1971

# Shock Intensity and Task Difficulty as Determiners of Avoidance and Escape Learning in Rats

Arthur Louis
*Wilfrid Laurier University*

# SHOCK INTENSITY AND TASK DIFFICULTY AS DETERMINERS OF AVOIDANCE AND ESCAPE LEARNING IN RATS

by

Arthur Louis, B.A.

Thesis submitted to the Council of Graduate Studies in Partial Fulfillment of the Requirements for the Degree of Master of Arts in Psychology

WATERLOO LUTHERAN UNIVERSITY

November, 1971

## ABSTRACT

Thirty-six naive female hooded rats were divided randomly into three groups and tested in an instrumental escape and avoidance learning situation involving three degrees of task difficulty. Each group was also randomly subdivided into four subgroups, each of which underwent a different shock intensity level. The purpose of this study was to test the Yerkes-Dodson law which states that (a) there is an optimal level of punishment intensity for any given task (or an inverted-U curve relating shock intensity and performance) and (b) this optimal intensity decreases as task difficulty increases. The results supported (a) but not (b).

## ACKNOWLEDGMENT

The author wishes to express his sincere gratitude to his thesis committee members for their helpful advice and criticism. Special thanks is due to Dr. Vernon Schaefer for his untiring guidance and Mr. Cameron McRae for his technical assistance.

# TABLE OF CONTENTS

## TABLES

FIGURES

## INTRODUCTION AND PURPOSE

This study was concerned with the independent and interaction effects of shock intensity and task difficulty on avoidance and escape learning. The earliest study investigating this problem dates back to 1908 and the formulation of the Yerkes-Dodson law which stated that (a) the rate of discrimination learning is a function of punishment intensity and (b) the optimal level of this punishment intensity decreases as task difficulty increases. The formulation of this law was based on the results from the initial Yerkes and Dodson (1908) experiment with mice in a white-black discrimination-learning situation in which grid shock was used as motivator.

The prediction of the Yerkes-Dodson law was neither supported nor challenged for many decades until Broadhurst (1957) reported an experiment with rats (also in discrimination-learning situation) and interpreted his results as confirming the Yerkes-Dodson law.

However, Brown (1965) challenged the Broadhurst interpretation, pointing out that the Broadhurst data did not show the expected relation between task difficulty and performance. Further, Brown questioned whether the Broadhurst data could really provide confirmation for the Yerkes-Dodson law, for which a two-stage method is required.

In the last two decades, many investigators used rats to test the applicability of the Yerkes-Dodson prediction in avoidance and/or escape situations. Some held task difficulty constant and varied the levels of shock. Others held shock constant and varied the levels of task difficulty. In the former case, investigators in the sixties (but not the fifties) seemed to have found support for the first part of the Yerkes-Dodson law, i.e., an inverted-U function relating shock intensity and the rate of acquisition of the desired responses. In the latter case, investigators seemed to have found support for the second part of the Yerkes-Dodson law, i.e., the optimal levels of performance for three or more tasks employed did follow the predicted order: Difficult < Medium < Easy. However, no studies of avoidance and/or escape learning have covaried shock and task.

The Yerkes-Dodson law was formulated on the basis of results from discrimination-learning situations. How fully it operates in other learning situations, such as instrumental avoidance and/or escape, is still somewhat uncertain. Since all of the studies in avoidance and/or escape situations relevant to the test of the Yerkes-Dodson law mentioned above, varied only one independent variable (either shock or task), it would therefore seem important to covary both independent variables (shock and task) in order to achieve a two-stage test of the law.

The present study is an attempt to achieve a two-stage test of the Yerkes-Dodson law, using three degrees of task difficulty and four levels of shock intensity. Restated in two parts again, the law predicts (a) there is an optimal level of punishment intensity for any given task and (b) this optimal intensity decreases as task difficulty increases.

## HISTORICAL REVIEW

In more than fifteen years since Hebb (1955) published his influential address, it has become axiomatic that performance is optimal at intermediate level of motivation. Many studies using shock as motivator in different learning situations have been done, partly to test this axiom and partly to test an older generalization which involved the variable of task difficulty as well as those of performance and motivation level, the Yerkes-Dodson law. The historical review will cover (a) the Yerkes-Dodson experiment, (b) the Broadhurst experiment, (c) the Brown challenge, (d) studies on avoidance and/or escape learning varying shock intensities, and (e) studies on avoidance and/or escape learning varying task difficulties.

### The Yerkes-Dodson Experiment

The initial Yerkes-Dodson (1908) experiment involved a discrimination box. Forty mice were each given ten tests daily until they succeeded in chosing the correct (white) box on three consecutive days, i.e., for 30 tests. A choice was recorded as wrong if the mouse entered the incorrect (black) box and received a shock. Shock intensities were in Martin units, ranging from 125 to 500. Three tasks were involved and they were differentiated in terms of decreasing brightness in the white box. The results are summarized in Fig. 1.

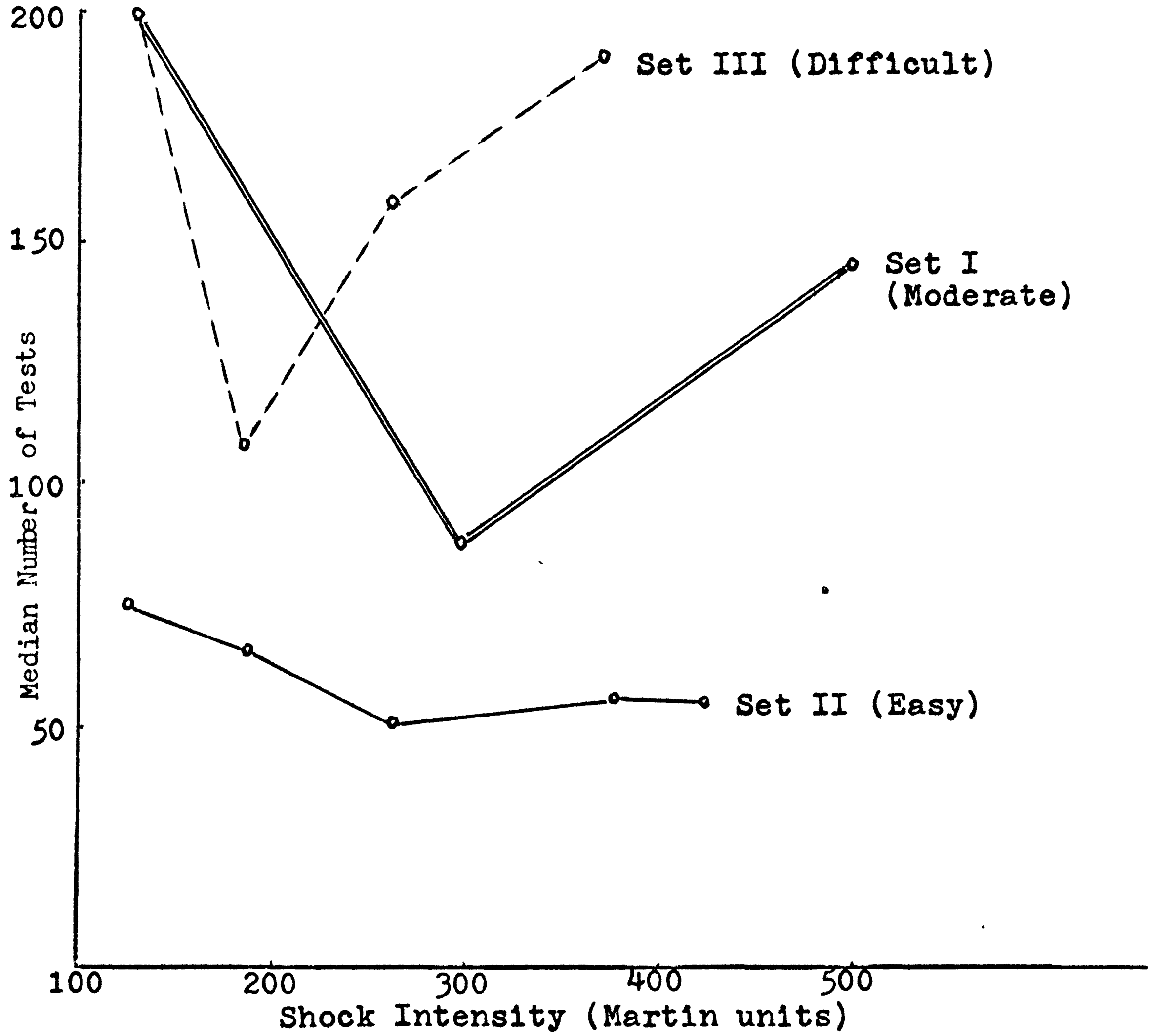



Fig. 1 Number of tests to criterion of perfect correct choices in three consecutive days.

The generalization given by Yerkes and Dodson was: "as difficulty of discrimination increases, that strength of electrical stimulus which is most favourable to habit formation approaches the threshold." The insignificant difference found in Set II was explained in terms of the small number of animals (four) in each subgroup in the experiment.

## The Broadhurst Experiment

A contemporary version of this Yerkes-Dodson law states that "the optimum motivation for a learning task decreases with increasing difficulty." Broadhurst (1957), to whom we owe that wording of the relationship, has reported a supporting experiment and, after a review of the absence of literature, has pronounced the Yerkes-Dodson law "revived" (Broadhurst, 1959).

The Broadhurst (1957) study used a factorial design (4 motivation levels X 3 difficulty levels) with 10 rats in each of the 12 experimental conditions. The task was again one of brightness discrimination, but the motivation, air-deprivation, was varied by holding the rats under water for 0, 2, 4, or 8 sec. The learning scores analysed were the total number of correct responses made during the 100 trials. The highest score for the easy discrimination was achieved by the 4-sec. group; those for medium and difficult discrimination were both made by the 2-sec. groups. An analysis of variance showed there was a significant interaction between motivation and difficulty levels. These findings were interpreted by Broadhurst (1957; 1959) and were cited, many years later, by other psychologists (Duffy, 1962; Cofer & Appley, 1964) as supporting the Yerkes-Dodson prediction, which has become one of empirical psychology's best-known laws.

The Brown Challenge

In an article entitled, "The Yerkes-Dodson Law Be-
pealed," Brown (1965) challenged the Broadhurst interpre-
tation. Brown idealized the Yerkes-Dodson prediction by
implying that the optima for the three tasks would be or-
dered as follows: Difficult < Medium < Easy. Broadhurst's
data, however, showed the pattern Difficult = Medium <
Easy. Since the Yerkes-Dodson law is a statement about
the relative magnitudes of optimum motivation levels for
two or more tasks, it follows that Broadhurst's data can-
not provide any confirmation.

What emerged from Brown's (1965) discussion was
that the Yerkes-Dodson law, with its three variables
(motivation, difficulty, and performance) required a two-
stage proof. The first stage was needed to show whether
or not performance is a function of motivation level.
The second stage was to compare the relative difficulty
of these tasks with their optimum motivation levels. Un-
less at least two tasks survive the first stage, i.e.,
optimum performance level found to vary with motivation,
it is improper to proceed to the second stage, i.e., to
see whether they follow the predicted order: Difficult <
Medium < Easy. Interestingly, Cofer and Appley (1964) also
cited Broadhurst's experiment as substantiating the Yerkes-
Dodson law.

Studies on Avoidance or Escape Learning varying the Shock Intensities

The idea of an optimal level of performance corresponding to the intermediate level of motivation (or an inverted-U function when performance is plotted against motivation) was made an axiom by Hebb (1955) in his influential address, and one of the beneficiaries of that axiom has been the Yerkes-Dodson law.

In the past two decades, many investigators have used rats in studying the applicability of this axiom to avoidance and/or escape situations. A review of the major findings reveals that studies in the fifties generally failed to find any inverted-U function when performance levels were plotted against shock intensities (Amsel, 1950; Campbell & Kraeling, 1953; Kimble, 1955; Boren, Sidman, & Herrnstein, 1959). However, in the sixties, several investigators did report inverted-U functions relating shock intensity and the rate of acquisition of avoidance or escape responses (Trapold & Fowler, 1960; Moyer & Korn, 1964; Johnson & Church, 1965; Bolles & Warren Jr., 1965; D'Amato & Fazzaro, 1966; Levine, 1966). With weak shock the subjects persisted in escape behaviour, but as shock was intensified the rate of learning to avoid increased, reached a maximum and then declined. The poor acquisition rate at high shock level, as pointed out in a recent review, may have been due to the disabling effects of shock (Hurwitz & Dillow, 1969).

The difference in results between studies in the two decades was perhaps due to the different measurements used. Most of the studies in the fifties were concerned with avoidance and/or escape latencies while the majority in the sixties compared number or percentage of responses. A summary of these studies are presented in Table 1, which shows the number of shock intensities employed, response requirement used, the kind of measurement, and the result in each study.

TABLE 1

Summary of Relevant Studies with varied Shock Intensity

| Author(s) | Number of Shock Intensities | Response Requirement | Measurement(s) | Result |
|---|---|---|---|---|
| Amsel, 1950 | 2 | Running | Latency | No inverted-U |
| Campbell & Kraeling, 1953 | 3 | Running | Latency | No inverted-U |
| Kimble, 1955 | 3 | Wheel-turning | Latency | No inverted-U |
| Boren, Sidman, & Herrnstein, 1959 | 8 | Lever-pressing | Latency | No inverted-U |
| Trapold & Fowler, 1960 | 5 | Running | Latency[1] | Inverted-U |
| Moyer & Korn, 1964 | 7 | Running | Latency & Percentage | Inverted-U |
| Johnson & Church, 1965 | 2 | Shuttling | Percentage | Inverted-U[2] |
| Bolles & Warren Jr., 1965 | 6 | Lever-pressing | Percentage | Inverted-U |
| D'Amato & Fazzaro, 1966 | 3 | Lever-pressing | Percentage | Inverted-U |
| Levine, 1966 | 5 | Shuttling | Percentage | Inverted-U |

[1]Trapold & Fowler (1960) study was concerned with escape rather than avoidance learning.

[2]Johnson & Church (1965) study supported the inverted-U prediction only in the sense that performance percentage increased over sessions in low shock level and decreased over sessions in the higher shock level.

Studies on Avoidance or Escape Learning varying the Task Difficulties

There is also a fair amount of recent literature on differential task difficulties in avoidance and escape situations which may lend support to the second part of the Yerkes-Dodson law. When shock is being held constant, the prediction of the Yerkes-Dodson law may be idealized (performances plotted against task difficulties) as: Difficult $<$ Medium $<$ Easy.

Kessen (1953), investigating the problem in terms of warning stimulus (CS) intensity, found that with increased CS intensity (easier task) produced increased speed of wheel turning. Badia and Levine (1964), defining task difficulty in terms of fixed ratio of response, found that latency of the first response is greater for the most difficult task (FR 10). Badia (1965), also defining task difficulty in term of fixed ratio response, but in a lever-pressing situation rather than shuttling, found number of animals reaching the highest ratio (8:1) decreased.

Differential task difficulty could also be considered in terms of response requirements. Mogenson, Mullin and Clark (1965), comparing avoidance rate in four situations (rotor, shuttle box, wheel-turning, and bar-pressing), found best performance in rotor (easiest) followed by shuttle box (moderate) and then by wheel-turning and bar-pressing (difficult). The number of escape responses made before the occurence of the first avoidance response were also compared, but found to be running counter to the trend in the avoidance responses, i.e., the bar-pressing animals made the most. This was accounted for by the fact of the bar-holding behaviour. When the total number of responses (avoidance + escape) were pooled and compared, the results corresponded very closely with the trend existed in the avoidance data.

## Concluding Remarks

From the above review, one obvious conclusion may be drawn. The lawfulness of the Yerkes-Dodson law remains to be somewhat dubious for two reasons. First, the so-called critical and supporting experiment by Broadhurst (1957) had actually failed to substantiate the second part of that law. Second, the law has not been fully tested in learning situations other than white-black discrimination learning, and those studies relevant to the test of the law in instrumental avoidance and/or escape situations had all failed to covary both shock and task.

The purpose of the present study, as stated above, is an attempt to achieve a two-stage test of the Yerkes-Dodson law in an instrumental avoidance and escape learning situation by covarying both independent variables--shock and task.

## METHOD

### Subjects

The *Ss* were 36 experimentally-naive female hooded rats three months old at the start of the experiment. They were housed in standard individual mesh cages and were given water and food *ad lib.* in the animal room of the Department of Psychology at Waterloo Lutheran University.

The animals were divided randomly into three task-difficulty groups, with 12 rats per group. Each of these groups was randomly divided into four subgroups, with three animals in each. The 12 subgroups were labeled A to L and assigned to experimental conditions as shown below.

| Task Difficulty \ Shock Intensity | Low (0.2 ma.) | Medium-Low (0.4 ma.) | Medium-High (0.6 ma.) | High (0.8 ma.) |
|---|---|---|---|---|
| Easy (3:3) | A N=3 | B N=3 | C N=3 | D N=3 |
| Moderate (2:2) | E N=3 | F N=3 | G N=3 | H N=3 |
| Difficult (2:1) | I N=3 | J N=3 | K N=3 | L N=3 |

## Apparatus

The animals were run in an experimental enclosure hexagonal in shape, 8 in. high and 9 3/4 in. separated opposite sides. The walls were made of aluminum. The floor was of stainless steel rods, 1/8 in. in diameter and spaced on 9/16 in. centers; the top is of transparent plastic. On each of the three 5 1/2 in. sides was mounted a light (#44 lamp behind white translucent 'jewel' lenses, 1 in. in diameter). A Lehigh Valley Electronics (LVE) 123-05 retractable bar was mounted 1 3/4 in. below each light. The three bars were identical, and interfaced on both input and output sides with electromechanical programming modules in an adjacent room (see Appendix I).

A Grason Stadler (GS) E1100H electronic timer was used to program the warning and shock durations. A constant-current shock generator (GS 700 model) with built-in scrambler delivered shock to the grid floor. White noise provided by a GS 901B white noise generator was delivered via a speaker mounted under the table holding the animal box; intensity level of the noise in the box was 72 db. Intertrial intervals were timed by a Gerbrands 1A 16 mm film reader. Six LVE digital counters were used, two connected to each bar for separate recording of avoidance and escape responses. Lighting was provided by a 25-watt light situated on a table six feet from the animal box.

The animals were run in a small, uncluttered, air- and sound-conditioned room.

## Procedure

Habituation. Five minutes of free exploration were given to each rat immediately preceding the first days' trials. The animal was allowed to explore the apparatus undisturbed, i.e., the room light and white noise were on and the bars were extended, but warning lights and shock were off.

Time and trials. The animals were divided into three squads, each squad consisting one rat from each of the 12 experimental conditions. Squad assignment was random, as was order in which the squads were subsequently run. Each animal in the first squad was given 25 trials per day for 10 consecutive days, followed by 30 trials per day for another 10 consecutive days, and by 50 trials on the last (21st) day (a total of 600 trials), or until avoidance criterion was reached, whichever occurred first. The second squad was started when all animals of the first squad had either met the avoidance criterion or completed 600 trials, and continued in the manner of the first squad. Similarly, the third squad was then run.

Running was begun at 8:00 a.m. each day and continued until approximately 1:00 p.m. Running orders were counter-balanced across days within each squad.

Definition of trials, responses, etc. A trial consisted of 5 sec. of warning signal (the blinking of one to three lights) followed by 20 sec. of shock. However, if the animal pressed the one or several bars defined as correct for his experimental condition during the warning signal (avoidance response), the signal was immediately terminated, all bars were retracted, and shock was omitted. If a correct bar was pressed during the shock interval (escape response), shock was immediately terminated and all bars retracted. If an incorrect bar was pressed during the warning signal, all bars were immediately retracted, but again extended at the start of the shock period. If an incorrect bar was pressed during the shock period, all bars were immediately retracted but shock continued for another 5 sec. or until the end of the regular 20-sec. shock period, whichever occurred first. In the latter three contingencies, the warning signal(s) stayed on until shock was terminated.

The intertrial interval was the time between either an avoidance response or the offset of shock and the onset of the next warning signal. The mean intertrial interval was 22.5 sec. varying randomly from 15 to 30 sec. in 5-sec. steps. Timing was accomplished by means of an appropriately punched film loop.

Bars were reinstated from 6 to 14 sec. (varying randomly in five 2-sec. steps) prior to the onset of the warning signal.

Measurements and criterion. A number of measures of learning were obtained. The critical ones were the number of trials to a criterion of 100% correct responses (defined as the combined total of avoidance and escape responses) and the number of trials to an avoidance criterion (defined as 60% of avoidances in three consecutive days). Other measures were: the ratio of correct responses to total trials; ratio of correct to incorrect responses; the ratio of avoidance to escape responses; the overall percent of avoidance responses; and the overall percent of escape responses, as well as the ratio of total bar-pressing responses (correct + incorrect) to total trials.

Experimental conditions. The 12 experimental conditions were generated by the two factors of shock intensity, expressed at 0.2, 0.4, 0.6, and 0.8 milliamps, and task difficulty. The three levels of the latter were: (a) With three lights blinking, a correct response is the pressing of any of the three bars; (b) With two lights blinking, a correct response is the pressing of either of the two bars under a blinking light; (c) With two lights blinking, a correct response is the pressing of the bar not under a blinking light.

## RESULTS

The findings of this study are presented in three sections. Number of trials to criterion of 100% correct responses (avoidance and/or escape) and the overall performance percentage of correct responses are considered first. Secondly, the ratio of total responses (correct + incorrect) to total trials and the ratio of correct to incorrect responses are reported. Thirdly, the overall percentage of avoidance responses, the overall percentage of escape responses, and the ratio of avoidance to escape responses are presented.

### (1) Number of Trials to Criterion of 100% Correct Responses and the Overall Performance Percentage of Correct Responses.

A comparison was made of subgroup scores on number of trials to criterion of 100% correct responses across shock intensities as well as across task difficulties. The mean scores indicated that animals in the 3:3 and 2:1 groups took fewer trials to reach the 100% correct responses criterion with higher shock levels while animals in the 2:2 group did better with the medium shock levels. A comparison was also made of subgroup scores on the overall performance percentage of correct responses. Animals in the 2:2 group seemed to have performed better with medium intensities while animals in the 2:1 group did best with the high shock level. Shock intensities did not appeared to have made any differences with animals in the 3:3 group. The results are presented in Table 2 and Table 3 where Table 2 shows the mean number of trials to criterion and Table 3 the mean percentage of correct responses, in each group. The same data are also summarized in Fig. 2 and Fig. 3 respectively.

A two-way analysis of variance was performed on the data in Table 2. It was found that both shock intensity and task difficulty had a significant effect upon learning to reach a 100% correct responses (For shock, $F(6,24)=11.63$, $p<.01$ and for task, $F(6,24)=32.65$, $p<.01$). No interaction effect was found ($F(6,24)=2.01$, $p>.05$). A summary of the analysis of variance (ANOVA) for data in Table 2 is presented in Appendix II.

A Newman-Keuls test was used on the data in Table 2. The result indicated that across shock intensities, the main effect was found between 0.2 ma. and each of the other three intensities (0.4; 0.6; and 0.8 ma.), but no significant differences were found between any of the other three. Across task difficulties, the main effect was found between the 3:3 and each of the other two task groups (2:2 and 2:1). No significant difference was found between 2:2 and 2:1 group. A summary of the Newman-Keuls comparisons is presented in

Table 4.

The data, as summarized in Fig. 2, showed some kind of trend for each of the task groups. Accordingly, a trend analysis was performed on these data. It was found that there is a decreasing linear trend across shock intensities in the 3:3 group ($F(1,8)=5.58$, $p<.05$), a quadratic or U-shaped trend in the 2:2 group ($F(1,8)=9.21$, $p<.05$); but nothing seemed to fit the data in the 2:1 group.

A two-way analysis of variance was also performed on the data in Table 3. It was found that both shock and task had a significant effect upon the overall performance rate of correct responses (for shock, $F(6,24)=3.82$, $p<.01$ and for task, $F(6,24)=3.30$, $p<.05$). Again, no interaction effect was found ($F(6,24)=.53$, $p>.05$). A summary of the ANOVA for data in Table 3 is presented in Appendix III.

A Newman-Keuls method identified the main effect across task difficulties to be between the 3:3 and 2:1 groups ($F(3,24)=31.80$, $p<.05$), but it failed to find the detail differences across shock intensities. However, some of the values (between 0.2 ma. and 0.6 ma. as well as between 0.2 ma. and 0.8 ma.) did approach significance. The Newman-Keuls test on the 2:2 and 2:1 groups separately (for simple main effect) indicated the same result. Accordingly, a trend analysis was also performed on the data (as summarized in Fig. 3). A cubic function was found to be best fit for the

3:3 group ($F(1,8)=24.4$, $p<.01$), a quadratic or inverted-U for the 2:2 group ($F(1,8)=5.40$, $p<.05$), and a linear trend for the 2:1 group ($F(1,8)=12.69$, $p<.01$).

TABLE 2

Mean Number of Trials to Criterion of 100% Correct Responses (Avoidance and/or Escape) in each of the Subgroups designated by letters A to L

(N per Subgroup = 3)

| Task Difficulty \ Shock Intensity | Low (0.2 ma.) | Medium-Low (0.4 ma.) | Medium-High (0.6 ma.) | High (0.8 ma.) |
|---|---|---|---|---|
| Easy (3:3) | A 100 | B 33 | C 25 | D 25 |
| Moderate (2:2) | E 533 | F 313 | G 175 | H 435 |
| Difficult (2:1) | I 600 | J 450 | K 353 | L 323 |

TABLE 3

Mean Percentage of Correct Responses (Avoidance and/or Escape) in each of the Subgroups designated by letters A to L

(N per Subgroup = 3)

| Task Difficulty \ Shock Intensity | Low (0.2 ma.) | Medium-Low (0.4 ma.) | Medium-High (0.6 ma.) | High (0.8 ma.) |
|---|---|---|---|---|
| Easy (3:3) | A 93.7 | B 99.7 | C 96.7 | D 99.8 |
| Moderate (2:2) | E 55.0 | F 87.7 | G 94.3 | H 79.0 |
| Difficult (2:1) | I 35.7 | J 71.3 | K 73.7 | L 82.0 |

TABLE 4

Newman-Keuls Test of Differences
Between Pairs of Mean Responses in Shock Intensities

| Shock Intensities | 0.6 ma. | 0.8 ma. | 0.4 ma. | 0.2 ma. |
|---|---|---|---|---|
| 0.6 ma. | -- | 77 | 81 | 227** |
| 0.8 ma. | | -- | 4 | 150** |
| 0.4 ma. | | | -- | 146** |
| 0.2 ma. | | | | -- |

$^{**}p < .05$

Newman-Keuls Test of Differences
Between Pairs of Mean Responses in Task Difficulties

| Task Difficulties | 3:3 | 2:2 | 2:1 |
|---|---|---|---|
| 3:3 | -- | 318** | 386** |
| 2:2 | | -- | 68 |
| 2:1 | | | -- |

$^{**}p < .05$

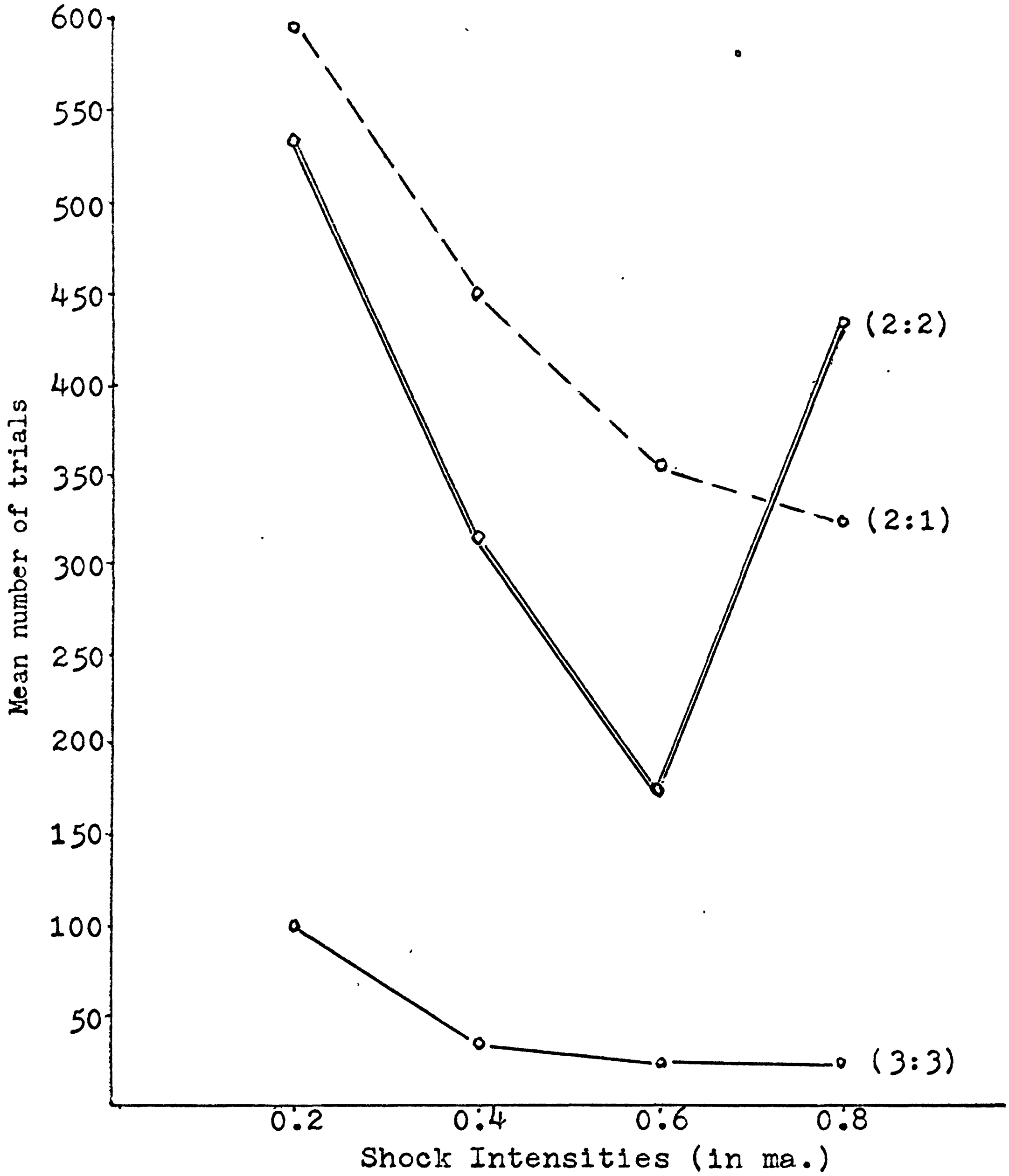



Fig. 2 Number of trials to criterion of 100% correct responses in each of the shock intensity.

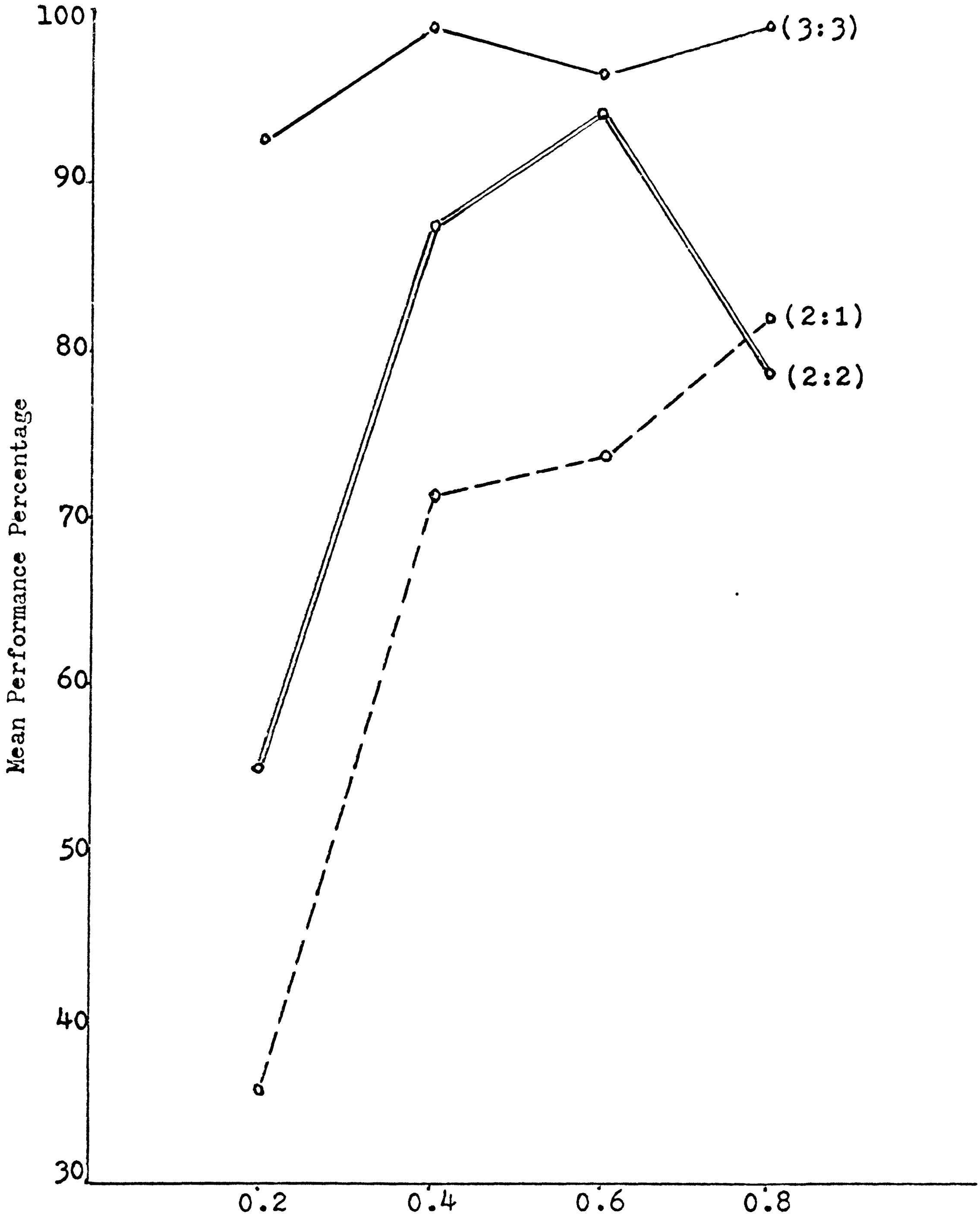



Fig. 3 Percentage rate of correct responses in each of the shock intensity.

(2) <u>The Ratio of Total Responses (correct + incorrect) to Total Trials and the Ratio of Correct to Incorrect Responses</u>.

The results of this section are presented in Table 5 and Table 6 where Table 5 shows the overall percentage of total responses in each group and Table 6 the mean ratio of correct to incorrect responses in task groups 2:2 and 2:1. The same data are summarized in Fig. 4 and Fig. 5 respectively.

A two-way analysis of variance was performed on data in Table 5. It was found that only shock intensity had a significant effect upon the rate of total bar-pressing responses ($F(6,24)=16.47$, $p<.01$). No significant effects were found between task difficulties ($F(6,24)=2.32$, $p>.05$) or the interaction of shock and task ($F(6,24)=1.90$, $p>.05$). A summary of the ANOVA for data in Table 5 is presented in Appendix IV.

A Newman-Keuls test found the main effect to be between 0.2 ma. and each of the other three shock intensities (0.4; 0.6; and 0.8 ma.). No significant differences were found between any of the other three. (A summary of Newman-Keuls comparisons across shock intensities is presented in Table 7.) These findings correspond neatly with the findings across shock intensities in Table 2 which gives the mean number of trials to criterion of 100% correct responses. However, the findings of nonsignificant effect across task groups fail to correspond with the findings of significant effect across task groups in Table 2. This discrepancy will be discussed in more detail in the discussion section.

A two-way analysis of variance was also performed on the data in Table 6 which shows the mean ratio of correct to incorrect responses for task groups 2:2 and 2:1. Again it was found that only shock intensity had a significant effect ($F(3,16)=6.54$, $p<.01$). No significant effects were found due to task difficulty ($F(3,16)=.97$, $p>.05$) or interaction of shock and task ($F(3,16)=1.60$, $p>.05$). A summary of the ANOVA for data in Table 6 is presented in Appendix V.

A Newman-Keuls method failed to identify the total main effect across shock intensities, but again some of the obtained values were approaching significance. The Newman-Keuls test for simple main effect on the two task groups separately found significant differences between 0.6 ma. and each of the other three intensities (0.2; 0.4; and 0.8 ma.) within the 2:2 group (see Fig. 5). These findings indicated that only 0.6 ma. shock level produces a superior correct/incorrect ratio. There were no significant differences between any of the other shock levels. These findings also shed some light on the problem of task difficulty which is to be discussed below (in discussion section).

TABLE 5

Mean Percentage of Total Responses (Correct + Incorrect) in each of the Subgroups designated by letters A to L

(N per Subgroup = 3)

| Task Difficulty \ Shock Intensity | Low (0.2 ma.) | Medium-Low (0.4 ma.) | Medium-High (0.6 ma.) | High (0.8 ma.) |
|---|---|---|---|---|
| Easy (3:3) | A 92.4 | B 99.5 | C 99.7 | D 99.6 |
| Moderate (2:2) | E 64.3 | F 98.1 | G 98.3 | H 99.0 |
| Difficult (2:1) | I 53.4 | J 93.7 | K 94.0 | L 97.6 |

TABLE 6

Mean Ratio of Correct to Incorrect Responses expressed as proportions in each of the Subgroups E to L

(N per Subgroup = 3)

| Task Difficulty \ Shock Intensity | Low (0.2 ma.) | Medium-Low (0.4 ma.) | Medium-High (0.6 ma.) | High (0.8 ma.) |
|---|---|---|---|---|
| Moderate (2:2) | E<br>7.3 | F<br>8.7 | G<br>46.0 | H<br>4.6 |
| Difficult (2:1) | I<br>2.2 | J<br>5.1 | K<br>6.2 | L<br>5.4 |

TABLE 7

Newman-Keuls Test of Differences
Between Pairs of Mean Responses in Shock Intensities

| Shock Intensities | 0.2 ma | 0.4 ma. | 0.6 ma. | 0.8 ma. |
|---|---|---|---|---|
| 0.2 ma. | -- | 27.1** | 27.3** | 28.6** |
| 0.4 ma. | | -- | 0.2 | 1.5 |
| 0.6 ma. | | | -- | 1.3 |
| 0.8 ma. | | | | -- |

$^{**}p < .05$

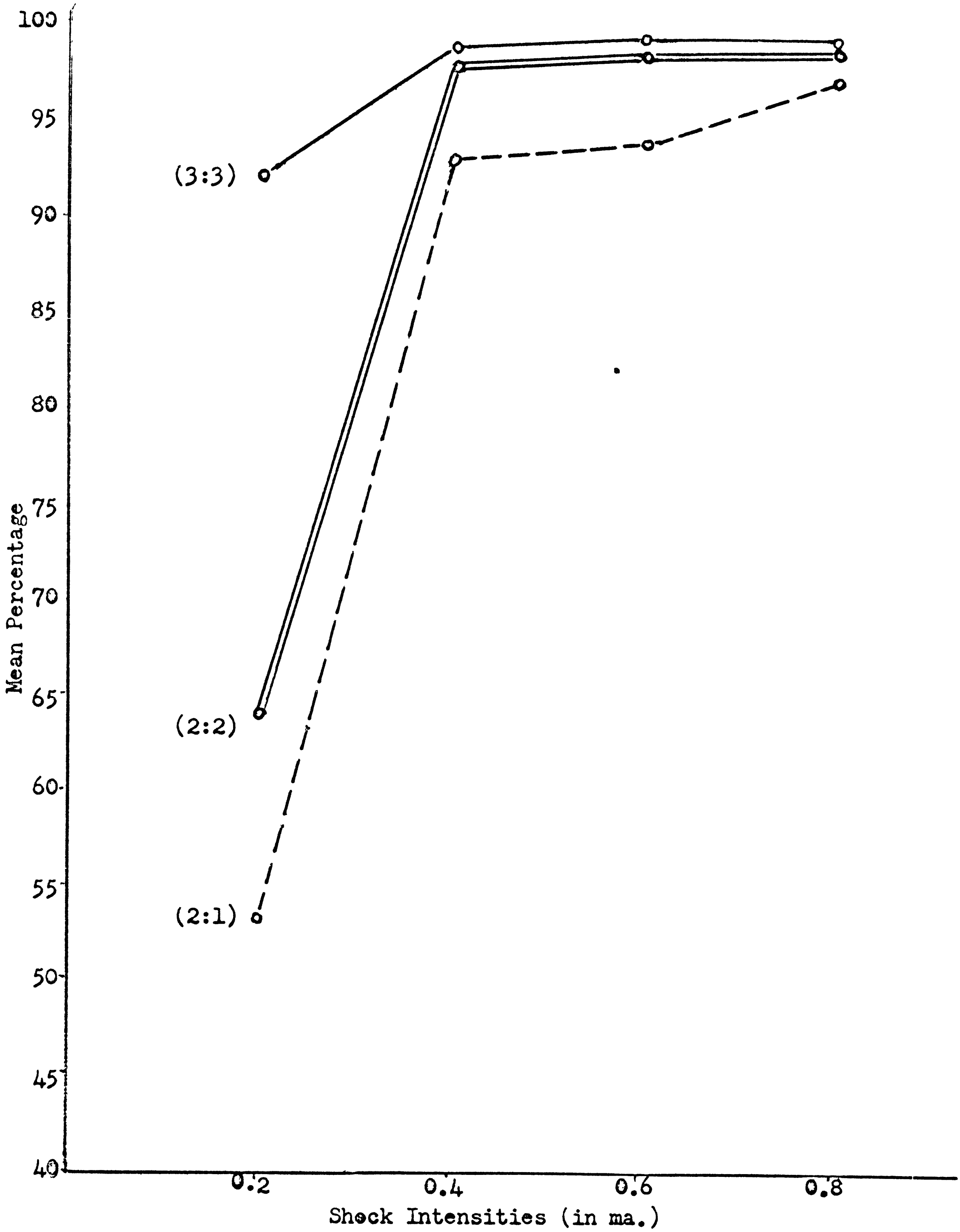



Fig. 4 Percentage rate of total (correct + incorrect) responses in each of the shock intensity.

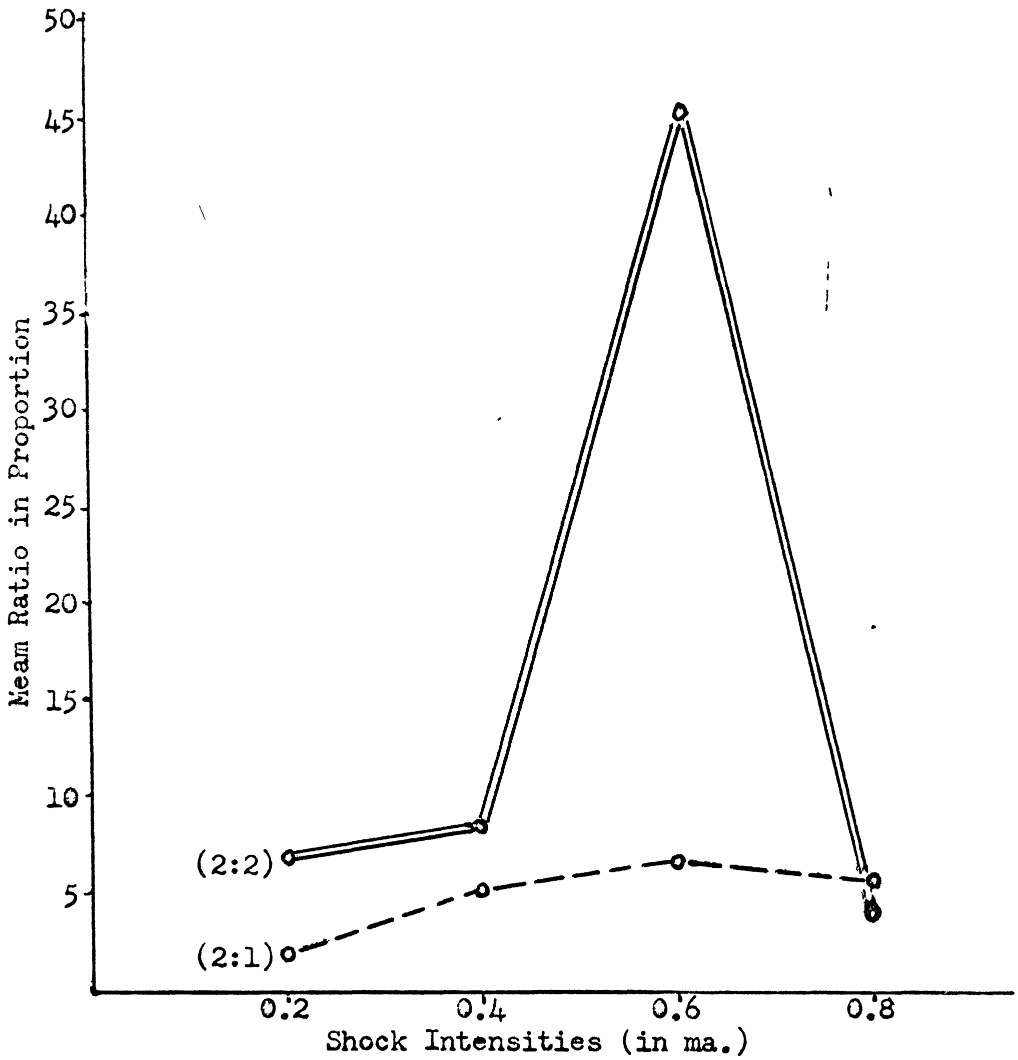



Fig. 5 Ratio of correct to incorrect responses in each of the shock intensity.

(3) <u>The Overall Percentage of Avoidance Responses; the Overall Percentage of Escape Responses; and the Ratio of Avoidance to Escape Responses</u>.

The original intention of this study was to compare the avoidance responses with two initial measures in mind, namely, number of trials to an avoidance criterion (60% avoidances in three consecutive days) and the overall percentage of avoidance responses. The first measure was not analysable due to the fact that only 5 out of 36 animals reached the avoidance criterion. The second is only of passing interest but not basically important, as the overall avoidance percentage was very low. The mean avoidance rates (in percent) were 6.5, 26.4, 2.2, and 21.3 in subgroups A, B, C, and D respectively; 4.6, 5.3, 15.7, and 8.9 in subgroups E, F, G, and H respectively; 1.0, 4.4, 10.6, and 12.0 in subgroups I, J, K, and L respectively. It appears that only animals in subgroup B (shock=0.4 ma., task=3:3) showed any consistency in an attempt to avoid. Most of the other animals learned only to escape most of the time. The avoidance data are presented in Table 8.

A two-way analysis of variance showed effects due to shock and interaction of task and shock. No significant differences were found due to task alone. A summary of the ANOVA for the avoidance data is presented in Appendix VI.

The overall escape percentage were analyzed by a two-way analysis of variance (the mean percentage of escape in each group is presented in Table 9. Significant differences were found between shock intensities ($F(6,24=4.54$, $p<.01$) and between task difficulties ($F(6,24)=4.32$, $p<.01$). No interaction effect was found ($F(6,24)=1.53$, $p>.05$). A summary of the ANOVA is presented in Appendix VII.

It should be remembered that comparison of escape data alone is just as dubious as comparison of avoidance data alone, as the escape data were confounded by the five animals that did reach avoidance criterion and by some other animals who were approaching such criterion. In other words, the more avoidance responses, the fewer escape responses. Consequently, no a posteriori tests were run.

Finally, the ratios of avoidance to escape responses were computed and ranked to see if any differences among the task groups. The results are presented in Table 10. A two-way analysis of variance found no significant differences due to shock, task, or interaction of the two independent variables.

TABLE 8

Mean Percentage of Avoidance Responses in each of the Subgroups labeled A to L

(N per Subgroup = 3)

| Shock Intensity / Task Difficulty | Low (0.2 ma.) | Medium-Low (0.4 ma.) | Medium-High (0.6 ma.) | High (0.8 ma.) |
|---|---|---|---|---|
| Easy (3:3) | A 6.5 | B 26.4 | C 2.2 | D 21.3 |
| Moderate (2:2) | E 4.6 | F 5.3 | G 15.7 | H 8.9 |
| Difficult (2:1) | I 1.0 | J 4.4 | K 10.6 | L 12.0 |

TABLE 9

Mean Percentage of Escape Responses (avoidances excluded) in each of the Subgroups labeled A to L

(N per Subgroup = 3)

| Shock Intensity / Task Difficulty | Low (0.2 ma.) | Medium-Low (0.4 ma.) | Medium-High (0.6 ma.) | High (0.8 ma.) |
|---|---|---|---|---|
| Easy (3:3) | A 85.7 | B 73.2 | C 94.6 | D 78.3 |
| Moderate (2:2) | E 50.6 | F 82.4 | G 78.6 | H 77.2 |
| Difficult (2:1) | I 34.4 | J 66.6 | K 62.8 | L 69.7 |

TABLE 10

Mean Ratio of Avoidance to Escape Responses in Rank in each of the Subgroups labeled A to L

(N per Subgroup = 3)

| Shock Intensity / Task Difficulty | Low (0.2 ma.) | Medium-Low (0.4 ma.) | Medium-High (0.6 ma.) | High (0.8 ma.) |
|---|---|---|---|---|
| Easy (3:3) | A 20 | B 5.7 | C 25 | D 7.3 |
| Moderate (2:2) | E 21.2 | F 18.8 | G 14 | H 28.2 |
| Difficult (2:1) | I 29 | J 20.3 | K 18 | L 14.5 |

## DISCUSSION

Three questions were asked in this study: (1) Is the Yerkes-Dodson law applicable to avoidance learning? (2) Is it applicable to escape learning? (3) Is it applicable to the combined total of avoidance and escape responses?

The first was not answerable by the data collected in this study since only 5 out of 36 animals reached an avoidance criterion. The second was also unanswerable as the escape data were confounded by the five animals that reached avoidance criterion. Therefore, the avoidance and escape responses were pooled as "correct responses," and the applicability of the Yerkes-Dodson law to these data is to be discussed.

(1) Data from Trials to Criterion of 100% Correct Responses and the Overall Performance Percentage.

The Yerkes-Dodson prediction of an U-shaped curve in learning, when number of trials required to reach a criterion is plotted against shock intensities, is supported only by the data of the second (2:2) task group. This can be seen in Fig. 2 and it was affirmed by a trend analysis. However, no such U-curve is found in either the first (3:3) task group or the third (2:1) task group, although the 2:1 group may come to support the prediction if still higher shock levels were used, as there is little doubt that the disruption effect will be great (Hurwitz & Dillow, 1969). If this were so, it would tend to run counter to the second Yerkes-Dodson prediction that the optimal shock intensity decreases as task difficulty increases. If the 2:1 group were considered to be a more difficult task (because there is a higher probability of making an incorrect response than the 2:2 group), then it should take a lower shock level to reach the optimal learning point. This, however, was not the case. It would seem that while 0.6 ma. is the optimal level for the 2:2 group, 0.8 ma. may very well be the optimal level for the 2:1 group.

The performance data corresponded very closely with the criterion data in that only the 2:2 group seems to have followed the Yerkes-Dodson prediction of an inverted-U curve. And again a trend analysis affirms this to be so. But the Yerkes-Dodson second prediction could not be supported by the performance data! The optimal point of the 2:2 group seemed to be the 0.6 ma. shock level (same as that which was borne out by criterion data) while the optimal point of the 2:1 group seemed to be the 0.8 ma. shock level (again same as that which was borne out by the criterion data). Accepting the consideration that 2:1 was a more difficult task, the tentative conclusion seemed to run counter to the second Yerkes-Dodson prediction. To affirm this counter-prediction, further research using higher shock levels is necessary.

Malmo (1959) in his theorizing about the concept of activation, also postulated an inverted-U curve which has low, moderate and high levels of activation corresponding to low, optimal, and low levels of performance. But he questioned whether the optimal level for one task is directly comparable to that of another task. This attitude of cautiousness points out that theoreticians are not willing to build doctrines (or principles) on the predictions of the Yerkes-Dodson law, which seemed to have been revived by Broadhurst (1957; 1959). The data from the present study may very well lend strength to Malmo's cautious approach.

(2) Data from Ratio of Total (correct + incorrect) Responses to Total Trials and the Ratio of Correct to Incorrect Responses.

The ratio of total (correct + incorrect) responses was computed mainly as a control to determine whether activity level, as represented by both correct and incorrect responses, would correspond to the level of performance (correct responses only). If they correspond, then one may question whether there was learning at all in this experiment. The result clearly indicated no such direct correspondance. The performance data indicated significant effects due to both shock and task while the activity data showed only shock level had a significant effect.

One interesting question here is whether the Yerkes-

Dodson prediction of an U-curve would hold in animal's activity level in terms of bar-pressing. The data as summarized in Fig. 4 did not seem to give a positive answer. Activity in terms of bar-pressing seemed to have increased as shock intensity increased to certain point and then plateaued off. Looking at the data again, one may even suspect a slight acceleration due to shock increase in the 2:1 group. But the increase (between 0.6 ma. and 0.8 ma. shock levels) was not statistically significant.

The ratio of correct to incorrect responses was computed mainly to see if the 2:1 task was really a "moderate" task rather than a "difficult" one. ( Ten psychologists were asked to rate the seven light-shock combinations, and the result indicated 2:1 as the more difficult task. Details of the seven light-shock combinations are presented in Appendix VIII.) Do rats think as human beings think? By comparing the observed with the expected ratio, a conclusion may be drawn. The expected ratio of correct responses between the 2:2 and 2:1 groups appeared to be 4 to 1, i.e., out of every 100 trials, animals in 2:2 had a 66.6% chance (2/1) making a correct response while animals in 2:1 had only 33.3% chance (1/2) making a correct response. The observed overall ratio of correct/incorrect responses was 16.7 for the 2:2 group, and 4.7 for the 2:1 group. Thus the observed ratio approximated the expected ratio which was 4 to 1 between 2:2 and 2:1 groups. Based on this information, one may conclude that the 2:1 was not performing relatively significantly better than the 2:2 group. It was performing a little bit better at the 0.8 ma. shock level, but it performed absolutely significantly worse at the 0.6 ma. shock level (see Fig. 5).

It may be argued that in fact the 2:2 and 2:1 tasks were much the same in terms of difficulty to the rat. This seemed to have been supported by the main effect identified across task groups by a posteriori tests, i.e., no significant differences were found between the 2:2 and 2:1 groups. Perhaps better design (such as using the 1:1 combination rather than the 2:1) and procedure (such as the correction method rather then the noncorrection method) are necessary to really differentiate the task difficulties.

(3) Data from Avoidance Responses, Escape Responses, and Ratio of Avoidance to Escape Responses.

Not much can be said about the avoidance or escape data separately for reasons already discussed above, and the avoidance/escape data (ratio) were nonsignificant. However, several points should be noted. First, of those animals who did reach avoidance criterion, three of them were in the 3:3 (easy task) group. This may point out that avoidance response involving no discrimination learning is easier to acquire than avoidance responses involving discrimination learning (such as in the 2:2 and 2:1 tasks). Animals in the 3:3 group generally developed a kind of jump-and-hit technique which was reinforced all the time (in terms of avoiding or terminating the shock) while animals in other task groups had to extinguish this jumping behaviour which was not reinforced all the time, and learn to do something else, i.e., to identify the correct bar(s). The 3:3 task is comparable to shuttle box situation which, by and large, would produce a better rate of avoidance. Now of the three animals that did reach avoidance criterion in the 3:3 task group, two of them were under 0.4 ma. shock level. It would appear that 0.4 ma. shock intensity is the best for avoidance training in situations comparable to the 3:3 task in this study. Recent research has found optimal shock level to be 0.5 ma. in running (Moyer & Korn, 1964) or shuttling (Levine, 1966) situations.

Secondly, the other two animals that did reach avoidance criterion were from the 2:1 group which may be comparable to a single lever-pressing avoidance situation. There the animals were at 0.6 ma. and 0.8 ma. shock levels. Interestingly, recent study of single bar-pressing avoidance by Bolles and Warren Jr. (1965) did indicate that 0.8 ma. is the point where best learning occurred. The Bolles and Warren data further indicated that learning drops when shock level increases beyond 0.8 ma. In order to see whether the 2:1 group would follow the same trend as reported by Bolles and Warren Jr., further experimentation using higher than

0.8 ma. shock level seems warranted.

Finally, a word about the animals in the 2:2 task group would be in order. None of the animals in this group reached avoidance criterion, but within this task group, animals in 0.6 ma. shock level did relatively better than animals in other shock levels (see Table 8). It is interesting to note that the seemingly optimal shock intensity in this task is exactly between the optimal intensities found in the 3:3 and 2:1 task groups.

# CONCLUSION

From the above discussion, two conclusions may be drawn. First, an inverted-U relationship between levels of motivation (in terms of shock) and levels of learning (in terms of bar-pressing terminating or avoiding the shock) occurs in a more difficult learning situation. But the same relationship does not occur in easy learning situation. This conclusion seems to agree with the results of the initial Yerkes-Dodson (1908) experiment from which the Yerkes-Dodson law was formulated.

Second, that the second part of the Yerkes-Dodson law which predicted the order of optima as Difficult < Medium < Easy (tasks), found no support from this study. On the contrary, it would seem that the order of optima with regard to tasks may very well be: Difficult > Medium > Easy.

## REFERENCES


Amsel, A. The combination of a primary appetitional need with primary and secondary emotional derived needs. J. exp. Psychol., 1950, 40, 1-14.

Badia, P., & Levine, S. Stable long term avoidance responding and fixed ratio avoidance training. Psychon. Sci., 1964, 1, 91-92.

Badia, P. Fixed ratio discriminated avoidance responding. Psychol. Rec., 1965, 15, 445-448.

Bolles, R. C., & Warren, J. A. Jr. The acquisition of bar press avoidance as a function of shock intensity. Psychon. Sci., 1965, 3, 297-298.

Boren, J. J., Sidman, M., & Herrnstein, R. J. Avoidance, escape, and extinction as function of shock intensity. J. comp. physiol. Psychol., 1959, 52, 420-425.

Broadhurst, P. L. Emotionality and the Yerkes-Dodson Law. J. exp. Psychol., 1957, 54, 345-352.

________________. The interaction of task difficulty and motivation: the Yerkes-Dodson Law revived. Acta Psychol., 1959, 16, 321-338.

Brown, W. P. The Yerkes-Dodson Law repealed. Psychol. Report, 1965, 17, 663-666.

Campbell, B. A., & Kraeling, D. Response strength as a function of drive level and amount of drive reduction. J. exp. Psychol., 1953, 45, 95-101.

Cofer, C. N., & Appley, M. H. Motivation: Theory and Research. New York: Wiley & Sons, Inc., 1964.

D'Amato, M. R., & Fazzaro, J. Discrimination lever-press avoidance learning as a function of type and intensity of shock. J. comp. physiol. Psychol., 1966, 61, 313-315.

Duffy, Elizabeth. Activation and Behaviour. New York: John Wiley & Sons, Inc., 1962.

Hebb, D. O. Drive and the c.n.s. (conceptual nervous system). Psychol. Rev., 1955, 62, 243-254.

Hurwitz, M. B., & Dillow, P. V. Discrimination and avoidance. In Gilbert, R. M., & Sutherland, N. S.(Eds.), Animal Discrimination Learning. London: Academic Press, 1969, Pp. 427-430.

Johnson, J. L., & Church, R. M. Effect of shock intensity on nondiscriminative avoidance learning of rats in shuttle box. Psychon. Sci., 1965, 3, 497-498.

Kimble, G. A. Shock intensity and avoidance learning. J. comp. physiol. Psychol., 1955, 48, 281-284.

Levine, S. UCS intensity and avoidance learning. J. exp. Psychol., 1966, 71, 163-164.

Malmo, R. B. Activation: A Neuropsychological Dimension. Psychol. Rev., 1959, 66, 367-386.

Mogenson, G. J., Mullin, A. D., & Clark, E. A. Effect of delayed secondary reinforcement and response requirements on avoidance learning. Can. J. Psychol., 1965, 19, 61-73.

Moyer, K. E., & Korn, J. H. Effect of UCS intensity on acquisition and extinction of an avoidance response. J. exp. Psychol., 1964, 67, 352-359.

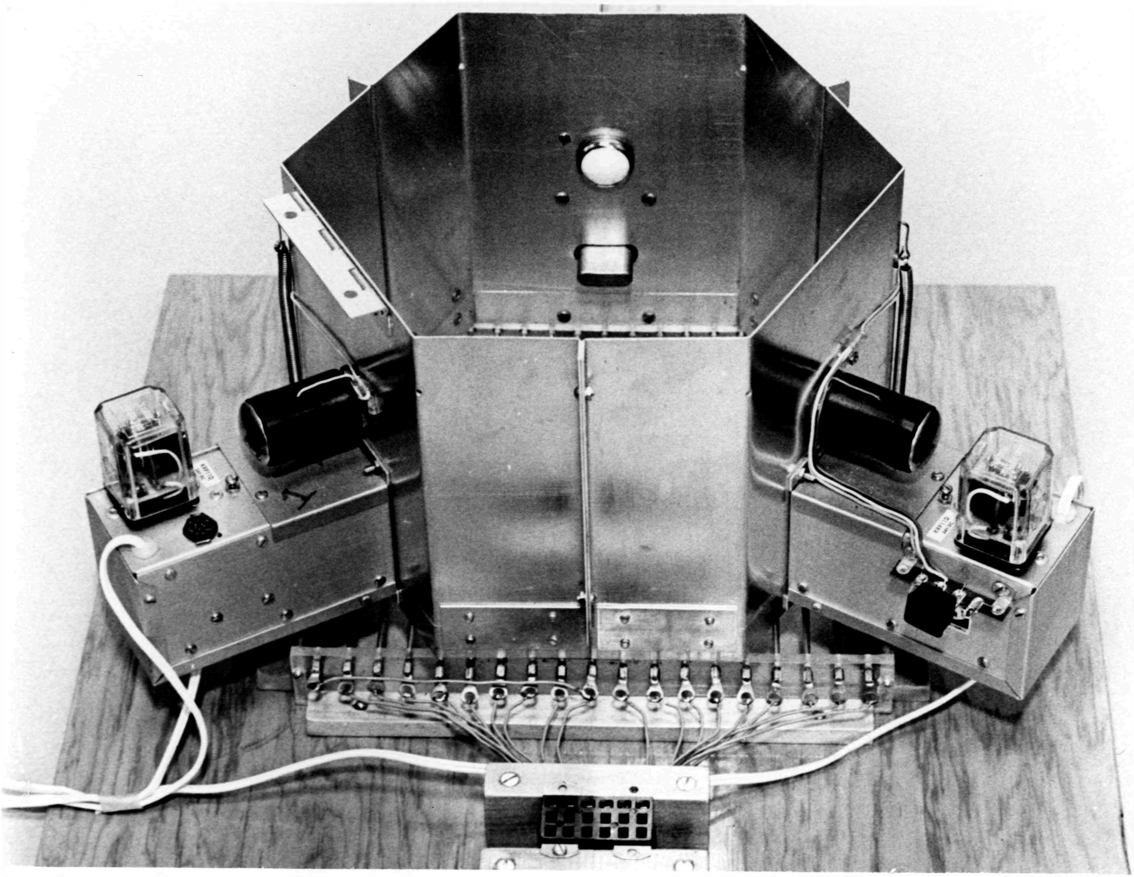
Trapold, M. H., & Fowler, H. Instrumental escape performance as a function of the intensity of noxious stimulation. J. exp. Psychol., 1960, 60, 323-326.

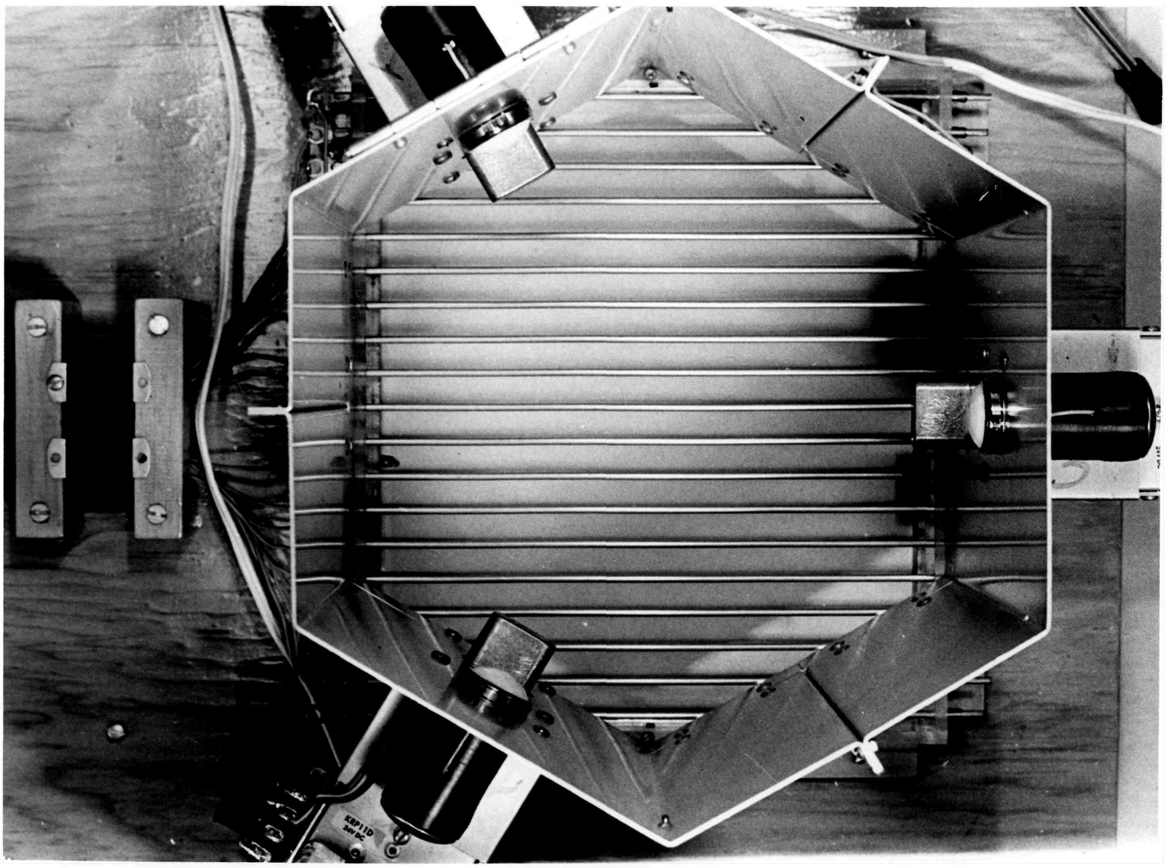
Winer, B. J. Statistical Principles in Experimental Design. New York: McGraw-Hill, 1962.

Yerkes, R. M., & Dodson, J. D. The relation of strength of stimulus to rapidity of habit-formation. In Boe, E. E., & Russell M. Church (Eds.), Punishment: Issues and Experiments. New York: Appleton-Century-Crofts, 1968, Pp. 27-41.

# APPENDIX I

Experimental Enclosure
Viewed from Side and from Top




KRP11D
24V DC

APPENDIX II

Analysis of Variance
of Mean Number of Trials to Criterion of 100% Correct Responses

| Source | SS | df | MS | F |
|---|---|---|---|---|
| Between Shock Intensities | 241966.7 | 2 | 120983.3 | 11.63** |
| Between Task Difficulties | 1019038.9 | 3 | 339679.6 | 32.65** |
| S x T Interaction | 125550.0 | 6 | 20925.0 | 2.01(n.s.) |
| Within Cells | 249733.3 | 24 | 10405.6 | |
| Total | 1636288.9 | 35 | | |

** $p < .01$

## APPENDIX III

Analysis of Variance
of Mean Percentage of Correct Responses

| Source | SS | df | MS | F |
|---|---|---|---|---|
| Between Shock Intensities | 4633.5 | 2 | 2316.75 | 3.82** |
| Between Task Difficulties | 6000.3 | 3 | 2000.10 | 3.30*** |
| S x T Interaction | 1927.5 | 6 | 321.25 | .53(n.s) |
| Within Cells | 14569.3 | 24 | 607.05 | |
| Total | 27130.6 | 35 | | |

** $p<.01$
*** $p<.05$

## APPENDIX IV

Analysis of Variance
of Mean Percentage of Total (correct + incorrect) Responses

| Source | SS | df | MS | F |
|---|---|---|---|---|
| Between Shock Intensities | 4965.9 | 2 | 2482.95 | 16.47** |
| Between Task Difficulties | 1049.0 | 3 | 349.67 | 2.32(n.s.) |
| S x T Interaction | 1714.2 | 6 | 285.70 | 1.90(n.s.) |
| Within Cells | 3612.2 | 24 | 150.68 | |
| Total | 11345.3 | 35 | | |

$^{**}p<.01$

APPENDIX V

Analysis of Variance
of Mean Ratio of Correct to Incorrect Responses

| Source | SS | df | MS | F |
|---|---|---|---|---|
| Between Shock Intensities | 1917.4 | 1 | 1917.4 | 6.54** |
| Between Task Difficulties | 853.3 | 3 | 284.3 | .97(n.s.) |
| S x T Interaction | 1406.2 | 3 | 468.7 | 1.60(n.s.) |
| Within Cells | 4694.8 | 16 | 293.4 | |
| Total | 8871.7 | 23 | | |

**$p < .01$

APPENDIX VI

Analysis of Variance
of Mean Percentage of Avoidance Responses

| Source | SS | df | MS | F |
|---|---|---|---|---|
| Between Shock Intensities | 359.35 | 2 | 179.68 | 2.51** |
| Between Task Difficulties | 422.36 | 3 | 140.79 | 1.97(n.s.) |
| S x T Interaction | 1427.09 | 6 | 237.85 | 3.33** |
| Within Cells | 1716.94 | 24 | 71.54 | |
| Total | 3925.79 | 35 | | |

** $p < .05$

## APPENDIX VII

Analysis of Variance
of Mean Percentage of Escape Responses

| Source | SS | df | MS | F |
|---|---|---|---|---|
| Between Shock Intensities | 2555.3 | 2 | 1277.65 | 4.54** |
| Between Task Difficulties | 3642.5 | 3 | 1214.17 | 4.32** |
| S x T Interaction | 2574.3 | 6 | 429.05 | 1.53(n.s.) |
| Within Cells | 6748.9 | 24 | 281.20 | |
| Total | 15521.0 | 35 | | |

** $p < .01$

## APPENDIX VIII

Seven light-shock combinations rated by ten psychologists

| Number of lights blinking | Number of bars that shut off shock | Most Difficult 1 | 2 | 3 | 4 | 5 | 6 | Most Easy 7 |
|---|---|---|---|---|---|---|---|---|
| 3 | (3) | | | | 3 | 1 | 1 | 5 |
| 2 | (2)+1 | | | 3 | | 3 | 4 | |
| 2 | (2) | | 2 | 2 | 3 | 1 | 2 | |
| 2 | 1 | 8 | 1 | 1 | | | | |
| 1 | (1)+2 | | | | 3 | 4 | 1 | 2 |
| 1 | 2 | 1 | 7 | 1 | | 1 | | |
| 1 | (1) | 1 | | 3 | 1 | | 2 | 3 |

Note:
Number(s) within bracket = Number of bar(s) under blinking light(s)