitate comparisons between the two punishment phases dwell time was expressed as a percentage of total session time occupied by each IRT category. Although the figures show some similarities between punishment phases for each bird, distinct trends do exist. If the tendency to emit bursting responses is any indication of poor temporal discrimination,
FIGURE 3
THE EFFECT OF PUNISHMENT ON INTER-RESPONSE TIMES (IRT). FOUR EXPERIMENTAL PHASES ARE SHOWN FOR EACH BIRD GOING FROM TOP TO BOTTOM. REINFORCED IRT'S ARE INDICATED BY DOTTED BARS.
the dwell time distributions for either 16-20 sec or 8-12 sec IRT punishment reflect superior temporal discrimination, relative to the burst punishment phase, for all three pigeons. Burst punishment dwell time distributions are indicated by broken lines whereas solid lines indicate dwell time for either 16-20 or 8-12 sec IRT punishment. Values shown are averages of the last five days in each condition. Figure 4 indicates that pigeon #1134 spent a greater percentage of session time emitting 0-2 sec IRTs during the burst punishment phase than during 16-20 sec IRT punishment. This finding is most marked in pigeons #533 and #5992 whose distributions may be found in Figure 5 and 6, respectively. Pigeons #533 and #5992 spent a relatively longer amount of session time emitting bursting responses when punishment was contingent upon their emission than when punishment was contingent upon 8-12 sec IRTs.

Figure 4 indicates a tendency for pigeon #1134 to spend more time emitting reinforced IRTs during 16-20 sec IRT punishment relative to the time spent emitting reinforced IRTs during the burst punishment phase. Table 6 in the Appendix shows that nearly twice as much time was spent emitting reinforced IRTs during 16-20 sec IRT punishment than during burst punishment. Figures 5 and 6 also show a tendency for pigeons #533 and #5992 to spend relatively more time emitting reinforced IRTs during 8-12 sec IRT punishment, than during burst punishment.

Table 1 shows post blackout response frequencies for the three pigeons. The post blackout response frequencies were derived from post
The proportion of total session time occupied by each IRT category for the two punishment phases. Values shown represent an average of the last five days in each condition.

**Figure 4**

**Dwell Time—Pigeon 1134**

The percentage of session time occupied by each IRT category in 2-sec. intervals.
The proportion of total session time occupied by each IRT category for the two punishment phases. Values shown represent an average of the last five days in each condition.
The proportion of total session time occupied by each IRT category for the two punishment phases. Values shown represent an average of the five days in each condition.
blackout latency distributions composed of just those IRTs following blackout. All values shown represent averages of the last five days in each condition. Table 1 shows that post blackout response frequencies are higher following burst punishment than following punishment of either 8-12 or 16-20 sec IRTs for all three pigeons.

Post blackout efficiency is shown in Table 2. Post blackout efficiency, like post blackout response frequency, was derived from a post blackout frequency distribution of responses. Post blackout efficiency was calculated by dividing the total number of reinforced responses following blackout by the total number of responses following blackout. Each value is an average of the last five days in each punishment phase. Table 2 shows that efficiency tended to be higher following punishment of long IRTs than following burst punishment. This finding is in agreement with the finding that response frequencies following long IRT punishment were lower than response frequencies following burst punishment.

Complete tables of Response Frequency, Reinforcement Frequency and Efficiency may be found in the Appendix. A table showing the percentage of reinforced dwell time for both punishment phases may also be found in the Appendix. The tables of Response Frequency (3), Reinforcement Frequency (4), and Efficiency (5) are contained in the Appendix due to the fact that they do not show the marked changes during the punishment phases as do the IRT distributions.
### Table 1
**Post Blackout Response Frequency**
- responses per minute -

<table>
<thead>
<tr>
<th>pigeon</th>
<th>Burst Punishment</th>
<th>8-12 sec. IRT Punishment</th>
<th>16-20 sec. IRT Punishment</th>
</tr>
</thead>
<tbody>
<tr>
<td>1134</td>
<td>5.76</td>
<td></td>
<td>4.81</td>
</tr>
<tr>
<td>533</td>
<td>5.90</td>
<td>5.73</td>
<td></td>
</tr>
<tr>
<td>5992</td>
<td>6.70</td>
<td>6.02</td>
<td></td>
</tr>
</tbody>
</table>

Each value shown represents an average of the last five days in each condition.

### Table 2
**Post Blackout Efficiency**
Percentage of reinforced responses following blackout

<table>
<thead>
<tr>
<th>pigeon</th>
<th>Burst Punishment</th>
<th>8-12 sec. IRT Punishment</th>
<th>16-20 sec. IRT Punishment</th>
</tr>
</thead>
<tbody>
<tr>
<td>1134</td>
<td>16.07%</td>
<td></td>
<td>18.54%</td>
</tr>
<tr>
<td>533</td>
<td>5.59%</td>
<td>6.04%</td>
<td></td>
</tr>
<tr>
<td>5992</td>
<td>1.57%</td>
<td>2.60%</td>
<td></td>
</tr>
</tbody>
</table>

Each value shown represents an average of the last five days in each condition.
Kramer and Rilling (1970) hypothesized that the punishment of a band of IRTs around the modal IRT might produce an effect similar to the punishment of all unreinforced IRTs. The effect referred to is the reduction of short IRTs and a subsequent shift in the IRT distributions toward longer IRTs; (Holz and Azrin, 1963; Holz, Azrin, and Ulrich, 1963; Kramer and Rilling, 1969). Data from the present study on modal IRT punishment appears to support this hypothesis. The lowest percentage of bursting responses emitted by pigeons #1134 and #5992 occurred during 16-20 and 8-12 sec IRT punishment respectively. Concomitant with a decrease in bursting responses an increase in long IRTs occurred. Pigeon #533 likewise emitted relatively few bursting responses during 8-12 sec IRT punishment and also demonstrated a tendency to emit long IRTs.

Kramer and Rilling (1970) suggested that bursting responses appear to be due in part to a lack of stimulus feedback from the response manipulandum. Kelleher, Fry, and Cook (1959), noted that the removal of a response produced relay click, for rats emitting relatively few bursting responses and stabilized on a DRL 20 second limited hold 5 second schedule, produced an increase in the percentage of bursting responses. Kramer (1968) and Sidman (1956) found bursting to occur
relatively infrequently following reinforcement. Kramer and Rilling (1970) thus reasoned that if bursting is due to a lack of stimulus feedback then punishment consequent on burst emission should reduce the probability of a burst response. Data from the present study demonstrates just the opposite to be the case, namely burst response produced blackout facilitated burst responding.

Along this same line Holz and Azrin (1963) postulated that the rapid reduction of bursting responses, when all unreinforced IRTs were punished, was a direct result of bursts being the most sensitive variety of IRTs due to their relative overall unimportance to reinforcement frequency and their high rate of emission. Data from the present study, namely post blackout response frequencies and post blackout efficiency indicate that short IRTs are more likely to occur following burst punishment, whereas the percentage of bursting responses are reduced during long IRT punishment.

One plausible explanation for the finding that burst responding was maintained and facilitated by burst punishment is one of self-imposed time out (TO). TO is a condition analagous to extinction during which further responding has no consequences. Hernstein (1955) has shown that TO can function either to reward or punish behavior depending upon the baseline schedule upon which it is imposed. Hearst, Koresko, and Poppen (1964) believe the DRL schedule to be semi-aversive and Shimp (1968) has demonstrated pigeons prefer to emit short IRTs. Kramer and Rilling (1970)
have hypothesized that since DRL schedules require long IRTs pigeons might respond to escape DRL parameters.

Data from the present study indicated burst responding was maintained and facilitated by response produced blackout. In other words, blackout was not serving as a punisher as defined by Azrin & Holz (1966), but rather that of a reinforcer. Blackout in this instance exhibits the reinforcing properties which would be expected if it served to escape an aversive state of affairs. However, when the data on modal IRT punishment was examined, two pigeons showed definite suppression of the punished IRT category with the third pigeons punished IRT category remaining relatively unchanged. Large increases in the punished IRT category were not obvious but rather there was a tendency in all pigeons to emit longer IRTs than the ones falling in the punished category. If in fact pigeons were responding to escape during long IRT punishment one would expect to see large increases in the IRT bin just prior to the punished IRT category. However the data shows that this is not the case (Fig. 3). The notion that blackout was serving as a TO from an aversive schedule does not seem to be supported by the present data or the findings of Kramer and Rilling (1969). Thus it follows that blackout serves as a reinforcer when made contingent upon burst responses, but not when its presentation is made contingent upon relatively long IRTs. It is obvious then that blackout should be reevaluated as a punisher.

It was the observation of the experimenter, during burst punishment, that upon the termination of blackout pigeons pecked the re-illuminated
center key light immediately. Typically it was the observation that the majority of the burst responses which occurred during burst punishment followed blackout. This observation gains some substantiation from the finding that post blackout rates were higher following burst punishment for all birds. It should be noted that a response following blackout by less than 2 seconds was punished the same as was a response that followed a prior response by less than 2 seconds. The experimenter is of the opinion that if the bursts which immediately followed blackout were ignored, a decrement in burst responding would have occurred during burst punishment.

The observation that pigeons tend to key peck as soon as a key is illuminated following blackout is compatible with recent findings of auto-shaping in pigeons (Brown & Jenkins, 1968; Gamzu & Williams, 1971; Gamzu & Williams, 1973). Using an auto-shaping procedure pigeons will peck a lighted key following associations of response-independent food presentations with illumination of a key. Gamzu and Williams (1973) hypothesize that the occurrence of key pecking in auto-shaping can be considered to depend on associative processes similar to classical conditioning. Gamzu and Williams (1973) point out that the similarity between auto-shaping and classical conditioning is not limited to procedure but is likewise present in the behavioral outcome. They believe that the pecking that develops during auto-shaping is analagous to other anticipatory responses observed in delay conditioning. Brown and Jenkins (1968) view key pecking as a species specific tendency of the pigeon to peck at things it looks at. They postulated that the temporal conjunction
of reinforcement with noticing leads to orienting and looking at the key. Thus if key pecking is not an arbitrary operant response but rather a species specific response to grain or to stimuli that have been correlated with occasions of reinforcement and nonreinforcement, the present finding that pigeons tended to peck a re-illuminated center key following blackout appears less than paradoxical. A similar explanation may also be applicable to the Williams and Williams (1969) finding that pigeons will persist in pecking despite contingent non-reward.

Along these same lines of reasoning Rachlin (1973) postulated that operant behavior may be composed of biological and economic responses. The biological principle states that "a transition from a stimulus signaling a period of low reinforcement value to one signaling a period of high reinforcement value excites certain responses irrespective of other contingencies. The excited responses are most frequent immediately after the point of transition and subsequently decrease in frequency." The economic principle is simply the law of effect. Behavior is said to be under schedule control.

Rachlin (1973) conducted a study to test this hypothesis. Pigeons were exposed to a multiple schedule consisting of identical variable interval 2 minute schedules. However, free reinforcement was delivered on a variable time 15 second schedule in the second component. According to the biological principle pecking rate should be higher in the second component than in the initial component. The economic principle would predict just the opposite because free reinforcement should increase the value of periods of not pecking. Half of the experimental pigeons were
exposed to the multiple schedule alternating every 8 seconds with the other half being exposed to the multiple schedule, alternating every eight minutes. The results showed that with eight second alteration the pigeons pecked more in the component with free reinforcement. With eight minute alteration, the pigeons pecking rate was slightly higher in the component without free reinforcement.

Rachlin's findings appear to be a plausible explanation of the present studies findings of burst facilitation by blackout. If the 10 seconds of blackout were viewed as one component of a multiple schedule signaling a low probability of reinforcement, the transition from blackout to DRL should engender pecking. In the experimental phase in which blackout was contingent upon bursting, repeated pecking of the reilluminated key signaling DRL would be analogous to a rapidly alternating multiple schedule thereby resulting in burst facilitation. When blackout was contingent upon long IRT emission, pecking the reilluminated center key would not result in blackout. Thus the probability of an occurrence of a bursting response would be expected to be low since blackout would be expected to occur less frequently. Data from the present study (Figure 1) showed that bursting tended to be low during long IRT punishment.

Findings of the present study suggest that several experimental extensions of the present experimental design are in order. First of all the effects of electric shock on burst responding should be investigated. In particular it would be interesting to assess the effects of punishment contingent upon a series of bursts or "multiple pecks" rather
than upon a single short IRT. The question of whether or not the key peck is as arbitrary operant could be assessed by attempting to stabilize pigeons on a DRL schedule employing water reinforcement. Would there still exist a tendency for the pigeons to burst?
CHAPTER 5

SUMMARY

With the DRL schedule, an increase in rate of responding leads to a decrease in reinforcement frequency. Since punishment decreases the probability of a response, punishment should improve DRL responding. Research with pigeons employing blackout as punishment (contingent on all responses) has demonstrated improved behavior. It has been shown that the IRT frequency distribution does not change uniformly as a function of punishment but that bursts (0-2 sec IRTs) are greatly reduced. Due to their rapid elimination, Holz and Azrin (1963) concluded bursts to be most sensitive to punishment since they are least relevant to reinforcement frequency.

The present study examined the effects of blackout on specific IRT categories. Would punishment have the same effect on responses terminating bursts, as on responses terminating longer IRTs? Pigeons maintained on a DRL 20 sec schedule for grain were exposed to 3 successive schedules during which IRTs of 0-2, 8-12, or 16-20 seconds were punished with 10 seconds of blackout. Punishment conditions were separated by recovery baselines.

Results showed that response produced blackouts following both 8-12 and 16-20 IRTs decreased the probability of short 0-2 sec IRTs. Responding was suppressed and IRT frequency distributions shifted toward longer
IRTs. However blackouts following 0-2 sec IRTs increased the probability of 0-2 sec IRT emission. The data suggests that blackout was serving either as a reinforcer or punisher depending upon its scheduling. Results did not indicate that blackout served as an escape from an aversive "state of affairs." Krammer and Rilling's (1970) hypothesis that bursting results from a lack of stimulus feedback was not supported since blackout provided feedback while facilitating bursting. Burst facilitation by blackout is discussed from the standpoint of the key peck as a species specific response to stimuli correlated with occasions of reinforcement, e.g. pecking a reilluminated key immediately following blackout.
REFERENCES

Anger, D. The dependence of interresponse times upon the relative reinforcement of different interresponse times. *Journal of Experimental Psychology*, 1956, 52, 145-161.


Williams, D. R. & Williams, H. Automaintenance in the pigeon; sustained pecking despite contingent non-reinforcement. *Journal of the Experimental Analysis of Behavior*, 1969, 12, 511-520.

APPENDIX
### TABLE 3
**FREQUENCY OF RESPONDING**  
- responses per/minute -  
(experimental phases in order of occurrence)

<table>
<thead>
<tr>
<th>pigeon</th>
<th>INITIAL 20 sec. DRL</th>
<th>16–20 sec. IRT PUNISHMENT</th>
<th>RECOVERY</th>
<th>BURST PUNISHMENT</th>
<th>RECOVERY</th>
</tr>
</thead>
<tbody>
<tr>
<td>1134</td>
<td>4.71</td>
<td>4.15</td>
<td>4.40</td>
<td>4.76</td>
<td>4.60</td>
</tr>
<tr>
<td></td>
<td></td>
<td>8–12 sec. IRT PUNISHMENT</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5992</td>
<td>8.91</td>
<td>12.22</td>
<td>8.09</td>
<td>7.40</td>
<td>6.34</td>
</tr>
</tbody>
</table>

Each value shown represents an average of the last five days in each condition.

### TABLE 4
**FREQUENCY OF REINFORCEMENT**  
-reinforcements per/minute-  
(experimental phases in order of occurrence)

<table>
<thead>
<tr>
<th>pigeon</th>
<th>INITIAL 20 sec. DRL</th>
<th>16–20 sec. IRT PUNISHMENT</th>
<th>RECOVERY</th>
<th>BURST PUNISHMENT</th>
<th>RECOVERY</th>
</tr>
</thead>
<tbody>
<tr>
<td>1134</td>
<td>1.32</td>
<td>1.58</td>
<td>1.55</td>
<td>1.41</td>
<td>1.07</td>
</tr>
<tr>
<td></td>
<td></td>
<td>8–12 sec. IRT PUNISHMENT</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>533</td>
<td>0.24</td>
<td>0.40</td>
<td>0.36</td>
<td>0.37</td>
<td>0.56</td>
</tr>
<tr>
<td></td>
<td></td>
<td>BURST PUNISHMENT</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5992</td>
<td>0.12</td>
<td>0.07</td>
<td>0.15</td>
<td>0.23</td>
<td>0.09</td>
</tr>
</tbody>
</table>

Each value shown represents an average of the last five days in each condition.
### TABLE 5

**EFFICIENCY RATIOS**

- Percentage of reinforced responses -

<table>
<thead>
<tr>
<th>pigeon</th>
<th>Initial 20 sec DRL</th>
<th>16–20 sec IRT Punishment</th>
<th>Recovery</th>
<th>Burst Punishment</th>
<th>Recovery</th>
</tr>
</thead>
<tbody>
<tr>
<td>1134</td>
<td>22.50%</td>
<td>38.90%</td>
<td>36.31%</td>
<td>30.81%</td>
<td>24.24%</td>
</tr>
<tr>
<td>533</td>
<td>3.5%</td>
<td>6.42%</td>
<td>6.34%</td>
<td>3.62%</td>
<td>11.34%</td>
</tr>
<tr>
<td>5992</td>
<td>1.20%</td>
<td>0.60%</td>
<td>1.70%</td>
<td>1.88%</td>
<td>1.37%</td>
</tr>
</tbody>
</table>

Each value shown represents an average of the last five days in each condition.

### TABLE 6

**Percentage of reinforced dwell time**

The proportion of total session time occupied by reinforced IRTs

<table>
<thead>
<tr>
<th>pigeon</th>
<th>Burst Punishment</th>
<th>8–12 sec IRT Punishment</th>
<th>16–20 sec IRT Punishment</th>
</tr>
</thead>
<tbody>
<tr>
<td>1134</td>
<td>27.4%</td>
<td>56.5%</td>
<td></td>
</tr>
<tr>
<td>533</td>
<td>12.7%</td>
<td>14.1%</td>
<td></td>
</tr>
<tr>
<td>5992</td>
<td>3.7%</td>
<td>5.2%</td>
<td></td>
</tr>
</tbody>
</table>

Each value shown represents an average of the last five days in each condition.