A HABIT STRENGTH ANALYSIS OF THE RELATIONSHIP BETWEEN RESPONSE EFFORT AND RESISTANCE TO EXTINCTION

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Thomas J. Stachnik

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AN ABSTRACT OF A THESIS

Submitted to
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ABSTRACT

A HABIT STRENGTH ANALYSIS OF THE RELATIONSHIP BETWEEN RESPONSE EFFORT AND RESISTANCE TO EXTINCTION

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This study was designed to determine the importance of effort as a variable in experimental extinction. Current textbooks either admit that the importance has not been determined, or assume it is important on the basis of data which cannot be considered definitive. Contrary to previous studies, the present work includes the assumption that a heavy-bar habit subsumes a light-bar habit, but that the converse is not true. Seven groups of animals (rats) were given various amounts of training on differentially weighted bars in a Skinner box and then extinguished to a 5 minute no-response criterion with the following results:

1. Contrary to the prediction of Ir, the difference in resistance to extinction between groups trained and extinguished on a light bar and those trained and extinguished on a heavy bar is non-significant when an asymptote has been reached and operant level is taken into account.

2. A partial replication of a previous study in which effort and extinction were shown to be directly related indicated that an asymptote had not been established, and

that the findings are better interpreted in terms of differential habit strengths.

3. Also contrary to the prediction of Ir, animals trained on a heavy bar and extinguished on a light bar show a facilitation when compared with animals trained and extinguished on a light bar.

4. The facilitation resulting from heavy bar training and light bar extinction was significantly reduced by inserting light bar responses prior to extinction. This suggests that the facilitation is a function of a contrast effect and not the magnitude of the acquisition task. The incidence of contrast effects in various experimental situations was briefly reviewed and the lack of information of the parameters involved was pointed out.

5. An interference theory of extinction was suggested as being more parsimonious and appropriate in accounting for the present findings.

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TABLE OF CONTENTS

LIST OF TABLES

I. INTRODUCTION

It is painfully clear to anyone who has ever chopped wood, done calisthenics, or run long distances that some behaviors fatigue muscle tissue to the point where continued responding becomes aversive. Any man on the street knows this to be true. However, the effect of responding *per se*, i.e., when lesser amounts of work are involved and tissue is not fatigued, is not nearly so well understood. In fact, although this problem has received considerable attention from experimental psychologists, it remains unresolved.

It is of interest to note how the relationship between the effort variable and resistance to extinction has been treated in recent textbooks. Twenty years ago Hull (1943) introduced the constructs of reactive inhibition (Ir) and conditioned inhibition (sIr) in an attempt to account for a variety of learning and inhibitory phenomena. These constructs emphasized the presumed inhibiting value of response, *per se*, and generated extensive research. Many of the findings from this research failed to confirm the predictions of Ir and sIr, yet current textbook treatments of the effort variable place a great deal of importance on effort as a variable in experimental extinction.

A case in point is a recent book by Donald Lewis (1963). His discussion of the effort variable is largely a summary of the findings of Capehart, Viney, and Hulicka (1958) and their conclusion that "the number of extinction responses is an almost linear function of the effort required to push the bar" (1958, p. 209). Another recent text by Howard Kendler (1963) refers to a 1943 study by Mowrer and Jones, accompanied by a graph which also shows resistance to extinction as an inverse linear function of the effortfulness of the task. However, both of these studies, which will later be discussed at length, are open to alternative interpretations and cannot be considered definitive.

Probably the most comprehensive text dealing with learning and inhibitory phenomena is Gregory Kimble's revision of Hilgard and Marquis' Conditioning and Learning (1961). In the discussion of extinction and the effortfulness of the response, Kimble lists a number of studies which have demonstrated that increased effort resulted in faster extinction, and also mentions that one study yielded negative results. He follows with this statement:

> Although the evidence seems clear on the point that effort does influence extinction, the form of the function, and the importance of this variable, are still in doubt. This is because the problems of manipulating effort, but no other variable, in studies of extinction are greater than might have been anticipated (1961, p. 285).

One of the problems he subsequently refers to is that in training an animal to press a heavy bar it is first necessary to teach it to press a lighter bar, and that this may result in animals extinguished on a light bar receiving more training than those extinguished on a heavy bar.

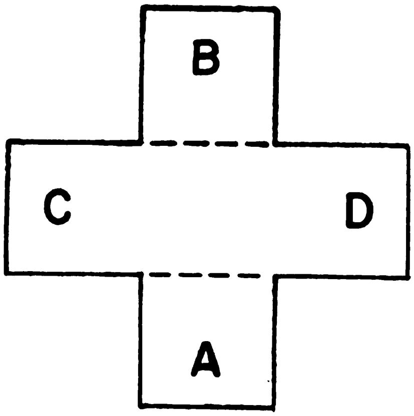
Current textbooks, then, either admit that the importance of the effort variable has not been determined, or assume it is important on the basis of data which cannot be considered definitive. The present study will examine the effect of the effort variable, hopefully with the proper controls, in an attempt to determine the importance of effort as a variable in experimental extinction. Specifically, the role of effort is being evaluated in a free-responding, operant situation.

A Brief History

The concept of Ir which generated so much effort-variable research was defined by Hull as, ". . .a condition or state which acts as a primary negative motivation in that it has an innate capacity to produce cessation of the activity which produced the state" (1943, p. 278). Two explicit characteristics of Ir were also formulated, one of which is the relationship between Ir and the work or effort involved in responding. "The net amount of functioning inhibitory potential resulting from a sequence of reaction evocations is a positively accelerated function of the amount of work (W) involved in the performance of the response in question" (1943, p. 278). The second characteristic of Ir explicitly stated is that it ". . .diminishes progressively with the passage of time according to a simple decay or negative growth function" (1943, p. 281). This suggests that Ir is like fatigue in that it is reduced through rest.

Many of the studies designed to test the predictions of Ir have occurred in the framework of the spontaneous alternation phenomenon. Alternation is said to have occurred when on the second trial in a T-maze the animal enters the arm opposite the one visited on trial one; either or both arms of the T-maze may or may not contain a reward. When one reviews this work, two things are apparent: first, it is extensive, and second, the results are conflicting, often with two findings directly contradicting each other. An example of the latter is the 1948 study by Solomon (1948a) and a study by Walker, Dember, Earl, Fawl, and Karoly (1955). Solomon inclined the goal arms of a T-maze 16° from the horizontal, which meant more work was involved in the response, more Ir presumably generated, and hence more alternation--and in this instance the prediction of Ir was supported. Walker _et_ _al_. inclined the goal arms to 45°, which should have resulted in even more alternation, but such was not the case; in fact, the frequency of alternation was lowered.

The most direct refutation of an Ir prediction in a spontaneous alternation framework occurred in similar studies by Montgomery (1952) and Glanzer (1953). Both experimenters utilized a cross maze:



Rats were placed in the starting alley at point A and allowed to turn into either one of goal arms C or D (B was blocked off). Following this, the animals were immediately taken out and placed in the starting alley at point B and again allowed to turn into either goal arm C or D (A was blocked off). If on trial one, the animal turned right into goal arm D, Ir would predict that on trial two the animal would turn left, returning into goal arm D, i.e., would alternate responses rather than goal arm visited. In both studies the Ir prediction was wrong--the animals repeated the previous response and visited the yet unexplored goal arm.

Varying intertrial interval has also served as a test of Ir, since the theory predicts that the inhibition diminishes progressively with the passage of time. The most extensive attempt to test this was conducted by Walker (1956), again using the amount of alternation in a T-maze as the dependent variable. Reactive inhibition predicts that the probability of alternation should decrease as the

intertrial interval is increased, i.e., with a long intertrial interval, the Ir presumably generated by a previous response should dissipate so the repetition of a previous response is possible. Walker used 21 values of intertrial interval ranging from 1 to 300 minutes, and his results generally supported the theory. But there was no clear relationship between amount of alternation and length of intertrial interval. The amount of alternation varied in a random fashion around a value of 75 percent for intervals up to about 60 minutes; between 60 and 90 minutes there was a sharp drop to chance level. At longer intervals there were some below-chance levels of alternation.

Maatsch (1955) gave rats extended training on both spaced and massed trials in a straight alley maze and compared the predictions made by Ir with those of an interference theory. He found that none of the major predictions drawn from Ir were confirmed. If given two trials in a straight alley maze with the second trial immediately following the first, the Ir generated on trial one should be present at the beginning of the second trial and should inhibit performance. The data indicated that no inhibition was present as a result of the first trial.

The effort variable has also been manipulated in more complex instrumental situations. Aiken (1957) had rats push a weighted swinging door to obtain food. Half of the Ss were trained under low effort conditions and half under high.

During extinction each group was divided in two and extinguished on either low or high effort. The results indicated that on the first extinction day, the animals trained and extinguished on high effort actually made more responses than those trained and extinguished under low effort, though not significantly so. However, the results are equivocal since on the second day of extinction the reverse was true; in this case, the difference was significant.

The Skinner box has also provided a convenient means of testing the predictions of Ir, since the bar loading, and hence the effort involved in responding, can easily be manipulated by the experimenter. But the relationship between effort and resistance to extinction remains unclear because most of these studies failed to include the proper controls, particularly for the habit strength of the response in question.

In the 1943 Mowrer and Jones study previously referred to, 30 rats were trained with variously weighted levers, so that during acquisition every rat made 180 responses on a 5 gm. weight, 20 responses each on 30 and 55 gm., and 60 responses on an 80 gm. weight. Ten animals were then randomly assigned to each of three groups and extinguished on either 5 gm., 42.5 gm., or 80 gm. bar loadings. The results indicated that resistance to extinction was a decreasing monotonic function of the bar loading. Hull called their report "convincing evidence" (1943, p. 279), and

Solomon regarded it to be "unequivocal in supporting some kind of formulation which takes into account the negative motivating aspect of work or effort" (1948a, p. 93). However, since the rats received more reinforcements on the light bar than they did on the heavy during acquisition, differences in habit strength would be a more parsimonious explanation of the extinction differences than effort and Ir.

Two other studies, both purporting to have controlled for habit strength, report that in a lever-pressing situation, resistance to extinction is an inverse linear function of the effortfulness of the task; yet neither of these studies can be considered definitive. Applezweig (1951) began his experiment with 179 rats, but eventually discarded 79 of them, mostly those trained on the heavy bar. This was true because animals have a weak initial tendency to press a heavy bar, and this resulted in a non-random selection of Ss in some groups. His results are also questionable because the design of the study assumed that if a rat is trained to depress a light bar, it depresses heavier bars with the same facility that rats trained to depress heavy bars depress lighter bars. One has only to observe the behavior of the animals to conclude that this assumption is not tenable. A rat trained to depress a heavy bar will easily depress all lighter bars, but the reverse is not true. Unless the loadings on the bar are graduated, the rat trained on a light bar and then switched to a heavy bar will extinguish quickly if the extinction criterion is, say, five minutes of no responding. Maatsch, Adelman, and Denny (1954) make this point in their study which showed no relationship between effort and extinction. In the Applezweig study, the animals switched to heavy bars during extinction did extinguish quickly; but there was little or no relationship between the bar loading and resistance to extinction when the animals were extinguished under the same condition they were trained under. When the data were combined, however, it appeared that resistance to extinction was a function of the effort of the task.

In the second study, Capehart, Viney, and Hulicka (1958) equated the number of reinforcements at each bar loading, but it can be argued that they failed to control for habit strength because of the same assumption, namely, that rats trained to push light bars push heavier bars with equal facility. After three days of pre-training, which consisted of habituation to the apparatus and the association of food with the "click" of the food-delivery mechanism, each animal made 15 reinforced responses per day for six consecutive days on bar loadings of 5, 40, 70, 5, 70, and 40 gm. Thus, each animal made a total of 90 reinforced responses. But it is quite legitimate to consider the reinforcement of a bar press of a given loading weight to reinforce the bar-pressing habit for all bars of equal or lesser weight, but not for bars of greater weight. This would mean that each animal had 90 reinforcements of the habit for the 5 gm. bar (30 on 5, 30 on 40, 30 on 70) but only 60 reinforcements of the habit for the 40 gm. bar (30 on 40, 30 on 70) and only 30 reinforcements of the habit for the 70 gm. bar (30 on 70 only). In this specific sense, all studies which have presumably demonstrated the inverse relationship between effort and resistance to extinction can be considered confounded with a differential habit strength variable.

In summary, experiments designed to test the predictions from Ir have been somewhat inconclusive, although largely nonsupportive. Studies employing the Skinner box have been contradictory and particularly inconclusive because of a lack of control of a number of variables. The most conspicuous is the habit strength of the response in question. The present study is a special attempt to determine the relationship between effort and extinction with habit strength controlled.

Predictions To Be Tested

The predictions which follow are based on a habit strength interpretation which includes the assumption that a heavy-bar habit subsumes a light-bar habit, but that the converse is not true. These predictions can be better understood once the procedures have been described, and therefore will be reiterated in the description of the groups. Some of these predictions, e.g., number 6, were not formulated in the original design, but evolved as the experiment progressed.

1. There will be no significant difference in the number of responses to extinction between animals trained and extinguished on a light bar (Group L L 200) and those trained and extinguished on a heavy bar (Group H H 120). Reason: Habits are equal.

2. There will be no significant difference in the number of responses to extinction between animals given 120 heavy-bar reinforcements (Group H H 120) and those given 200 reinforcements (Group H H 200) when both are extinguished on a heavy bar. Reason: Both groups at asymptote.

3. Animals given 90 reinforcements on varied-bar loadings (Group LMH L 90) and then extinguished on a light bar will make more responses during extinction than those similarly trained, but extinguished on a heavy bar (Group LMH H 90). Reason: Unequal habit strengths.

4. Animals given 120 reinforcements on a heavy bar (Group H H 120) and then extinguished on a heavy bar will make more responses during extinction than those given 90 reinforcements on varied bar loadings and extinguished on a heavy bar (Group LMH H 90). Reason: Unequal habit strengths.

5. Animals trained on a heavy bar and extinguished on a light bar (Group H L 120) will make more responses during extinction than those trained on a light bar and extinguished on a light bar (Group L L 200). Reason: Previously found

by other investigators. Interpretation: Differential habit strength or behavior contrast.

6. a) If the facilitation in Group H L 120 is a function of greater habit strength resulting from increased response effort, there will be no significant difference in the number of extinction responses when animals are trained similarly but given light-bar reinforcements just prior to extinction (Group HL L 120). Reason: The interspersed light-bar reinforcements will not affect habit strength.

b) If the facilitation in Group H L 120 is a function of a contrast in acquisition and extinction stimulation, animals trained similarly but given light-bar reinforcements just prior to extinction (Group HL L 120) will make less responses during extinction. Reason: The interspersed light-bar reinforcements will minimize the contrast effect.

II. METHOD

Table 1 below summarizes the groups used and the comparisons made among them. The letter and number designations for each group indicate the following. The first letter or group of letters refers to light (L), medium (M), or heavy (H) bar training; the second letter indicates the bar-loading during extinction; and the number refers to acquisition reinforcements.

Table 1.--Summary of groups and experimental design.

Group	N	No. and Bar-Loading of Reinforcements	Bar-Loading During Extinction	Comparisons
L L 200	14	200 on 5 gm.	5 gm.	H H 200 vs. H H 120-H H 200
H H 120	10	80 on graduated loadings, 120 on 80 gm.	80 gm.	H H 120 vs. H H 200
H H 200	10	80 on graduated loadings, 200 on 80 gm.	80 gm.	
H L 120	10	80 on graduated loadings, 120 on 80 gm.	5 gm.	H L 120 vs. H H 200
HL L 120	10	50 on graduated loadings, 120 on 80 gm., 30 on 5 gm.	5 gm.	HL L 120 vs. H L 120; HL L 120 vs. H H 200
LMH L 90	10	30 on 5 gm., 30 on 40 gm., 30 on 70 gm.	5 gm.	LMH L 90 vs. LMH H 90
LMH H 90	10	30 on 5 gm., 30 on 40 gm., 30 on 70 gm.	70 gm.	LMH H 90 vs. H H 120

Subjects

Seventy-four male rats, both albino and grey hooded, served as Ss. The animals were approximately 90-140 days old at the beginning of the experiment and were from the colony maintained by the Psychology Department at Michigan State University. Possible age and strain differences were controlled for by counterbalancing the Ss across all groups between which comparisons would be made. The data indicated, however, that neither of these variables had any observable effect upon performance in the present study.

Apparatus

The apparatus employed was a Skinner box 14 in. long, 14 in. deep, and 9 1/4 in. wide. The sides were a clear plexiglass, while the bar, which was 4 in. long, 3/4 in. wide and 1/8 in. thick, was of red plexiglass and protruded 1 in. into the box at a height of 3 1/2 in. from the floor. A metal food cup was located just to the right of the bar, 1 1/8 in. from the floor. The bar could be counterweighted so that the effort required to activate the food-delivery mechanism could be set as low as 5 gm., as high as 80 gm., or at any value in between. An electric counter recorded all bar-press responses which activated the feeding mechanism. The food reward used was a 45 mg. pellet, 4 mm. by 3.3 mm., made by the P. J. Noyes Company.

Training

All Ss were kept on a reduced diet of 8 gm. of Wayne

Lab Blox in their individual home cages for a period of 8 to 10 days prior to beginning the experiment. Water was available at all times, and the animals were handled for 3 min. periods daily. The *S*s were under approximately 21 hr. of food deprivation at the beginning of each experimental session, and were fed in their home cages at the end of each session. They received 8 gm. of food in addition to the pellets obtained during training.

Training was similar for all *S*s in Groups L L 200, H H 120, H H 200, H L 120, HL L 120. At the beginning of training for these *S*s, the bar required only a 5 gm. depression to activate the delivery mechanism. Three food pellets were available in the food cup. After these pellets were eaten, *E* manually supplied approximately 15 additional pellets to associate the click of the feeding mechanism with the arrival of food in the cup. Then, by using the method ofsuccessive approximation, *E* shaped the bar-press response until each *S* had made approximately 25 reinforced responses, which terminated the session. The number of reinforced responses allowed per session varied slightly according to the bar loadings and total responses designated for each experimental group (see Table 1), but the number was never less than 25 or more than 29. The bar loading during subsequent sessions was gradually increased until the *S*s of Groups H H 120, H H 200, H L 120, and HL L 120 were able to depress an 80 gm. bar per the schedule given in Table 1.

Each S was extinguished on the day following the completion of acquisition to a 5 min. no-response criterion.

The training for Groups LMH L 90 and LMH H 90 was slightly different, since they represented a partial replication of the Capehart, Viney, and Hulicka study (1958). Their procedure for the groups used was followed exactly. After 8-10 days of reduced diet and handling, Ss received three days of preliminary training during which time the bar was removed from the apparatus. On the first day each S was placed in the apparatus for 20 min. and allowed to eat food pellets placed in the food cup. On days 2 and 3, E operated the feeding device so that the audible click of the device was associated with the arrival of food. During the next six days, S was required to make 15 responses per day on bar loadings of 5, 40, 70, 5, 70, and 40 gm. respectively. The animals were not shaped during this time, nor was the bar loading graduated, i.e., the day following the first 15 responses on the 5 gm. loading, the loading was increased to 40 gm. with no intermediate weights. Ss therefore made a total of 90 reinforced responses and upon completing these were divided into two groups equated in terms of the mean response latency of the last 45 acquisition responses. One group was extinguished on a 5 gm. loading and the other on a 70 gm. loading on the day following the completion of acquisition trials to a 5 min. no-response criterion.

Description of Groups and Experimental Comparisons

The comparisons referred to in the following paragraphs are between the mean number of responses made by each group during extinction to the same extinction criterion.

Group L L 200.--All Ss were required to make a total of 200 reinforced responses, all of which were on a light bar loading (5 gm.), and were then extinguished on a light bar. It should be noted that 14 animals were used in this group, whereas in all other groups N = 10. This was the only group to receive training solely on a 5 gm. bar.

Group H H 120.--All Ss were required to make 80 reinforced responses on lighter bar loadings followed by 120 responses on a heavy bar (80 gm.); extinction followed on a heavy bar. Although Group L L 200 received 200 responses at the bar loading on which they were extinguished and Group H H 120 only 120, it was assumed that an asymptote had been reached by 120 reinforcements. Since the habit strengths were equivalent, Groups L L 200 and H H 120 should make the same number of responses during extinction. The prediction derived from Ir theorizing would be that Group L L 200 would be more resistant to extinction than Group H H 120.

Group H H 200.--The purpose of this group was to check on whether an asymptote had actually been reached at 120 acquisition responses in Group H H 120. Ss were required to make 200 responses on the heavy bar preceded by 80 preliminary trials as in Group H H 120. If there were no difference in the number of responses made during extinction in Groups H H 120 and H H 200, the assumption of equivalent habit strength with 120 and 200 responses would be tenable. Furthermore, the data from Groups H H 120 and H H 200 could be combined for a comparison with Group L L 200. Habit strength prediction: No significant difference.

Group H L 120.--*S*s received the same training as Group H H 120, i.e., 120 responses on the heavy bar preceded by 80 responses on lighter bars, but were then extinguished on the *light* bar. Group H L 120 was compared with Group L L 200 as a further check on the concept of Ir. Whereas previous studies have indicated that heavy-bar training and light-bar extinction results in a facilitation in extinction responding, the Ir prediction would be no significant difference between the two groups since the effort required following the termination of reinforcement is identical.

Group HL L 120.--This group was included when a marked facilitory trend was observed in the first two or three animals to be run in Group H L 120. It was argued that the facilitation was due either to a behavior contrast effect or to greater habit strength in H L 120 resulting from the greater magnitude of effort involved in the acquisition of the bar-pressing response. In an attempt to identify the relevant variable, *S*s in Group HL L 120 received only 50 preliminary reinforcements (instead of 80 as in H H 120, H H 200, and H L 120) prior to making 120 responses on the heavy bar. The 120 reinforcements on the heavy bar were followed by 30 reinforcements on the light bar and then by extinction on the light bar. The 30 interspersed reinforcements on the light bar was an attempt to eliminate or minimize the contrast effect. Comparisons were then made between Groups H L 120 and HL L 120 and between Groups L L 200 and HL L 120. If Group HL L 120 made significantly fewer responses during extinction than Group H L 120, the facilitation would be attributable to a contrast effect. If no difference were observed, the facilitation might better be accounted for by an increase in habit strength resulting from the greater magnitude of the acquisition task (Jaynes, 1950). A comparison between Groups L L 200 and HL L 120 would be in order if the facilitation was a result of a contrast effect. If contrast effect has been eliminated, there should be no significant difference between L L 200 and HL L 120.

Groups LMH L 90 and LMH H 90 (Capehart, Viney and Hulicka).--Ss made a total of 90 responses, 30 at each of three bar loadings: 5 gm., 40 gm., and 70 gm. They were then divided into two groups, LMH L 90 extinguished on a 5 gm. bar and LMH H 90 on a 70 gm. bar. As previously argued, the habit strength of the bar-press response has presumably not been equated in these two groups. If a reinforcement on a bar of a given loading can be considered a reinforcement on all bars of equal or lesser weight, but not on bars of greater weight, then LMH L 90 had 90 reinforcements, but LMH H 90 had only 30. Habit strength prediction: The LMH L 90 group will make more responses during extinction than LMH H 90, whereas as already predicted no significant difference between L L 200 and H H 120 where habit strength was asymptotic and equated. Furthermore, if H H 120 makes more responses during extinction than LMH H 90, this would indicate that an asymptote had not been reached in LMH H 90 and that the conclusion of Capehart *et al.* was open to question.

One important methodological consideration should be mentioned, namely, the differential sensitivity of the bar during extinction. The number of responses made in a Skinner box is manually and/or electrically recorded, the criterion for a response simply being a given excursion of the bar. This allows for a clean, precise measurement of the number of responses made, but when the bar is differentially weighted, certain disadvantages are also apparent. An animal extinguished on a light bar (5 gm.) makes many tangential or incidental moves around the bar, which because of the light bar sensitivity are recorded as responses, i.e., the operant level is high. This is not true when the animal is extinguished on an 80 gm. loading which requires a well-executed response to move the bar the prescribed distance. One has only to observe the animals during extinction to conclude that this is an important factor in light-bar animals' showing a greater resistance to extinction. The incidence of exploratory behavior, which is minimal after the first few acquisition sessions in the apparatus, immediately increases during extinction following the first flurry of responses. Much of this exploration consists of the animal's standing on his hind legs, while smelling and looking at the top of the box. Often, on returning to a position on all fours, the animal bumps the bar, resulting in a recorded response on the light bar, but not on the heavy bar. Since this is not an infrequent occurrence, the tangential responses made by animals extinguished on a light bar were recorded. They were then subtracted from the total before a comparison was made with animals extinguished on a heavy bar. Obviously, comparing two groups, when both have been extinguished on a light bar, the subtraction is not necessary.

III. RESULTS

The method of analysis throughout is *t*-ratios of the mean number of responses made during extinction by the various groups for the specific comparisons dictated by theory; two-tailed tests are used in every comparison.

Table 2, page 23, summarizes the data obtained from Groups H H 120 and H H 200. This comparison was made first since the two groups could be combined for a more reliable comparison with Group L L 200 if they did not differ significantly. The difference is not significant, indicating that an asymptote had been reached at 120 responses.

The crucial comparison of animals trained and extinguished on a light bar with those trained and extinguished on a heavy bar is presented in Table 3 on page 23. The former group made more responses during extinction, and although the difference is significant at the .05 level, the difference is non-significant following subtraction of tangential responses. The significant difference prior to subtraction is discrepant with the findings of both Maatsch, Adelman, and Denny (1954) and a portion of Aiken's study (1957). Both these studies, as mentioned earlier, found no differences between low and high effort groups in extinction responding.

The mean number of tangential responses was 13.4 (155.7 - 142.3). However, it should be pointed out that this

Table 2.--A comparison of the mean number of responses made during extinction by Groups H H 120 and H H 200.

Group	M	S.D.	t	df	Level of Significance
H H 120	110.1	46.7	.36	18	.40
H H 200	101.9	53.9			

Table 3.--A comparison of the mean number of responses made during extinction by Groups L L 200, and H H 120 and H H 200 combined.

Group	M	S.D.	t	df	Level of Significance
Before Tangential Bar Presses Are Subtracted					
L L 200	155.7	56.2	2.67	32	.05
H H 120 plus H H 200	106.0	49.3			
After Tangential Bar Presses Are Subtracted					
L L 200	142.3	53.8	1.95	32	.10
H H 120 plus H H 200	106.0	49.3			

number represents only those responses which were <u>clearly</u> tangential; those that were questionable were not tallied. The number of questionable responses greatly exceeded those that were clearly tangential, and it could reasonably be argued that the difference between L L 200 and H H 120 and H H 200 combined would shrink to zero if it were possible to identify all tangential responses. Nevertheless, we must point out that at this point in our analysis the evidence for a habit strength interpretation is quite inconclusive.

The comparison between Groups L L 200 and H L 120 presented in Table 4 on page 25 is the most damaging finding of the present study to the concept of Ir. Since the response effort required of each group during extinction is identical, Ir would predict that the two groups should show approximately equal resistance to extinction. But it can be seen that Group H L 120 made almost <u>twice</u> the number of responses made by Group L L 200. This difference is statistically significant well beyond the .01 level.

Table 5, page 25, presents the data relevant to whether the response facilitation in Group H L 120 was due to a contrast effect or to the greater magnitude of the acquisition response. Here it can be seen that the difference between HL L 120 and H L 120 is significant at the .01 level. Since the 30 light-bar responses inserted just prior to extinction were enough to significantly reduce extinction

Table 4.--A comparison of the mean number of responses made during extinction by Groups L L 200 and H L 120.

Group	M	S.D.	t	df	Level of Significance
L L 200	155.7	56.2	6.55	22	$<.01$
H L 120	310.8	57.9			

Table 5.--A comparison of the mean number of responses made during extinction by Groups H L 120 and HL L 120.

Group	M	S.D.	t	df	Level of Significance
H L 120	310.8	57.9	3.25	15[1]	$<.01$
HL L 120	193.0	104.0			

[1] An F-test was significant, so degrees of freedom were computed with Welch's formula.*

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*Welch's Formula for Degrees of Freedom:

$$df = \frac{\left(\frac{s_1^2}{N_1} + \frac{s_2^2}{N_2}\right)^2}{\left(\frac{s_1^2}{N_1}\right)^2 \frac{1}{N_1 + 1} + \left(\frac{s_2^2}{N_2}\right)^2 \frac{1}{N_2 + 1}} - 2$$

responding, it appears that the facilitation in Group H L 120 was due to a contrast effect rather than the magnitude of the response during acquisition.

To determine the extent to which the contrast effect was removed by the manipulations used in HL L 120, this group was compared with L L 200. The comparison is presented in Table 6 on page 27. Since the difference is non-significant, it is possible to conclude that the contrast was essentially eliminated by the insertion of 30 light bar responses prior to extinction in the HL L 120 group.

Table 7, page 27, summarizes the comparison between Groups LMH L 90 and LMH H 90, a partial replication of the Capehart *et al*. study described earlier. The tangential responses (6.6) are subtracted from the total number of extinction responses for the light-bar group in the table. It can be seen that the group extinguished on the light bar (LMH L 90) made *three times* as many responses during extinction as the group extinguished on the heavy bar (LMH H 90). The same ratio of heavy-to-light bar responses was found by Capehart *et al*. The difference is significant beyond the .01 level even though tangential responses have been subtracted from the light-bar group total. The original contention of unequal habit strengths in these two groups for the training procedure used is clearly supported, for a non-significant difference was obtained between L L 200 (tangential responses subtracted) and H H 120 and H H 200

Table 6.--A comparison of the mean number of responses made during extinction by Groups L L 200 and HL L 120.

Group	M	S.D.	t	df	Level of Significance
L L 200	155.7	56.2	1.03	14[1]	.20
HL L 120	193.0	104.0			

[1] An F-test was significant, so degrees of freedom were computed with Welch's formula.

Table 7.--A comparison of the mean number of responses made during extinction by Groups LMH L 90 and LMH H 90.

Group	M	S.D.	t	df	Level of Significance
LMH L 90	97.4	36.4	4.88	18	$<.01$
LMH H 90	32.3	20.5			

combined when it was clear an asymptote had been reached by all groups.

That the habit strength in LMH H 90 for the heavy bar was quite weak is apparent when this group is compared with H H 120 (Table 8). Although the latter received only 30 more reinforcements, they made <u>three times</u> as many responses during extinction ($t = 4.37$). The magnitude of this difference indicates that the assumption that rats trained on light bars push heavier bars with equal facility is not tenable.

Table 8.--A comparison of the mean number of responses made during extinction by Groups H H 120 and LMH H 90.

Group	M	S.D.	t	df	Level of Significance
H H 120	106.0	49.3	4.82	14[1]	<.01
LMH H 90	32.3	20.5			

[1] An F-test was significant, so degrees of freedom were computed by Welch's formula.

Table 9 on page 29 presents a summary of all comparisons made in the present study.

Table 9.--Summary of comparisons made.

Group	Treatment	Mean	Level of Significance
H H 120	120 heavy-bar responses, extinguished heavy	110.1	.40
vs.			
H H 200	200 heavy-bar responses, extinguished heavy	101.9	
L L 200	200 light-bar responses, extinguished light (without tangential bar presses subtracted)	155.7	.05
vs.			
H H 120 plus H H 200	120 and 200 heavy-bar responses, extinguished heavy	106.0	
L L 200	200 light-bar responses, extinguished light (with tangential bar presses subtracted)	142.3	.10
vs.			
H H 120 plus H H 200	120 and 200 heavy-bar responses, extinguished heavy	106.0	
L L 200	200 light-bar responses, extinguished light	155.7	.01
vs.			
H L 120	120 heavy-bar responses, extinguished light	310.8	
H L 120	120 heavy-bar responses, extinguished light	310.8	.01
vs.			
HL L 120	120 heavy-bar responses, 30 light-bar responses, extinguished light	193.0	
L L 200	200 light-bar responses, extinguished light	155.7	.20
vs.			
HL L 120	120 heavy-bar responses, 30 light-bar responses, extinguished light	193.0	
LMH L 90	30 responses on 5, 40, and 70 gm. bars; extinguished light	97.4	.01
vs.			
LMH H 90	30 responses on 5, 40, and 70 gm. bars; extinguished heavy	32.3	
H H 120	120 heavy-bar responses; extinguished heavy	110.1	.01
vs.			
LMH H 90	30 responses on 5, 40, and 70 gm. bars; extinguished heavy	32.3	

IV. DISCUSSION

The findings justify a number of conclusions: (1) There is no significant difference in extinction responding between high and low effort groups when an asymptote has been reached and operant level is considered; (2) Animals trained on a heavy bar and extinguished on a light bar show a marked facilitation; (3) The facilitation is the result of a contrast in stimulation since the insertion of light-bar reinforcements just prior to extinction essentially eliminates it; and (4) The assumption that rats trained on light bars depress heavier bars with equal facility is rejected.

In general, the results indicate that the importance of the effort variable has been over-emphasized in experimental extinction, particularly when small amounts of work are involved, such as in a Skinner box. It is important to note that this conclusion is made for small amounts of work, and says little or nothing about the effect of fatigue upon behavior.

Since work or effort is of minimal importance it follows that Ir is of minor importance in extinction. What, then, accounts for extinction? One interpretation of the present findings can be made in terms of a one-factor interference theory of experimental extinction, as incorporated in elicitation theory (Denny and Adelman, 1955). This is particularly appropriate because this theory was the impetus for the Maatsch, Adelman, and Denny study (1954), which was the first to cast doubt on the importance of the effort variable in extinction. Traditionally, three arguments have been raised against an interference interpretation, but none poses a threat to the elicitation position. The first argument contends that it is not clear where the competing response comes from. Elicitation theory holds that the omission of reward is a frustrating situation which elicits a class of avoidant responses which then compete with the originally learned behavior. Two studies have directly tested the validity of this assumption. Amsel and Roussel (1952) employed a two-stage straight runway, with each stage terminating in a goal box. Rats were run over a long series of trials in which food was available in each goal box, and then during extinction food was omitted from the first box. The results showed a decrease in running time for the second stage of the alley during extinction, clearly indicating the energizing effect of frustration on learned behavior.

Adelman and Maatsch (1956) examined more directly the relationship between frustration and extinction. Using a box 10 inches high, the response of jumping out of the box was reinforced differently for three groups of rats. One group was rewarded with "curiosity" satisfaction, and a second group with food, the third group with escape from frustration. This procedure resulted in great differences in resistance to extinction. Group one extinguished very quickly; group two at the end of about 60 trials; but group three, rewarded with escape from frustration, showed no signs of extinguishing at the end of 100 trials.

A second common objection to a competing-response explanation of extinction has been that since extinction is a non-reinforcement situation, there is nothing to reinforce the competing response when it <u>does</u> appear. This argument is not damaging to elicitation theory, since the theory does not view reinforcement in a Thorndikian fashion, i.e., the strengthening of a closely preceding response. Rather, reinforcement is viewed as occurring simultaneously with the eliciting of the response, i.e., it <u>is</u> the eliciting of a response. Furthermore, the theory holds that the omission of reward in an established behavior sequence constitutes an instance of reinforcement (elicitation) the same as the consistent elicitation of some response, or class of responses, by food, water, shock, etc. Since the strengthening of a particular response tendency results from the consistent elicitation of that response, the continued elicitation of avoidant-type responses during extinction in a Skinner box strengthens these responses which then compete with the original learned sequence.

The third argument against an interference theory of extinction has centered around the fact that basically one process, conditioning, is used to explain both acquisition and extinction. This being the case, it is argued that both should respond to experimental variables in the same way, e.g., the spacing of practice. The contention is that massing of trials results in rapid extinction while having the opposite effect on acquisition, but a number of weaknesses are apparent in this argument. First, a number of studies have shown that massed trials do not necessarily facilitate extinction. This indicates that variables other than the massing alone are operating. Secondly, in those studies in which massing has resulted in rapid extinction, one can analyze the results in terms of degree of frustration. Indeed, one can argue that it is this variable rather than the massing _per se_ which is related to resistance to extinction, i.e., the greater the frustration, the greater the incidence of competing responses, the more quickly extinction occurs. The third very apparent weakness in the argument is that it does not take into account the fact that totally different responses are elicited during acquisition and extinction. They are in fact antagonistic response classes of approach and avoidance, so the expectation of responding similarly to certain experimental variables seems naive.

The rejection of the assumption that rats trained on light bars depress heavier bars with equal facility also supports a major contention of Denny and Adelman's elicitation theory. The theory holds that ". . .the <u>exact</u> nature of the response elicited at any instant in time is a fundamental consideration in explaining behavior" (1955, p. 4). Again, one has only to <u>observe</u> the animal in a Skinner box to conclude that the depression of a light bar is <u>not</u> the same response as the depression of a heavy bar. During advanced stages of acquisition training on a light bar, the rat often positions himself with one paw on the food cup and the other on the bar. This posture enables him to secure the food pellet following a bar depression even before it comes to rest in the cup. A heavy bar response is very dissimilar, usually requiring the animal to lean over the bar and grasp the back edge of it with both paws, his downward thrust usually resulting in the rear legs rapidly sliding forward. "Plowing a field" may suggest a certain class of responses, but if one man plows riding a tractor and another following a horse, the behavior involved is obviously different.

Additional evidence of the dissimilarity between heavy and light bar responses and the importance of the exact nature of the response is available in the findings of Stanley and Aamodt (1954). They trained half of their <u>S</u>s (rats) to depress a 50 gm. bar and the other half to depress a 100 gm. bar. Half of each were then extinguished on a 50 gm. bar and half on a 100 gm. bar. The results indicated a high positive correlation between the force requirement during acquisition and the forcefulness of responding during extinction. Specifically, Ss trained on a 50 gm. loading and extinguished on 100 gm. made significantly more incomplete responses during extinction than Ss extinguished on loadings equal to, or less than, the loading employed during acquisition. In other words, it appears that extinction responding was a function of the exact response which was consistently elicited during training.

The problem of tangential and incidental responses being recorded because of the sensitivity of a 5 gm. bar was mentioned earlier. By utilizing an apparatus of a slightly different nature in future research, such as in the Stanley and Aamodt study (1954), the problem might be circumvented or at least minimized. Rather than an all-or-none situation in which a given excursion of the bar either closes or does not close a microswitch, a pressure-sensitive bar might be arranged so that any contact with the bar would be recorded. If each bar contact were then translated into grams of pressure on some continuous recording device, the advantage would be obvious. Responses made during heavy-bar extinction which equalled or exceeded the amount of pressure necessary to activate the light bar could then be added to the total number of responses made. This would be a more objective procedure than subtracting what appear to be tangential responses made by animals on a light bar, as in the present study.

The facilitation observed when animals were trained on a heavy bar and extinguished on a light bar is of interest in terms of the generalization-decrement hypothesis. Any extinction procedure involves a change from the acquisition situation in that the proprioceptive consequences of reinforcement, and eventually responding, are eliminated. Generalization decrement extends this idea and postulates that the speed of extinction is inversely related to the similarity in stimulation between acquisition and extinction. One might argue that the theory would make a wrong prediction in the present study since it would hold that _S_s trained on a heavy bar and extinguished on a light bar would extinguish faster than _S_s trained on a light bar and extinguished on a light bar. The prediction would be based on the fact that kinesthetic feedback differs during acquisition and extinction in the former but not in the latter. However, this argument includes the assumption that the animals _feel_ the difference in stimulation--which may or may not be true. It seems more appropriate to question the applicability of the generalization-decrement hypothesis in the present case rather than to reject it outright.

Differing kinesthetic feedback was used by Aiken (1957) in an attempt to account for the fact that his high effort _S_s showed the same resistance to extinction as low effort _S_s, during the first extinction session. He suggests that the feedback stimulation from the bar-pressing responses is analogous to Hull's V (stimulus intensity dynamism), and that the prediction of a greater habit strength following high rather than low effort can be obtained from the formula:

$_sH_r = {}_sH_r \times V_1$. The present findings, however, indicate that this explanation is inappropriate. The facilitation resulting from heavy bar training and light bar extinction was essentially eliminated by inserting light bar reinforcements prior to extinction; therefore, the increment in extinction responding is a function of a stimulus change and <u>not</u> greater habit strength following high effort. This in effect destroys Aiken's attempt to make his data mesh with Hullian theory.

At this point one might speculate as to why Aiken's <u>S</u>s which were trained light and extinguished light made more responses than <u>S</u>s trained heavy and extinguished heavy during the second extinction session, but not during the first. The panel-push response employed is no different from a bar-press response in that tangential responses would augment the low-effort group total but not the high effort total. If it can be assumed that the incidence of exploratory behavior is greater during the second extinction session than during the first, it follows that the number of tangential responses would also be greater and might account for the difference between the two groups. This interpretation seems especially plausible since any movement by the animal which displaced a swinging door 1/2 inch within 30 seconds after the door was exposed counted as a response and terminated the trial. The dependent variable was defined as the number of trials to extinction, and extinction was said to have been reached when S failed to respond on two consecutive 30 second periods with the swinging door exposed.

Applezweig's (1951) conclusion was the same as Aiken's. He found a significant positive relationship between effort during training and number of extinction responses. This was largely a result of the facilitation of Ss trained heavy and extinguished light because he reports that when animals were trained and extinguished at the same effort, there were not ". . .any determining factors, other than chance, underlying the correlation between effort level and rate of extinction" (1951), p. 230). He then concludes that there is greater habit strength when the effort involved in learning is greater, which according to the present results is erroneous.

Facilitation as a result of a contrast in stimulation is not a new phenomenon, nor is it restricted to a particular set of experimental conditions. If one views it as the instrumental analogue of positive induction in classical conditioning, the first mention of it was made by Pavlov (1927). Skinner (1938) spoke of a contrast effect in his book, and Verplanck (1942) and Solomon (1943) observed it in running speed in a maze and in jump-stand latency, respectively. It has frequently been observed in studies of incentive magnitude when Ss are switched from one incentive value to another (Crespi, 1942). Aiken (1957) referred to it in his instrumental panel-push study. One of the most recent examples (Brethower and Reynolds, 1962) demonstrates the facilitative effect of punishment on unpunished behavior. The experimenters reinforced the key pecking of pigeons on a variable-interval schedule during the presentation of each of two stimuli (red and green lights). Later, punishment followed every response emitted in the presence of the red light, but not in the presence of the green. The result was that when the rate of punished responding changed during the presentation of the one stimulus, the rate of unpunished responding during the other stimulus changed in the opposite direction. In other words, when punished responding decreased, unpunished responding increased; and when previously punished responding increased following termination of the shock, the always unpunished responding decreased.

It is of interest to speculate as to why such a pronounced facilitation occurred in the present study, while in some other studies it was absent or greatly diminished. One explanation might be that two essential conditions for its appearance involve asymptotic habit strength and a large differential in the light and heavy bar loadings, both of which are characteristic of the present study, but missing in some previous works. For example, the loading differential in the Capehart *et al*. study (1958) was 65 gm. (70 gm. minus 5 gm.) but just prior to extinction the *S*s were reinforced on a 40 gm. bar, not a 5 gm. bar. Also, these data strongly suggest that an asymptote had not been reached. In the Stanley and Aamodt (1954) experiment, an asymptote was established (124 acquisition responses at the extinction bar loading) but the weight differential was only 50 gm. (100 gm. minus 50 gm.). The present study included the establishment of an asymptote and a differential of 75 gm. (80 gm. minus 5 gm.).

Implications for Future Research

In general, little is known about facilitation resulting from contrast effects, particularly concerning the parameters which affect it. Pereboom (1957) has, in part, accounted for the phenomenon in incentive magnitude studies with an explanation based on competing, exploratory behavior, but other areas remain in need of research. An immediate question suggested by the present study concerns the manipulation required to eliminate the demonstrated contrast effect. Since following heavy-bar training, 30 light-bar reinforcements essentially eliminated the facilitation, one might ask what are the minimum number of reinforcements necessary to achieve the same result. It is possible that the number is related to the length of time at the onset of extinction that an animal continues to make a heavy-bar response when trained on a heavy bar but extinguished on a light bar. That is, following heavy-bar training, an animal extinguished on a light bar initially exerts enough force to depress an 80 gm. bar when a 5 gm. effort is sufficient to activate the food delivery mechanism. This excessive force in responding usually diminishes anywhere between the tenth and fiftieth extinction response, and, as in facilitory effects, perhaps represents the minimal amount of kinesthetic feedback necessary to effect a behavior change.

V. SUMMARY

This study was designed to determine the importance of effort as a variable in experimental extinction when the habit strength of the response has been controlled. Seven groups of animals were given various amounts of training on differentially weighted bars in a Skinner box with the following results:

1. Contrary to the prediction of Ir, the difference in resistance to extinction between groups trained and extinguished on a light bar and those trained and extinguished on a heavy bar is non-significant when an asymptote has been reached and operant level is taken into account.

2. A partial replication of a previous study in which effort and extinction were shown to be directly related indicated that an asymptote had not been established, and that the findings are better interpreted in terms of differential habit strengths.

3. Also contrary to the prediction of Ir, animals trained on a heavy bar and extinguished on a light bar show a facilitation when compared with animals trained and extinguished on a light bar.

4. The facilitation resulting from heavy bar training and light bar extinction was significantly reduced by inserting light bar responses prior to extinction. This suggests that the facilitation is a function of a contrast

effect and not the magnitude of the acquisition task. The incidence of contrast effects in various experimental situations was briefly reviewed and the lack of information of the parameters involved was pointed out.

5. An interference theory of extinction was suggested as being more parsimonious and appropriate in accounting for the present findings.

REFERENCES

1. Adelman, H. M., and Maatsch, J. L. (1956) Learning and extinction based upon frustration, food reward, and exploratory tendency. _J. exp. Psychol._, 52, 311-315.

2. Aiken, E. G. (1957) The effort variable in the acquisition, extinction, and spontaneous recovery of an instrumental response. _J. exp. Psychol._, 53, 47-51.

3. Amsel, A. and Roussel, J. (1952) Motivational properties of frustration: I. Effect on a running response of the addition of frustration to the motivational complex. _J. exp. Psychol._, 43, 363-368.

4. Applezweig, M. H. (1951) Response potential as a function of effort. _J. comp. physiol. Psychol._, 44, 225-235.

5. Brethower, D. M. and Reynolds, G. S. (1962) A facilitative effect of punishment on unpunished behavior. _J. exp. Anal. Behav._, 5, 191-199.

6. Capehart, J., Viney, W. and Hulicka, I. (1958) The effect of effort upon extinction. _J. comp. physiol. Psychol._, 51, 505-507.

7. Crespi, L. P. (1942) Quantitative variation of incentive and performance in the white rat. _Amer. J. Psychol._, 55, 467-515.

8. Denny, M. R. and Adelman, H. M. (1955) Elicitation theory: II. The formal theory and its application to instrumental escape and avoidance conditioning. Unpublished paper, Department of Psychology, Michigan State University.

9. Glanzer, M. (1953) The role of stimulus satiation in spontaneous alternation. _J. exp. Psychol._, 45, 387-393.

10. Hull, C. L. (1943) _Principles of behavior_. New York: D. Appleton Century.

11. Jaynes, J. (1950) Learning a second response to a cue as a function of the magnitude of the first. _J. comp. physiol. Psychol._, 43, 398-408.

12. Kendler, H.H. (1962) Basic psychology. New York: Appleton-Century-Crofts, Inc.

13. Kimble, G. A. (1961) Hilgard and Marquis' Conditioning and Learning. New York: Appleton-Century-Crofts, Inc.

14. Lewis, D. J. (1963) Scientific principles of psychology. New Jersey: Prentice-Hall.

15. Maatsch, J. L. (1955) An experimental test of the differential effects of work and frustration upon learning. Unpublished Ph.D. thesis, Department of Psychology, Michigan State University.

16. Maatsch, J. L., Adelman, M., and Denny, M. R. (1954) Effort and resistance to extinction of the bar pressing response. J. comp. physiol. Psychol., 47, 47-50.

17. Montgomery, K. C. (1952) A test of two explanations of spontaneous alternation. J. comp. physiol. Psychol., 45, 287-293.

18. Mowrer, O. H. and Jones, H. M. (1953) Extinction and behavior variability as functions of effortfulness of task. J. exp. Psychol., 33, 369-386.

19. Pavlov, I. P. (1927) Conditioned reflexes. (Trans. by G.V. Anrep) London: Oxford University Press.

20. Pereboom, A. C. (1957) A note on the Crespi effect. Psychol. Rev., 64, 263-264.

21. Skinner, B. F. (1938) The behavior of organisms. New York: D. Appleton Century Co.

22. Solomon, R. L. (1943) Latency of response as a measure of learning in a "single-door" discrimination. Amer. J. Psychol., 56, 422-432.

23. Solomon, R. L. (1948a) Effort and extinction rate: A confirmation. J. comp. physiol. Psychol., 41, 93-101.

24. Solomon, R. L. (1948b) The influence of work on behavior. Psychol. Bull., 45, 1-40.

25. Stanley, W. C. and Aamodt, M. S. (1954) Force of responding during extinction as a function of force requirement during conditioning. J. comp. physiol. Psychol., 47, 462-464.

26. Verplanck, W. S. (1942) The development of a discrimination in a simple locomotor habit. J. exp. Psychol., 31, 441-464.

27. Walker, E. L. (1956) The duration and course of the reaction decrement and the influence of reward. *J. comp. physiol. Psychol.*, 49, 167-176.

28. Walker, E. L., Dember, W. N., Earl, R. W., Fawl, C. L., and Karoly, A. J. (1955) Choice alternation: III. Response intensity vs. response discriminability. *J. comp. physiol. Psychol.*, 48, 80-85.