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SPONTANEOUS RECOVERY OF OPERANT RESPONSES: 
EFFECTS OF TIME AND SITUATION

BY

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Theories of spontaneous recovery including those of Pavlov, Hull, Skinner, Liberman, and Estes, are presented and their predictions compared against the record of empirical research. An alternative decay model, uniquely predicting a non-monotonic trend for spontaneous recovery over time, is also outlined. An experiment designed to explore the effect of recovery interval duration over periods as long as one week, and the effect of the degree of similarity of the recovery interval situation to the original learning situation, is presented. The failure to find any effect of time or situation is interpreted with respect to prior conflicting empirical results, and in relation to the theories of Estes, Skinner, and Hall. Topics of future research are suggested which could resolve some of the doubts and contradictions which have prevented a clear understanding of the basic phenomenon of spontaneous recovery.
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# TABLE OF CONTENTS

## Abstract

### I. Introduction .........................................................1

A. Practical Relevance ..................................................1

B. Theoretical Relevance .................................................2

C. Lack of Research .....................................................2

### II. Background – Setting the Stage .................................4

A. Pavlov and Recovery of Conditioned Reflexes ......................4

B. Early Studies of Operant Recovery ................................5

1. Skinner (1938) .........................................................5

2. Youtz (1938) ..........................................................6

3. Ellson (1938) ..........................................................7

4. Graham and Gagne (1940) ............................................9

5. Summary of Early Studies ...........................................9

### III. Theories of Learning: Predictions for Spontaneous Recovery .........................................................11

A. Pavlovian Theory ......................................................11

B. Hull’s System ..........................................................11

C. Skinner’s Theory ......................................................13

1. The Construct of Response Reserve ...............................13

2. The First Trials Hypothesis .......................................15

D. Liberman’s Interference Interpretation .........................16

E. Estes’ Stimulus Sampling Theory ..................................18

1. Spontaneous Regression Predicted .................................18

2. Spontaneous Recovery Predicted ..................................19

F. The Decay Model .....................................................21

1. General Structure ...................................................21
2. Predictions of Recovery and Regression ........ 23
G. Summary of Predictions....................... 24
IV. Subsequent Research and Performance of Theories .... 27
   A. Individual Differences .................. 27
   B. Long-term Recovery ..................... 27
   C. Situation During Recovery Interval ..... 29
   D. Interpolated Tasks During Recovery Interval .... 29
   E. Discriminant Extinction Effects .......... 30
   F. Effects of Drive ........................ 31
   G. Multiple Extinction Effects ............. 32
   H. Effects of First Trial Stimulus Characteristics .. 33
   I. Effects of the Extent of Original Conditioning ... 33
   J. Effects of Spacing During Acquisition or Extinction ............................ 34
   K. Summary of Theoretical Performance .......... 35
      1. Hull .................................. 35
      2. Skinner ................................ 35
      3. Interference ........................... 36
      4. Stimulus Sampling ...................... 36
      5. Decay .................................. 36
V. An Experiment on Effects of Time and Situation .... 38
   A. Subjects ................................ 41
   B. Task ................................... 41
   C. Procedure ................................ 42
   D. Results ................................ 43
   E. Discussion ............................... 44
VI. References .................................. 49
Over the last fifty years, the study of behavior has revealed much about the fundamentals of learning. The orderly increases in frequency of a behavior which has been rewarded, and likewise, the orderly decreases when it is no longer rewarded, are well documented. Yet a third learning phenomenon, less intuitively apparent than those above, but just as ubiquitous, follows from rewarding and then ceasing to reward a response. After a time, the original learned response will increase in strength, apparently spontaneously. Spontaneous recovery has not been as adequately explored as learning and "unlearning," even though its prediction and manipulation would have a wide variety of practical applications.

For people concerned with shifting from one set of behaviors in a situation to another, spontaneous recovery is of direct interest. If a permanent shift is desired, then minimal recovery would be desired, to prevent interference with the new behavior. For a temporary shift, on the other hand, maximal recovery would be desired to coincide with the need for the original behaviors. One application could be different training techniques for workers filling in at a job temporarily, than for workers being trained for a permanent job assignment. A clinical application could be to vary teaching methods to prevent recovery when a new behavior is intended to replace some maladaptive behavior, and facilitate recovery when it is intended to be used within a repertoire of other behaviors in the situation.
Beyond directly practical considerations, spontaneous recovery is an ideal dependent variable for testing the many competing theories of learning. It is certainly not an isolated phenomenon. On the contrary, it appears characteristic of learning processes in general. Spontaneous recovery occurs in classical conditioning, in learning by reward, in avoidance learning, and in learning of verbal list responses. Munn (1950, p. 243) calls it "one of the most universally established phenomena in conditioning."

Because spontaneous recovery is such a basic phenomenon, and because of its potential to discriminate among learning theories that provide similar predictions for acquisition and extinction it is surprising that so little research has explored it. By the mid-fifties this lack of potentially important research began to gain attention. Underwood (1953, p. 45) complained that "of the scores of studies which have taken extinction measures, very few have gone ahead to gather data on spontaneous recovery. The effect of this is that evaluation of theories of extinction is markedly hindered." More specifically, Lewis (1956, p. 45) complained that "extremely few experiments have attempted to determine the effect of (stimulus variables other than time) upon spontaneous recovery." And Murphy, Miller, and Finocchio (1956) noted the lack of data on long-term recovery.¹ This attention spurred a cluster of

¹The inattention to recovery is evident in that a mathematical model for basic learning phenomena published in a major journal made no predictions whatsoever for recovery. (Bush and Mosteller, 1950)
experiments on recovery during the mid to late fifties, but enthusiasm was not sustained, and research over the next one and a half decades was sporadic, leading MacKintosh (1974, p. 471) to reiterate, in view of the theoretical issues at stake, "it is surprising that the phenomenon of spontaneous recovery should have attracted so little experimental attention." As the 1980s begin the situation has changed little. Nevertheless, sporadic studies have accumulated over the decades, despite the lack of sustained research intensity. Moreover, the variety of scattered research has focused on testing specific aspects or specific theories of recovery, and not on contrasting the predictions of different theories. For these reasons, a review of the literature to contrast the predictions of different theories of operant behavior is especially timely.
Background: Setting the Stage For Recovery Theories

To understand the theories put forward to explain spontaneous recovery, the findings of the early research on which they were based must be introduced. And to understand the focus of early research, the historical context of spontaneous recovery should also be introduced.

Pavlov and Recovery of Conditioned Reflexes

When Pavlov published *Conditioned Reflexes* (1927), several studies on spontaneous recovery of classically conditioned responses were made public. The salivary response in dogs was found to recover after extinction. Extent of recovery was found to be a monotonic function of time. The longer the interval for recovery, the more recovery. Ultimately, "all those reflexes which have been fully established return sooner or later to their full strength." (Pavlov, 1927, p. 48)

Factors determining the speed of recovery were, most importantly, the extent of the preceding extinction and the intensity of the conditioned response. These findings must certainly have influenced expectations for operant recovery, especially after many similarities between conditioned reflexes and operant responses were found. However, it was a decade before study of operant responses extended to spontaneous recovery.

Through the early and middle 1930s, research on operant conditioning focused on acquisition and extinction. That these experiments preceded research on spontaneous recovery is to be
expected, since they are required before recovery can be observed anyway. By 1938, enough basic research has been done on acquisition and extinction to warrant investigation of spontaneous recovery. Attention from a variety of sources converged virtually simultaneously on spontaneous recovery. Three studies of recovery were reported in 1938, and one in 1940, and these formed the basis of early conclusions and theories of recovery. For the most part, these studies evaluated aspects of operant recovery corresponding to Pavlov's findings on conditioned reflexes. After examining the results of these basic studies we will be in a position to review the different theories and models proposed to account for recovery. We will then compare their predictions with later experiments on more specific aspects of recovery.

**Early Studies of Operant Recovery**

Among the first reports of spontaneous recovery from an extinguished operant response is that of Skinner (1938), from studies of bar-pressing behavior. Skinner found that rats exposed to a second extinction period, after having been removed from the experimental situation for a day, responded at much higher rates than they had at the end of the first extinction session. He also reported that no spontaneous recovery would occur if extinction were prolonged enough so that a state of "complete extinction" was reached. This is in accord with Pavlov's relationship between extent of extinction and recovery. Finally, he mentions an unpublished study by F. S. Keller
(Skinner, 1938, p. 83) which investigated the relationship between length of the recovery interval and degree of recovery. Two groups of four rats were the subjects; one group was checked for recovery one day after original extinction and the other group 44 days after extinction. The rats in the 1-day group emitted, on average, 37 responses, while those in the 44-day group averaged 46. These figures were congruous with Pavlov's finding that recovery of a classically conditioned response was an increasing function of the length of the recovery interval. It is unfortunate that so few subjects were used, as studies of long-term recovery remain very rare.

Skinner was to interpret the results in terms of his construct of response reserve which we will examine later.

Only a few months after Skinner's book, Youtz (1938) published a study that sought to determine the relationship between number of reinforcements during acquisition and strength of recovery. Youtz extinguished a bar-pressing response in each of two groups of 9 rats after 1 day, and then a second time after 55 days. One groups received 40 reinforcements, the other 10. As expected, the group with more reinforcements showed more recovery, recovery being roughly proportional to number of reinforcements. Interestingly, during the extinction period on day 55, the 40 reinforcement group emitted roughly 3/4 as many responses as during the first extinction, and the 10 reinforcement group actually showed an increase in number of responses, indicating a long-term persistence in
recovery. Again, however, sample size was small, and Youtz attributes this increase to sampling variability. Again, one of Pavlov's findings, that strength of original conditioning is directly related to extent of recovery, was confirmed.

The last study published in 1938 was the most definitive study up to that time, and today remains the classic study on spontaneous recovery. Ellson (1938) looked at the general short-term temporal course of recovery and at the extent to which extinction of one response affected recovery of another similar response. These he called recovery from specific and generalized effects of extinction. Unlike the earlier experiments which used 4 and 9 subjects per group, Ellson used 25 per group. He trained rats on both a horizontal and vertical bar-pressing response, extinguished the horizontal bar response, and then checked for recovery of the horizontal (specific) or vertical (generalized) bar response, at times of 5.5, 25, 65 or 185 minutes after extinction. The results for specific recovery are shown in figures 1 and 2. Two measures of central tendency are shown in figure 1 for number of responses during extinction. These curves reaffirmed the earlier findings of monotonically increasing recovery. An interesting surprise was the measure of rate of response at different recovery intervals. (Figure 2) This is the only study in the spontaneous recovery literature in which response rate was measured as a dependent variable in a free response situation. The difference between these two measures is that time is accounted
for in the measure of response rate but not in number of responses. For example, an animal responding occasionally over a long period could conceivably emit more responses than an animal which responded at a high rate for a short time. This is essentially what happened in the Ellson (1938) study. Since he extinguished to a 5-minute no-response criterion, animals emitting an occasional response could prolong the recovery interval significantly and amass a large number of responses albeit at a low rate. The curve for response rate shows drastic differences from number of responses. The non-monotonic shape of the curve was simply uninterpretable with the available theories, so it was generally overlooked. Since this study, no one has mentioned, much less attempted to explain, the response rate data.

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Insert Figures 1 and 2 about here.
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The response means and response rates for generalized recovery were parallel to those of specific recovery, but showed higher degrees of recovery, as would be expected if only certain aspects of the response had been extinguished.

Overall, the response mean data strengthened the notion that recovery was an increasing monotonic function of time by providing data from a large sample for the first time. The data on response rate was dissimilar from any previous data, unexpected, and largely ignored. Spontaneous recovery was found to exhibit generalization for similar tasks.
Graham and Gagne (1940) found similar results for the short-term course of recovery, but with an entirely different dependent variable. They measured the latent period for running to a goal box containing food. Different groups of 5 rats were checked for recovery at 2, 4, 6, and 10 minutes after extinction. The inverse of the logarithm of the latent period plotted against time for recovery yielded a curve resembling Ellson's results.

From these early studies several general ideas about spontaneous recovery emerged. Most importantly, it appeared that spontaneous recovery increased over time. Ellson (1938) and Graham and Gane (1940) found increasing recovery for short intervals with different dependent variables. For the long-term, Skinner (1938) reported increases in recovery between 1 and 44 days, and Youtz (1938) found significant recovery from a second extinction after 55 days. Youtz (1938) also found that the strength of the original response, as measured by number of reinforcements, increased spontaneous recovery, while Skinner (1938) reported extent of extinction to decrease it. All three of these findings, on recovery over time, acquisition effects, and extinction effects, were right in line with Pavlov's findings in classical conditioning. Evidence from Ellson's (1938) data on response rate that recovery might eventually decrease, and the unanimous finding that recovery did not approach the complete recovery reported by Pavlov were not considered as critical problems for viewing
both kinds of conditioning as parallels. With these early findings providing a context, I would now like to review the predictions and explanations which various learning theories present for spontaneous recovery.
Theories of Learning: Predictions for Spontaneous Recovery

Pavlov

Because Pavlov's influence on early research and theory was so important, I will first give a brief account of his theory of spontaneous recovery, even though it was never intended to apply to operant conditioning. Pavlov's is essentially a two-factor theory of recovery. By pairing a conditioned stimulus with an unconditioned stimulus, an excitatory reflex becomes associated with the conditioned stimulus. During extinction, when the conditioned stimulus is presented without the unconditioned stimulus, a competing inhibitory reflex gains strength. Extinction is then a process of "struggle taking place between the nervous processes of excitation and inhibition before one or the other of them gains the mastery." (Pavlov, 1927, p. 60) While the excitatory strength is permanent, the inhibitory strength gradually decreases, and the result is spontaneous recovery. Accordingly, spontaneous recovery should increase over time until the response has returned to its original strength.

Hull's System

Hull's (1943, 1951) system of learning principles is most similar to Pavlov's. This isn't surprising in that Hull considered both operant and classically conditioned responses to result from the building of receptor-effector connections. Like Pavlov, he postulates a competition between separate...
excitatory and inhibitory influences. Reaction potential, $S^E_R$, is the excitatory construct. It is a function of habit strength, drive, incentive, stimulus intensity, and delay of reinforcement. Without going into each of these constructs in detail, their relation is multiplicative, and their product yields $S^E_R$. The inhibitory aggregate, $I_R$, is composed of the sum of two factors in the Hullian system. These are $I_R$, inhibitory potential, which arises as a consequence of the work, or fatigue, caused by responding and conditioned inhibition, $S^E_R$, which results when an organism learns not to respond in order to reduce $I_R$. $I_R$ thus works both as a direct inhibiting force, and as a negative drive, which when reduced gives rise to conditioned inhibition.

Spontaneous recovery results because $I_R$ dissipates according to a simple negative growth function of time:

$$I'_R = I_R \times 10^{-at}$$

where $I'_R$ is the inhibitory potential remaining at time $t$, and $a$ is a constant.

To the extent that the inhibitory aggregate is composed of $I_R$, the response is predicted to recover strength. To the extent that it is composed of $S^I_R$, it should show a permanent loss in strength, since conditioned habits in the Hullian system retain their strength over time.

Hull's system, then, predicts a monotonic, increasing function of recovery over time, corresponding to the
dissipation of $I_R$. It predicts that situations in which $I_R$ is minimized should show little recovery, while situations where $sI_R$ is minimized should show much recovery. The circumstances for producing a minimum of $I_R$ would be spaced acquisition and extinction trials, in which $I_R$ would have the opportunity to dissipate between trials, and have no opportunity to accumulate. The reverse tendency, producing much recovery, would be produced by massed acquisition and extinction trials, resulting in large amounts of $I_R$, which would subsequently dissipate and result in spontaneous recovery. Hull's model rests very well with the early data showing a direct, asymptotic relation between recovery and time. Moreover, the added $sI_R$ construct could explain the failure to find complete recovery as predicted by Pavlovian theory.

The Response Reserve Construct

Skinner's (1938) theory, in contrast, relies on only one construct, response reserve, rather than two opposing constructs, to predict recovery. He defends this formulation on logical grounds, because it is more parsimonious, and because it is difficult to determine whether recovery occurs because of removal of inhibition or spontaneous renewal of strength. According to Skinner, the response reserve grows during acquisition, and is roughly proportional to response frequency, although length of acquisition and multiple response schedules of reinforcement tend to increase it as well. Extinction,
then, is represented as the depletion of this reserve. The rate at which responses are made available from the reserve is a function of its size, so that the rate of response during extinction should be negatively accelerated, as it is. Recovery occurs because even after the response has been extinguished to some criterion, and the animal removed from the experimental situation, the reserve continues to make responses available. When the animal is reintroduced into the experimental situation then, the accumulation of responses made available over the recovery interval may be emitted, and the resulting jump in response rate is spontaneous recovery. Like Hull and Pavlov, then, Skinner predicts an increasing asymptotic function for recovery over time. Skinner never developed a precise mathematical formulation for his theory, arguing that not enough data was available (Skinner, 1938) and that there were too many complicating factors to make mathematical models worthwhile (Skinner, 1950). Nonetheless, there are definite predictions about the course of recovery that may be tested. For one thing, the number of responses emitted during recovery should not surpass the number of responses that would have been emitted had extinction been continued over the recovery interval time. Moreover, the total number of responses emitted during multiple extinctions (multiple recovery checks) should be approximately the same as for during a single check for recovery. These predictions both follow from the way responses are made available over time, quite independently
of whether or not they can be immediately emitted, with responses accumulating for later if they cannot be emitted in the present situation. With respect to the early data, the prediction that recovery responses should not exceed those which would have occurred had extinction been continued, seems clearly wrong. Ellson (1938) observed a mean of 7.6 responses after a 5.5 minute recovery interval, after extinction to a criterion of 5 minutes without response. The second prediction, on the other hand, that the total number of responses emitted should be the same no matter the number of extinctions, seems to be confirmed by the study Skinner reported. When the group of rats extinguished after 1 day was reextinguished 43 days later, the total number of responses emitted was very close to the responses emitted by the 44 day recovery group.

**The First-trial Stimuli Hypothesis**

Skinner (1950) suggested another, different kind of variable that would cause recovery, and which can bail out the failure of the response reserve construct taken alone. This variable is a situational one, namely, that an animal becomes conditioned to expect reinforcement when placed in a new (first-trial) situation. Spontaneous recovery, then, would be at least partially a response conditioned to the reintroduction to the experimental situation. If we reexamine the Ellson (1938) study from this perspective, we find that by adding a constant of about 7 responses to the predictions of
the response reserve construct, to account for the situational variable, we get very close to the actual data at intervals of 5.5, 25, and 65 minutes. This is assuming that response rate would not have diminished further had extinction been continued. At 185 minutes, recovery is overestimated significantly, but at this longer interval the assumption above would no longer be reasonable, since if extinction had continued response rate should diminish even further over long intervals, and we should expect an overestimate. So, with the exception, again, of the non-monotonic response rate data of Ellson (1938), the response reserve model, combined with the first-trial situational variable is in accord with the early data.

**The Interference Interpretation**

Another well known theory of learning is interference theory, which views the learning of a response as interference with previously learned competing responses. This theory has been proposed as an explanation for spontaneous recovery by Liberman (1944, 1948). If events occurring during the supposedly inert recovery interval are actually interfering with a learned tendency to "not respond" acquired during extinction, then we should expect "spontaneous" recovery. At the same time, however, it must be explained why the original learned response should not be interfered with equivalently during the recovery interval, to offset interference with
extinction. This is the crux of Liberman's argument: During acquisition a precise response to a well-defined aspect of the experimental situation is learned. However, during extinction, no such definite response to a definite stimulus is learned, but rather a more general tendency to "not respond" to the situation in general. Thus, since extinction would involve learning a more general set of behaviors, we should expect greater interference from whatever general behavior that occurs during the recovery interval.

First, this theory predicts, as the other theories, that recovery should increase as a function of the recovery interval; more interference should occur with more behavior over more time. Secondly, it predicts that tasks interpolated into the recovery interval should lead to greater recovery by providing greater opportunity for interference. And third, it predicts that if extinction is learned as a discrimination task, that is, as a specific situation for not-responding, that recovery should be reduced from less interference. Some difficult conceptual problems plague this hypothesis, however. A whole sequence of motor responses may occur during acquisition. That many of these do not cease during extinction conflicts with the notion that extinction is not specific to the response learned in acquisition. In fact, it is difficult to find any response occurring in a simple recovery situation that could not also continue to occur during extinction as well. If anything, a greater number of responses
occur during extinction, including such "emotional" reactions as, for example, the pigeon which "coos in an identifiable pattern, moves rapidly about the cage, defecates, or flaps its wings in a squatting position." (Skinner, 1950, p. 203) Despite these problems, Liberman would test the predictions of the theory, as we will see later.

**Stimulus Sampling Theory**

Estes's (1950, 1953, 1955a, 1955b) Stimulus Sampling Theory attempts to explain recovery from yet another perspective. According to Estes's model, any situation is characterized by some population of stimulus elements, labeled S*. Over a short interval of time, an organism samples (is affected by) a given subset of these elements, labeled S. As each interval of time passes, there is some probability that each element in S will pass into the unsampled portion of S*, labeled S', and some probability that each of the elements in S' will pass into S, such that there is an equilibrium maintaining a roughly constant proportion of elements in S and S', as elements fluctuate between the sampled and unsampled subsets.

During acquisition, elements in S become conditioned to the learned response, and some number of conditioned elements, depending on the length of acquisition and the rate of fluctuation, will move into S'. Likewise, some number of unconditioned elements in S' will move into S and become conditioned to the response as well. Since the probability
of response equals the proportion of conditioned elements in S, the probability of response should grow during acquisition, as it does.

Now if we remove the animal from the experimental situation for a time, as in the recovery interval, except before extinction, we should expect the random fluctuation between S and S' to have an equalizing effect on the proportion of conditioned elements in each, resulting in a lower conditioned proportion in S and therefore a lower probability of response. In fact, this phenomenon, which is operationally very similar to spontaneous recovery, does indeed occur, and has been variously called "spontaneous regression," "warm-up decrement," or simply "forgetting." In view of the operational similarity to spontaneous recovery, I will use the term "spontaneous regression."

None of the previously considered theories can account for this phenomenon, with the exception of Skinner's, which must appeal to a separate characteristic of the response reserve—that it lessens over time—although he describes this loss to be slight. Adams (1961) review of spontaneous regression does find a theoretically separate influence, effects of "set," that is, not being "warmed up to" or "in rhythm with" the experimental situation, to account for a large part of spontaneous regression. Nevertheless, Adams concludes there is a "second facet" to regression, besides warm-up, and this fits nicely with stimulus sampling theory.
What about predictions for spontaneous recovery? They come about in a similar way. During extinction, elements in S become unconditioned to the response. Now, during the recovery interval, the situation is the reverse of during the regression interval. The conditioned elements are at first more prevalent in S' than in S, but as fluctuation and equilibrium proceed the proportions even out, and the predicted result is spontaneous recovery. (See figure 3) The precise mathematical derivation of these principles is presented by Estes (1955a), but a simple verbal summary should suffice here. The shape of the predicted recovery curve is increasing and negatively accelerated. This agrees with previous theories and data. Since spaced acquisition should allow time for more conditioned elements to escape into S', we should expect spaced acquisition to increase recovery. Conversely, we should expect spaced extinction to allow more of the conditioned elements in S' to return to S, become unconditioned, and decrease recovery. Finally, we should expect that if the situation during recovery were changed little from the conditioning situation, then less stimulus fluctuation and therefore less recovery should occur than if the recovery situation were changed more completely.

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Insert Figure 3 about here

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The Decay Model

The final theory of spontaneous recovery I will survey has not been presented previously, so my summary will be in slightly greater detail. Some aspects of the theory which are not directly related to recovery will be presented for the sake of a more general understanding, since other sources for this are not available. This theory I call the decay theory of spontaneous recovery. It is conceptually very simple. It holds that the strength of any conditioned response will decay according to a function of time. A period of reinforced activity contributes some positive influence to the probability of future response, while a period of extinction contributes some negative influence\(^2\) to the probability of future response. The magnitude of both of these influences decays over time.

Influence is determined by the reward conditions operating and by units of time. The dependent variable is defined as the sequence of behaviors necessary to cause some reinforcing event. This differentiates between different schedules of reinforcement. For example, in an FR3 schedule\(^3\) the reinforced sequence would be defined as the set of all three repetitions

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\(^2\)The magnitude of this negative influence is initially relatively small and is attributed to work affects. Punishment results in negative influences of higher magnitude.

\(^3\)One reinforcement per three responses.
of a behavior required for reinforcement. The length of time that such a schedule has been operating determines the strength of the influence as well, by determining the number of contributing units of influence.

Other factors affecting the contribution of a time unit's influence are the magnitude of reward, motivation, and effort required for response. These constitute a factor labeled $R$.

$$R = (\text{magnitude of reward} - \text{effort}) \times \text{motivation}$$

From this follows a correct prediction for higher response rates during ratio schedules of reinforcement. Since magnitude of reward should be large in comparison to effort for most responses, it follows that the multiplication of the effort value, and resulting reduction in $R$, caused by requiring multiple responses for reinforcement, is more than offset by the new definition of the reinforced sequence. In short, since the predicted units of behavior now consist of multiple responses this over compensates for the increased effort required for the multiple response. Therefore, the number of responses increases, even though the number of reinforced sequences decreases.

Situational influences are accounted for by a factor labeled $S$. The $S$ factor is an index of similarity between a last conditioning situation and a present situation. The strength of previously conditioned responses is multiplied by $S$, which ranges from 0.0 (completely dissimilar) to 1.0
(identical) to determine their influence on behavior in the present situation. A simplifying assumption for the following discussion is that the experimental situation always has an S of 1.0, while other situations have an S of 0.0.

The concepts explained thus far can be expressed mathematically in the following way:

\[ b = \sum_{i=1}^{t} S_i \cdot R_i \cdot f(t-i) \]

where \( b \) is the frequency of the reinforced sequence, where each of the summed terms is the contributed influence of some time interval \( i \), where \( t \) is the time at present (or at the time for which a prediction is being made), and where \( f(t-i) \) is then some function of the elapsed time for each time interval.

If we assume \( f \) is a simple inverse linear function of the form \( 1/c(t-1)+k \), where \( k \) and \( c \) are constants, we can then make quantitative predictions for the course of response strength following acquisition and extinction, given estimates of acquisition and extinction values for \( R \) and assuming \( S = 1.0 \) (or some other constant) during all the experimental trials. (See figure 4)

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Insert Figure 4 about here.

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The predicted course of response strength exhibits spontaneous recovery. A rapid early rise in strength is
caused because the more recent negative contributions of extinction intervals decay more rapidly than the older acquisition intervals.\textsuperscript{4} After a time, however, this effect peaks, and the predicted response strength begins to decline. This is because the differences in rate of decline between acquisition and extinction eventually becomes insignificant, the decline of the acquisition contributions outweighs the decline of the smaller number of extinction contributions, and predicted recovery declines. This eventual decline in the expected recovery function sets the decay model apart from every other theory. Because of the decay in acquisition contributions over time, spontaneous regression is predicted as well. Ellson's (1938) data showing an eventual drop in response rate supports the prediction of non-monotonic recovery, while Skinner's (1938) report of 4 rats showing greater recovery after 44 days than after 1 day contradicts it. Based on the early data, the status of the decay model remains tentative.

**Summary of Predictions**

Having reviewed six different learning theories in relation to spontaneous recovery, a summary of their unique predictions is in order.

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\textsuperscript{4}Ironically, the only recovery hypothesis resembling this most recent model was suggested by Miller and Stevenson (1938) in the first published study of operant recovery, in which they suggest the more rapid decay of the more recent extinction influence as a cause for recovery.
Hull's system predicts massed acquisition and extinction to result in the greatest amount of spontaneous recovery since these conditions produce a maximum of inhibitory $I_R$, which dissipates over time.

Skinner's response reserve construct predicts that the number of extinctions (checks for recovery) in a given time period should not significantly affect the total number of responses emitted since the size of the reserve is unaffected and responses becoming available may be accumulated.

Liberman's interference interpretation predicts that if the specific extinction situation is discriminated, then spontaneous recovery should not occur, since only then will interference affect acquisition and extinction equivalently.

Estes's stimulus sampling theory predicts that spaced acquisition should produce greater recovery, since a greater number of conditioned stimulus elements would fluctuate out of sampling and avoid extinction. Spaced extinction, on the other hand, should allow more conditioned elements to fluctuate back into sample and become extinguished, reducing recovery. A dissimilar recovery situation should allow for more recovery than a situation similar to the conditioning situation, since more fluctuation of conditioned elements back into sampling should occur in the former case.

The decay model, in contrast to the monotonic increases predicted by the other models, predicts that the temporal course of recovery should be characterized by eventual
reductions in recovery after a sharp initial rise and flattening.

Now, in a roughly chronological order, we'll review the later experiments on spontaneous recovery.
Later Research On Spontaneous Recovery

Individual Differences

Estes (1942) investigated whether differences between maze-bright and maze-dull strains of rats would also exhibit differences in recovery. He tested for recovery 40 days after extinction. The "bright" rats showed no recovery at all, while the recovery shown by the "dull" rats was so small as to be statistically insignificant. Murphy, Miller, and Finocchio (1956) found little or no recovery in an escape response after a 205 day interval for 3 rhesus monkeys, while 2 showed moderate recovery, and 3 large amounts of recovery. Since the experimental procedures for the two studies differed, no direct comparisons are possible, but taken together, they elucidate two general points. First, there are apparently individual differences affecting the occurrence and extent of recovery. Secondly, these differences do not appear to be directly related to a factor of general intelligence. That monkeys show at least as much a disposition for long-term recovery as rats provides additional support for the later hypothesis.

Long-Term Recovery

The same two studies (Estes, 1942 and Murphy, Miller, and Finocchio, 1956) along with a study on recovery of conditioned suppression by Burdick and James (1970), comprise the later data on long-term recovery. The finding by Estes (1942) of
little or no recovery after 40 days contradicts the earlier report by Skinner (1938) of increasing recovery at 44 days after extinction. Whereas Estes used 24 rats per group, as opposed to 4 per group, his study carries a greater weight. Since Estes only checked recovery at one time, we can not be sure that his finding reflects an eventual decrease in recovery. Nonetheless, the finding of so little recovery after so long an interval appears to contradict all but the decay theory, since recovery is posited as an increasing function of time. The data from Murphy, Miller and Pinocchio's (1956) study of a shock avoidance response by 8 monkeys after 205 days showed a mean of 58% recovery. Again, since recovery at other time intervals wasn't checked, it is impossible to determine whether recovery was rising or declining at that point. As noted previously, there was a great deal of variance among individuals, and combined with the lack of any other study on recovery by monkeys, it is difficult to generalize at all from this study. Burdick's (1970) study on recovery of conditioned suppression by groups of 12 rats, checked recovery at 3.5 minutes, 30 minutes, 1 hour, 3 hours, 24 hours or 72 hours. Through the 24 hour check, recovery was found to be an increasing function reminiscent in shape of the Ellson (1938) study. This is the same result found by Leeming, Lightman, and Newsom (1969), for a conditioned escape response, making it reasonable certain that recovery of negatively and positively reinforced responses follow the same
course over time. However, at 72 hours, recovery was found by Burdick to have declined to a level between that found at the 1 and 3 hour checks. This contradicts all but the decay model. Overall, the few studies of long-term recovery support the decay hypothesis. Estes's (1942) finding of little or no recovery after 40 days contradicts the earlier report by Skinner (1938) that long-term recovery was an increasing function. Murphy, Miller, and Finocchio (1956) is a difficult study to generalize from, but Burdick and James's (1970) finding of a decrease in recovery from 24 to 72 hours can only support the decay model.

Recovery Interval Situation

Another variable Burdick and James (1970) manipulated for two groups at the 3.5 minute interval was the situation during the recovery interval. One group was left in the experimental situation with the response apparatus removed, while the other was returned to their home cages. Although Estes's stimulus sampling theory predicts the group removed from the experimental situation should recover more, no significant differences were found between the groups, and even the direction of the difference was contrary to the theory. More study is needed, but this evidence runs against stimulus fluctuation as the cause for recovery.

Recovery Interval Tasks

Liberman (1944, 1948) has attempted to confirm the predictions of the interference interpretation of spontaneous
recovery. In the first series of these experiments (Liberman, 1944) he tested the effects of reinforcing or extinguishing a previously conditioned eyeblink response during the recovery interval for a conditioned galvanic skin response. He expected to find interpolated activity to have less effect on retention of a previously conditioned response than on a previously extinguished one. He also tested the effect of similarity between original and interpolated activity on recovery. All of his expectations were confirmed. Interpolated extinction led to less recovery, while interpolated conditioned led to greater recovery. Interpolated extinction had the greater effect. Similar activity to the original conditioning had a greater effect than dissimilar activity. The problem is that these results can as easily be interpreted to be simple generalization of conditioning as they can to be interference. Moreover, even if the interpolated tasks are taken to cause interference, there is no indication that similar interference occurs during "rest" intervals, which is what the interference interpretation requires for recovery. In short, even if the effect of interpolated tasks is taken to be interference, which is by no means clear, there is still no reason to believe interference is more than a peripheral influence on recovery, not the primary cause.

**Discriminant Extinction**

The second experiment (Liberman, 1948) provided a better test of the interference hypothesis. While one group of rats
had a running response extinguished indiscriminately in two goal boxes, the other group had trials in only one of the goal boxes extinguished. This set up the second extinction condition as a discrimination task, so that the possible set of interfering activities during the recovery interval would be restricted. Lieberman found an effect in the expected direction, that is, less recovery from discriminated extinction, but the greater part of recovery still occurred, reaffirming the suspicion that while interference may be an influence, it is not a primary cause of spontaneous recovery.

**Drive**

Pilley, Jones, Parker, and Lyles (1974) studied the effect of drive on recovery after 5 minutes and 24 hours. While high drive groups (24 hour water deprivation) showed greater recovery than low drive (5 minute deprivation) groups at both intervals, as expected by all theories, the time interval was the most influential variable, as recovery after 24 hours was much greater than after 5 minutes. This was the same finding as Barry's (1967), except that he found significant differences due to drive only at a longer (48 hour) interval and not after a 45 minute interval. This may have been caused by the small number of extinction trials he ran. Drive seems to be, as is expected theoretically, a factor which increases recovery.
Successive Extinctions

A follow-up study by Ellson (1940) on his original (1938) study looked at the number of responses emitted on successive extinctions at intervals of 5.5, 24, 65 or 185 minutes. Ten extinctions were performed for the 2 shorter intervals, and 5 for the longer intervals. Successive extinctions were found to comprise fewer and fewer responses, as predicted by all the theories. Remembering that a specific requirement for the success of Skinner's response reserve construct is whether the total number of responses for multiple extinction is about the same as the number of responses for multiple extinctions within the same amount of time, we can make comparisons that Ellson did not originally check. The first three 5.5 minute recovery sessions would have taken a little more than 32 minutes total (since extinctions were taken to a criterion of 5 minutes without response). A single 25 minute recovery session would have taken a little over 30 minutes, so this is a roughly comparable time interval. Mean responses for these sessions were 16.0 for the three 5.5 minute sessions, and 15.9 for the 25 minute session. More comparisons are shown in Table 1. Since the experiment was not designed for such comparisons we can't be sure of the exact times involved in the extinction sessions, but the similarity of the response means certainly supports the response reserve construct, at least for short intervals.

Insert Table 1 about here.
First-Trial Stimuli

The second of Skinner's hypotheses concerning recovery, that there are stimulus characteristics of new "first-trial" situations which have signaled reinforcement in the past, and would therefore elicit spontaneous recovery, was partially validated by a recent experiment by MacMillan and Burstein (1976). A distinct red light stimulus was presented on the first trial only during acquisition of a key pecking response by 2 groups of pigeons. Two other groups had no distinctive stimulus. Following either immediately, or 30 minutes after extinction, recovery was checked with or without the distinctive stimulus. The group presented with the distinctive stimulus immediately showed significantly greater recovery than the group with no distinctive stimulus and 30 minutes delay. This demonstrates the potential of distinctive stimuli to cause a recovery-like effect, without demonstrating their existence or strength in conventional situations. Nonetheless, it supports the plausibility of Skinner's hypothesis that distinctive first-trial stimuli facilitate recovery.

Acquisition Strength

We have already seen that Youtz (1938) found spontaneous recovery to increase with the strength of acquisition, as measured by number of reinforcements. The later Jata confirms this finding. Homme (1956) gave groups of 24 rats 15, 50, 100, or 250 reinforcements and found number of reinforcements
directly related to recovery \((p < .01)\). Lewis (1956) found no difference between groups with 15 or 30 reinforcements, but number of reinforcements was confounded with schedule of reinforcement. Prokasy (1958), in a study of a classically conditioned eyelid response, found number of elicitations during acquisition to be inversely related to recovery. If anything, this reaffirms the danger in generalizing from recovery studies of classical responses to operant, or vice versa. Metzger, Cotton and Lewis (1957) found that magnitude of reinforcement, as measured by number of food pellets delivered as a reward, had no significant effect on recovery. Number of reinforcements within a given schedule of reinforcement seems the only measure of acquisition strength reliably related to recovery.

**Spacing in Acquisition and Extinction**

The last topic of research to be considered is the effect of spacing in acquisition and extinction on spontaneous recovery. If you recall, Hull's system predicted greater recovery from massed acquisition and extinction, while Estes' stimulus sampling model predicted greater recovery from spaced acquisition and from massed extinction. Homme (1956) varied spacing or reinforcement by giving either 5 or 2 50-reinforcement segments with intervening time intervals, or consecutive sessions of 100 or 250 reinforcements. The amount of recovery was more with spaced acquisition, but the difference was not significant. Lewis (1956), however, did find significant
differences in the same direction as Homme when he spaced each trial over 15 seconds or 2 minutes. These studies contradict Hull's theory resoundingly, and give Estes' a needed base of empirical support.

However, with respect to spacing during extinction, Lewis (1956) found no significant differences. Howat and Grant (1958) also found no significant differences from extinction spacing, for a classically conditioned response. The data on extinction spacing contradict both Hull and Estes at present.

Having reviewed the later studies, the following reiterates the empirical status of spontaneous recovery theories:

**Hull** - Slight support comes from the increasing function for short-term recovery. That long-term recovery seems to diminish over time is contrary to prediction. That massed acquisition causes less or no difference in recovery, and massed extinction no difference, is severely damaging to the construct of inhibitory potential ($I_R$). Spontaneous regression is not predicted. Overall, the record for Hull's system is poor.

**Skinner** - Again, the short-term function of recovery versus time is predicted, but not long-term decrements. Multiple extinctions, at least over short time intervals, seem to lend support to the response reserve construct when compared to data from single recovery intervals. The first-trial stimuli hypothesis has also found support. An experiment designed
specifically to compare responses over multiple and single recovery checks is needed to augment this moderate support.

Interference - Lieberman's work has shown that activity in the recovery interval can affect recovery, and that discriminant extinction reduces recovery, as predicted by his interference hypothesis. Still, there is no evidence for interference without interpolated tasks, and even discriminantly extinguished responses exhibit large amounts of recovery. Interference appears to effect a peripheral influence, not to underlie the basic phenomenon of recovery.

Stimulus Sampling - The temporal course of recovery over the short-term is supportive, over the long-term contradictory. The hypothesis derives some support from the increase in recovery associated with spaced acquisition, as well as from predictions of spontaneous regression. Predicted effects of spaced extinction have not been confirmed. What little data there is on situational differences during the recovery interval also fail to confirm the higher recovery predicted for a situational shift during the recovery interval. The latter effect needs to be demonstrated for the theory to retain strength.

Decay - The data on short and long-term recovery are consistent with the non-monotonic recovery function predicted. Still, data on long-term recovery are scant, and further replication of long-term decrements are needed to solidify support for this unique prediction. Spontaneous regression is
predicted. The little data suggesting that situational differences during the recovery interval have no effect is also supportive. Again, the existing empirical support needs replication before it can be considered solid.
An Experiment on Effects of Time and Situation

The following study investigates two major questions about spontaneous recovery of operant responses:

(1) Does recovery increase as a function of time, even over intervals as long as a week?

(2) Does the similarity of the recovery interval situation to the original learning situation affect the extent of recovery?

Both topics, long-term recovery and effect of situation, have received sparse attention, even though both are, as we have seen, critical to evaluation of recovery theories. Let us quickly recount the principal data and theory which prompts the present investigation:

The most frequently investigated variable influencing recovery has been time. Pavlov's (1927) early findings that recovery of a classically conditioned response increased over time were confirmed a decade later for operant conditioning. Skinner (1938), Eison (1938), and Graham and Gagné (1940) report that the amount of spontaneous recovery increases as a negatively accelerated function of the length of the recovery interval (the period between the end of extinction and the beginning of the recovery session). However, whether this trend continues over long intervals is uncertain. Skinner's data show increasing recovery as long as 44 days after extinction, but Burdick and James (1970) found decreasing recovery 3 days after extinction, following
increases during the first 24 hours. Ellson's data on response rate also show a drop after initial increases in recovery. Since none of the theories of spontaneous recovery (Pavlov, 1927; Hull, 1943, 1951; Skinner, 1938, 1950; Liberman, 1944, 1948; Estes, 1950, 1953, 1955a, 1955b) predict an eventual decline in recovery, it is important to extend the sparse empirical record on long-term recovery.

The similarity of the recovery interval situation to the original learning situation has important consequences primarily for Estes' (1950, 1953, 1955a, 1955b) Stimulus Sampling Theory. According to Estes' model, any situation is characterized by some population of stimulus elements, labeled S*. Over a short interval of time, an organism samples (is affected by) a given subset of these elements, labeled S. As each interval of time passes, there is some probability that each element in S will pass into the unsampled portion of S*, labeled S', and some probability that each of the elements in S' will pass into S, such that there is an equilibrium maintaining a roughly constant proportion of elements in S and S', as elements fluctuate between the sampled and unsampled subsets.

During acquisition, elements in S become conditioned to the learned response, and some number of conditioned elements, depending on the length of acquisition and the rate of fluctuation, will move into S'. Likewise, some number of unconditioned elements in S' will move into S and become
conditioned on succeeding trials to the response as well. Since the probability of response equals the proportion of conditioned elements in S, the probability of response should grow during acquisition, as it does.

Similarly, during extinction, elements in S become conditioned to alternative behaviors. So then, during the recovery interval the conditioned elements are at first more prevalent in S' than in S, but as fluctuation and equilibrium proceed the proportions even out, and the predicted result is spontaneous recovery. The shape of the predicted recovery curve is increasing and negatively accelerated. We should expect that if the situation during recovery were changed little from the conditioning situation, then less stimulus fluctuation and therefore less recovery should occur than if the recovery situation were changed more completely.

The only experiment to have manipulated the recovery interval situation (not task) was Burdick and James (1970) for their 3.5 minute recovery interval groups. One group was left in the experimental situation with the response apparatus removed, while the other was returned to their home cages. Although Estes' stimulus sampling theory predicts the group removed from the experimental situation should recover more, no significant differences were found between the groups, and even the direction of the difference was contrary to the theory. The present study will provide a more thorough manipulation of situation across time.
Subjects

Subjects were 99 University of Illinois undergraduates (45 men and 44 women), whose participation fulfilled a course requirement for introductory psychology.

Task

The subjects were presented with three slot machines represented on the screen of a PLATO interactive computer terminal. Subjects were instructed to try to win as much "money" as possible by gambling on the machines. A $5 prize was promised for the subject who finished with the most "money." Subjects were told that different machines could have different probabilities of yielding a win, and that probabilities for winning on a given machine could change during the course of the experiment. They were also informed of the mechanics and rules of the task: they were to select a machine to gamble on by pressing the key (F, G, or H) which corresponded to the letter displayed beneath the machine; each play cost them $1 of their "money," and each win gave them $10, for a net gain of $9; they were to be given $20 to begin with. After a machine had been selected, a series of symbols flashed in each of the three windows successively, much as an actual slot machine. A result of three dollar signs signified a win. A message was then flashed to the subject telling him that he had won or lost, and the amount of money that he then had.
Procedure

The first gambling session lasted ten minutes, during which the subjects repeatedly chose which machine they wanted to play. The first five minutes of this session served as an acquisition interval for gambling on machine G. The possibilities of winning on machines F and H were only 15%, while the probability of winning on machine G was 50%. Additionally, the first two "G" responses were always rewarded with a win in order to facilitate acquisition. The remaining five minutes of the session served as an extinction interval for the "G" response. Probability of winning on machine "G" dropped to 0%, while probability of winning on either of the other machines remained at 15%.

The recovery interval followed the first gambling session. Subjects answered the Legal Opinions Questionnaire, a variety of questions on current legal and legislative issues, during the interval. Subjects in the "dissimilar situation" condition were led across the street to a campus pizza parlor, where they filled out the LOQ, while subjects in the "similar situation" condition worked on the LOQ at their seats beside their PLATO terminals. The recovery interval was of five different durations for different sets of subjects: (10 min., 20 min., 30 min., 1 day, or 7 days). Since control of the situation was impossible for the 1 day and 7 day conditions, they were run only in the dissimilar condition. The experiment can be thought of as a 5 (recovery interval) by 2 (recovery
situation) between subjects design, without cells for similar situations beyond 30 minute duration.

Following the recovery interval, subjects returned to the gambling task for 2.5 minutes to measure recovery of the "G" response. Probabilities of winning remained identical to those of the extinction interval.

Results

Analyses of variance were performed on the number of "G" responses emitted during the acquisition and extinction periods to confirm that there were no sampling errors apt to cause differences in recovery. Two analyses were performed for each period. The first assessed situation and the three recovery intervals (10 min., 20 min., 30 min.) associated with the situational manipulation. The second was a one-way analysis of variance across all 5 recovery intervals. There were no significant effects or interactions for either acquisition or extinction. Means for these data are shown in Table 2.

Insert Table 2 about here.

Frequency of the "G" response summed across all subjects for every 15 second interval of gambling is shown in figure 5. The classic acquisition, extinction, and spontaneous recovery patterns are clear. For each of the first six 15-second intervals following the recovery period, response rate was higher than in each of the last six extinction intervals,
(e.g., there were more responses in the first 15 seconds after recovery than in the last 15 seconds before the recovery period). During the seventh 15-second interval after the recovery interval, response rate declined below the rate of the seventh interval before recovery, so the first six intervals (1.5 minutes) after the recovery period were established as the measure of recovery, and the last six intervals of extinction as the baseline. Response rate (from data summed across all conditions) was significantly higher \((t < .01)\) during the first 1.5 minutes after recovery than during the last 1.5 minutes of extinction.

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Insert Figure 5 about here.

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However, analysis of variance showed no significant effects \((p > .10)\) of situation, recovery interval (10, 20 or 30 min.) or interaction on response rate after the recovery interval. (Table 4) Moreover, a one-way analysis of variance including the 1-day and 5-day groups also failed to show an effect of time on recovery \((p > .10)\). (Table 5) Response rates for each condition are shown in Table 3.

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Insert Tables 3, 4, and 5 about here.

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**Discussion**

The failure to find any effect of recovery interval is puzzling, especially because of the conventional shape of the acquisition and extinction curves, and significant overall
recovery. That recovery increases with the time of the recovery interval, at least for intervals less than a day, is one of the few well-established empirical facts about spontaneous recovery. Why then, was there no effect of time in the present study?

A major difference between this study and the previous research tradition is the subject population. Humans, not laboratory animals, are the subjects here. Yet all their behavior—acquisition, extinction, and recovery—was parallel to that of their animal counterparts, except that time for recovery did not affect amount of recovery. Could it be that there are fundamental differences in human operant learning which manifest themselves only in their effect on recovery?

That is possible, but there are other explanations. What if humans do follow the same pattern of increasing recovery, except that they recovery much more quickly, and reach the "asymptote" of recovery much sooner? If so, the present study measured recovery only after the major temporal effects had passed, and reflected only the flat peak of the recovery curve. According to Stimulus Sampling Theory, more rapid recovery would be the consequence of more rapid fluctuation of stimulus elements. If stimulus sampling is the cause of recovery, and fluctuation of stimulus elements for human subjects is so rapid so as to cause maximum recovery to be reached within 15 minutes, then it would not be surprising that
the situational manipulations in the study had no effect since the recovery ceiling would already have been reached.

Another hypothesis, which fits the data without requiring any suppositions, is that recovery is a consequence of the stimuli particular to the beginning of conditioning (e.g., the beginning of a gambling session), which serve as discriminatory stimuli for reinforcement (Skinner, 1950). According to this hypothesis we should expect recovery to be uniform, for different recovery intervals, as data from the present study indicate. However, again we have the previous research showing temporal effects on recovery for laboratory animals. Skinner's hypothesis alone cannot account for these effects, but if we consider the possibility that different processes govern recovery in humans than in animals, and that the present study reflects these differences, then Skinner's hypothesis could account at least for the recovery exhibited by human subjects. MacMillan and Burstein (1976) demonstrated the plausibility of Skinner's hypothesis by artificially introducing a red light stimulus during the first trial of acquisition of a key-pecking response by pigeons. Immediately after 30 minutes of extinction trials, the red light stimulus was repeated, and the effect was a significant recovery-like effect which MacMillan and Burstein termed "spontaneous recovery without the recovery interval." This demonstrates the potential of distinctive stimuli associated with the onset of acquisition to cause recovery, without demonstrating their
existence or strength in conventional situations. Nonetheless, it supports the plausibility of Skinner's hypothesis.

The results raise new questions to be researched. Do human subjects simply reach the peak of recovery more quickly than animals? If so, is that a consequence of more rapid stimulus fluctuation as per Estes' theory? Then would there be effects of situation during these brief recovery intervals? If humans do not merely accelerate the recovery process, but rather exhibit uniform recovery for all recovery intervals, as evidenced in the present study, there are important differences between basic human and animal operant conditioning processes which are manifested only in patterns of recovery. If that were found to be the case, Skinner's hypothesis could account for the phenomenon of recovery, but not for the influence of recovery duration on animals.

A second, inhibitory influence on recovery, such as Hull's inhibitory potential \( I_R \), which dissipates after extinction, could account for temporal effects on recovery in animals. Lack of temporal influence in the present study could be attributed to a task which did not produce sufficient \( I_R \). Presumably, a more difficult task would produce sufficient \( I_R \) to bring about a temporal effect in humans, but this has yet to be demonstrated.

The questions raised here are specific empirical questions. If more of the long neglected empirical facts are collected, a belated understanding of the basic learning
phenomenon of spontaneous recovery will emerge. Only then will it be possible to manipulate recovery for tangible practical benefits as other basic learning phenomena have been used.
References


Miller, N. E. and Stevenson, S. S. Agitated behavior of rats during experimental extinction and a curve of spontaneous recovery. *Journal of Comparative Psychology*, 1936, 21, 205-231.


### Table 1

<table>
<thead>
<tr>
<th>Recovery Interval</th>
<th>Number of Recovery Ints.</th>
<th>Total Estimated Time</th>
<th>Total Mean Responses</th>
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<td>2.5 min.</td>
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<td>30 min.</td>
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<tr>
<td>5.5 min.</td>
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<td>185 min.</td>
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<tr>
<td>65 min.</td>
<td>3</td>
<td>210 min.</td>
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(From Ellson's (1940) Data)
Table 2

<table>
<thead>
<tr>
<th>Recovery Interval</th>
<th>10 min.</th>
<th>20 min.</th>
<th>30 min.</th>
<th>1 day</th>
<th>7 days</th>
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<td>DISSIMILAR</td>
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<td>22.2</td>
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Mean Number of Acquisition and Extinction Responses
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<th>30 min.</th>
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Response Rate After Recovery ('G' responses per minute)
Table 4

Analysis of Variance Summary Table

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<tr>
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<th>d.f.</th>
<th>M.S.</th>
<th>error d.f.</th>
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<th>p</th>
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<td>1.80</td>
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<tr>
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<tr>
<td>Within</td>
<td>73</td>
<td>6.39</td>
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### Table 5

Analysis of Variance Summary Table

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<th>M.S.</th>
<th>error d.f.</th>
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<tr>
<td>Within</td>
<td>94</td>
<td>6.77</td>
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Figure Captions

Figure 1. Central tendency measures for different recovery intervals. (Ellson, 1938)

Figure 2. Response rate after different recovery intervals. (Ellson, 1938)

Figure 3. Spontaneous recovery curves for different proportions of conditioned elements in $S'$, predicted by Stimulus Sampling Theory. (Estes, 1955a)

Figure 4. Recovery predictions of the decay model for various $k$ values. ($c = 1$, $R = 1$ during 10 preceding acquisition intervals, $R = -0.5$ during extinction)

Figure 5. Response totals (from all conditions) for each 15 second interval during acquisition and extinction, and after the recovery interval.
Figure 1