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DANSON, Carl Merrill, 1939—
THE PROGRESSIVE EFFECTS OF SATIATION ON SIMPLE AND COMPLEX OPERANT RESPONSE SEQUENCES.

The Ohio State University, Ph.D., 1965
Psychology, experimental

University Microfilms, Inc., Ann Arbor, Michigan
THE PROGRESSIVE EFFECTS OF SATIATION ON SIMPLE AND COMPLEX OPERANT RESPONSE SEQUENCES

DISSERTATION

Presented in Partial Fulfillment of the Requirement for the Degree Doctor of Philosophy in the Graduate School of The Ohio State University

By

Carl Merrill Danson, B.A., M.A.

*****

The Ohio State University
1965

Approved by

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Adviser
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ACKNOWLEDGMENTS

I would like to thank Dr. Reed Lawson whose concern and support provided a foundation for my own development. Undoubtedly, the years under his tutelage have been my most rewarding and gratifying educational experience. Dr. Lawson's acumen and demand for scientific creativity have been a constant source of inspiration. Although graduation is an indication of our success and I welcome the challenge of my own future, it is with deep regret that this relationship has come to a close.

A portion of the reported research was completed while the author was a National Institute of Health Training Fellow.
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BACKGROUND

Behavior is a process, a sequence of response occurrences, although it is typically symbolized and measured as a static event. Since Thorndike (1898) an understanding of the nonbehavioral and behavioral events that are sufficient and necessary to establish, maintain and/or modify response sequence has been sought. The isolation of significant factors or variables has been a primary concern. Inherent in the delineation of variables of which behavior is a function is that these factors are also employed as reference points in a behavioral description. The selection of one reference point rather than another or the theoretical status of a particular variable, however, is not restricted to the empirical data. Thus, one investigator may interpret behavior primarily in terms of events preceding it, another in relation to subsequent occurrences, and a third as a function of both antecedent and consequent conditions. The following analysis, acknowledging alternative conceptions, is principally devoted to one perspective.

Reinforcement is a reference point (Bindra, 1959) which in the operant case occurs at the termination of a response sequence. Empirically, it is defined as those events which increase the probability of a future response of the same class. The reliability of reinforcement in generating responses of many different topographies, in different situations, with different organisms is

1
well established, cf., Postman, 1947. Nevertheless, the accrued knowledge of reinforcers is based primarily on a few commonly employed types, e.g., food, water, and shock. These reinforcers, at least in the positive case, are dependent upon the particular state of the organism, i.e., their efficacy is dependent upon the organism being under certain conditions of deprivation. Since these reinforcers may decrease the deprivation of the organism, it has been hypothesized that a reduction in these states, frequently referred to as primary, interoceptive, or homeostatic drives, is a necessary condition for reinforcement, e.g., Hull, 1943.

The drive reduction position has been criticized as being restricted to a limited sample of reinforcing events, e.g., Harlow, 1953, Lawson, 1960. Critics of the current empirical and theoretical status of reinforcers have not been unproductive. Research and theory appear to be developing in two somewhat different directions although in both cases the proliferation of views is a result of the persistence of certain behavior in an apparently satiated organism. On one hand, a number of observers are concerned with an extension of research to other kinds of reinforcers, e.g., Harlow, 1953, while on the other, higher order concepts of reinforcement, i.e., conditioned reinforcers, have been of particular interest, e.g., Skinner, 1953. This dissertation is concerned with the latter case.

In the 1930's, several investigations, e.g., Bulgelski, 1938, Skinner, 1936, demonstrated that events correlated with the occurrence
of reinforcement may themselves acquire reinforcing properties. These events, secondary or conditioned reinforcers, have been the subject of numerous investigations, cf., Myers, 1958, Miller, 1951, but it was not until some 20 years after the initial work that secondary reinforcement was shown to be more than an ephemeral phenomenon, Zimmerman, 1957. Notwithstanding the dilatory empirical progress, theoretical speculation about conditioned reinforcement persisted, e.g., Skinner, 1953, Keller and Schoenfeld, 1950.

It is Skinner's thesis that some complex behavior, e.g., verbal behavior, is not usually dependent upon the particular motivating conditions of the organism for its occurrence. Behavior may occur independently of the state of the organism, says Skinner, if it is maintained by certain reinforcement conditions. One of these, generalized reinforcement, is a conditioned reinforcer which acquires its reinforcing properties by being associated with several other reinforcers. Thus, since any one of these is likely to be present in some strength at a given moment, the conditioned reinforcer probably exists in some strength (Skinner, 1953, 1958).

Regardless of the validity of Skinner's provocative conception, the adequacy of a conditioned reinforcement interpretation of complex behavior is dependent upon its relative ability to resist momentary motivational changes of the organism. Although secondary reinforcement is the most elementary instance of conditioned reinforcement, recent reviews (Kelleher and Gollub, 1962, Myers, 1958)
have both noted the sparsity of rigorous data. Therefore, an investigation of the effects of satiation on secondary reinforcement seems appropriate.

Statement of the Problem

The purpose of this dissertation was to investigate experimentally the effect of satiation of a relevant reinforcer on simple and complex response sequences. The simple sequence was observed in Experiment I in order to establish a procedure of satiation which would permit an assessment through a range of satiated conditions as well as being applicable to the complex case. The latter, explored in Experiment II, provided a situation in which techniques for explicitly estimating the status of a stimulus, i.e., a possible conditioned reinforcer, may be employed, and thus attempt to demonstrate conditioned reinforcing effects before the effects of satiation are evaluated.
EXPERIMENT I

Introduction

Studies dealing with the variation of relevant satiation following the establishment of an operant response have typically found a positive relationship between amount of deprivation and response strength, e.g., Koch and Daniel, 1945, Perin, 1942. Having theoretical implications, the findings of various experiments have then been combined to produce a continuous function, cf., Hall, 1961, p. 167. Although grouping data in and of itself does not negate its validity, inspection of the individual data when presented, e.g., Saltzman and Koch, 1948, shows marked between subject variability at least in terms of range. The variability suggests either that the combined data distorts the function of an individual organism and/or that the manipulation of satiation has low reliability, i.e., it might have different effects on different organisms or different effects on a single organism when the variable is administered a second time.

Few experiments have employed a within subject comparison. Those that have used this methodology also report some extreme between subject differences, e.g., Cotton, 1952. Since the present experiments involve measurement of a few subjects across a range of sated conditions, an orderly function is crucial. The
The purpose of this experiment was to determine if successive increases in body weight, i.e., increase in satiation, yielded systematic changes in the behavior of individual subjects.

**Method I**

**Subjects and apparatus.** Ss were four hooded rats; numbers 26 and 30 were naive female rats approximately 200 days old at the beginning of the experiment, and numbers 6 and 9 were male Ss approximately one year old which had been used in another investigation. Each S was housed in an individual cage.

The apparatus consisted of a commercially produced (Foringer) small animal chamber with a test compartment 9-7/8 in. wide x 10-5/8 in. long x 11-3/4 in. deep. A stainless steel tubular bar which was 2 in. long and 1/2 in. in diameter protruded 3/4 in. from the front wall of the compartment, its center located 3-1/4 in. above a grid floor and 2 in. from the wall of the box. A downward movement of the bar was required to close the contacts of a microswitch. The pellet trough was 1-3/4 in. above the floor and 1 in. to the left of bar center. J. P. Noyes rat food pellets 1.1mm x 3.3mm x 45mg were used as reinforcements. A General Electric 1819 miniature lamp with frosted cover 2-1/4 in. above the bar was lit for 1-1/2 sec. before the presentation of reinforcement. At all other times, the compartment, which was in a light shielded and temperature controlled room, was dark. A fan in the room partially masked the noise produced by the relay programming equipment in the adjoining room.
**Procedure.** After determining S's weight, the experimental procedures of establishing a feeding rhythm, magazine training, shaping, training, and testing were initiated.

Each S's weight was assessed under ad lib feeding conditions of Rockland rat diet until it appeared to have reached asymptotic level. Ss were then deprived to 80 percent of their body weight during approximately a three week period. Numbers 6 and 9, who had been trained in a different compartment, were on a deprivation schedule at the start of the experiment.

Magazine training and shaping the bar press response were accomplished on the same day by E. Thereafter, all events were programmed automatically. The reinforcement schedule was shifted from continuous reinforcement to variable interval 14 sec. to the final schedule of reinforcement during two sessions. The final schedule for number 6 was a variable interval 30 sec. (VI 30) and for numbers 9, 26, and 30 a variable interval 45 sec. (VI 45) schedule of reinforcement. Number 6 was maintained on a terminal schedule of VI 30 since he had previously exhibited stable responding at this value. Ss received from 16 to 90 hours of training on their respective variable interval schedule before testing. Apparatus difficulties e.g., malfunctions of the feeder, were primarily responsible for the large differences in the number of training hours. Ss were trained every day at approximately the same time of day. Each session lasted two hours.
Ss were tested under three different manipulations of satiation. Numbers 6, 26, and 30 experienced conditions 1, 2, and 3a, and number 9 was tested only in 3b.

**Test condition 1.** Ss' weights were gradually increased by progressively increasing the amount (weight) of food given to Ss until ad lib conditions were reached. The amount of food S was fed was estimated from the previous day's ration and body weight. An orderly increase in weight was usually maintained although there were days on which no weight change or slight decreases occurred (See Appendix). Under this procedure, Ss were tested at their usual training time on successive days. Each S, however, was tested somewhat differently. Number 26 was tested each time that a weight increase of about five grams or more occurred following an initial increment of 30 grams. Number 30 was tested under the same conditions as number 26 with the exception that responding was assessed from the onset of weight increases, i.e., from the first day that a weight increase of five grams or more occurred. For Ss 26 and 30, the number of days between tests varied. Number 6, on the other hand, was tested everyday regardless of weight change.

**Test condition 2.** In contrast to the gradual procedure of condition 1, Ss were administered ad lib feeding conditions immediately. Responding was measured during S's usual two hour session for at least ten consecutive days. Before test condition 2
was initiated, Ss were deprived as stated earlier and retrained on their respective final schedule of reinforcement. Retraining varied among the Ss from 5 to 15 sessions.

**Test condition 2.** Since the reinforcements (Noyes pellets) were available only during the two-hour sessions for Ss 6, 26, and 30, two different types of control procedures were employed to assess the effects of their absence from the maintaining diet.

3a) Ss were given ad lib reinforcements in their home cage after having reached their free feeding weights and tested on the following day.

3b) S 9 was maintained exclusively on a food diet of reinforcements both during deprivation and the ensuring satiation test. The test was conducted using the immediate satiation technique.

**Results I**

Total number of responses during each session as well as the four 1/2-hour segments of the two-hour session were recorded. The latter measure gives an indication of the variability within a session. The effect of manipulation 1 on total number of responses of each of the three Ss is shown in Figure 1. The figure, as are the subsequent figures of Experiment 1, is divided into three horizontal panels with the data of each S presented in one of the panels. The outstanding result exhibited in the figure is the discrete decrease in responding as a function of increases in body weight. The transition from one level of responding to another was abrupt, occurring typically after the weight of S had been increased through a considerable range of weight, i.e., the decrease in responding
appears to be a "step" rather than a continuous function. Responses are not represented at three body weights for numbers 26 and 30, e.g., at 260 grams for number 26, due to increases in weight which exceeded these points and not because of the omission of data. Lines have been arbitrarily drawn on the graphs to accentuate the different levels.

All of the data of Ss numbers 26 and 30 is presented, but since number 6 was tested regardless of weight change only the first session at any 10 gram interval of his weight is presented. Although responding during sessions at the same weight varied on successive days, the unreported data was consistent with the presented results. It should be noted that the final weight of Ss 26 and 30 approximated their previously determined free feeding estimate which was 290 grams and 260 grams respectively, but the last weight tested for number 6 (430 grams) was not his ad lib weight. The series of tests for the latter S was intentionally terminated prematurely.

Corresponding chronologically to the sessions represented in Figure 1 is the within session distribution of responses presented in Figure 2. Each bar represents the ratio of the smallest to the largest number of responses of the four 1/2-hour blocks. A comparison of Figures 1 and 2 shows that although total responses may be suppressed a concomitant change in the distribution of responses usually does not appear until ad lib feeding is more closely approximated, i.e., an increase in this measure of variability did not accompany the suppression of responding through
Figure 1. Total responses during each two-hour session as a function of gradual increases in body weight.
the middle range of body weight. An alteration of the distribution of responses does appear at near ad lib conditions. At this range of body weight, all Ss consistently responded the most during the first 1/2-hour and exhibited the greatest within session variability.

The effects of manipulation 2 are shown in Figures 3 and 4. The total number of responses are represented in Figure 3 as a function of the number of days this condition was in operation. No S reached its previously determined total number of responses for ad lib conditions in less than four days (denoted by arrow), i.e., when S is given ad lib food after having been deprived, the ultimate effect on total responding does not appear for a number of days.

The corresponding within session variability of days 1, 2, 3, 8, 9, and 10 is shown in Figure 4. The four bars of each day represents from left to right the first through fourth 1/2-hour segments of responses. Although in general within session differences are marked, there is a noticeable change in the distribution of responses between the days immediately following the manipulation and those occurring later in the sequence. The combined result of maximum relative response changes and greatest number of responses in the first 1/2-hour does not immediately occur.

Total number of responses during test conditions 1 and 2 as a function of comparable body weights is presented in Figure 5. The data is displayed in percentage form, responses of a test/
Figure 2. Ratio of the smallest to the largest number of responses of the four 1/2-hour segments within each two-hour session as a function of gradual increases in body weight.
Figure 3. Total number of responses as a function of ten consecutive days of ad lib feeding. Each point represents the total of a two-hour session.
responses in session before the start of the test series. Manipulation 1 resulted in a greater percentage of responses at all comparable weights.

The effect of manipulation 3a is displayed in Table 1. The table shows the effect that the primary reinforcer exerted on responding at a relatively low level of deprivation. All Ss gave a considerable number of responses when the reinforcer was only available during the two-hour sessions but few responses when it was always available.

TABLE 1
NUMBER OF RESPONSES OBTAINED WITH AND WITHOUT AD LIB REINFORCERS

<table>
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<th>SUBJECT</th>
<th>AD LIB</th>
<th>AD LIB plus REINFORCER</th>
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<tr>
<td>#6</td>
<td>259</td>
<td>42</td>
</tr>
<tr>
<td>#26</td>
<td>203</td>
<td>32</td>
</tr>
<tr>
<td>#30</td>
<td>225</td>
<td>18</td>
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Manipulation 3b was a control procedure which was performed in order to determine the role of the preferred reinforcer on the progressive effect of immediate satiation. The effect of satiation of the reinforcer on both total number and distribution of responses is represented in Figure 6. The results are essentially the same as those reported in Figures 3 and 4. The ultimate effect of satiation does not immediately occur when free feeding of the reinforcer is permitted, i.e., the finding is not a result of a difference between the feeding diet and the type of reinforcer maintaining the response.
Figure U. Total number of responses in 1/2-hour segments occurring during the first and last three days of immediate satiation.
NUMBER OF RESPONSES IN 1/2 HOUR SEGMENTS

DAYS
(Sessions)

30
26
6

0 60 120 180 240
0 50 100 150
0 100 200 300 400 500 600
Figure 5. A comparison of total responding during gradual and immediate satiation as a function of comparable body weights.
Figure 6. Total number of responses during the first and last five days (A) and distribution of responses during the first and last three days (B) of immediate satiation with the reinforcer.
Discussion I

The different functions generated by the gradual and immediate manipulations of satiation demonstrates that the effects of deprivation on VI responding may be successfully manipulated in at least two ways. The results suggest that a theoretical analysis such as Hull's and its empirical basis, e.g., Perin, 1942, which has suggested a function relating response strength to deprivation, seems to be an oversimplification. Instead of one function, there are possibly many different functions as a result of different manipulations. In fact, there may be as many functions as there are different manipulations. In other words, it is not that Hull's multiplicative relationship between drive (D) and habit strength (H) has been negated, but the function is seemingly irrelevant to the present data.

The inadequacy of the theory may in part be a function of a cursory analysis of previous experimental manipulations. Nevertheless, there are some examples which indicate that the complexity has been obscured or at least neglected. Skinner (1953, p. 115), for instance, has proposed that since body weight is easily observed and usually a direct result of a history of deprivation it can generally be substituted for the latter, but the history of deprivation is crucial when considering practical control. Subsequently, Ferster and Skinner (1957, p. 372) concluded that prefeeding and body weight are clearly different manipulations and Eisman (1956) has advocated the use of two parameters in determining the deprivation of the organism, one of which is the maintaining schedule.
of deprivation. Although compounding problems of an already confused area, the implication of the present results is the use of rate of satiation rather than prefeeding, hours of deprivation, or percent body weight as an independent variable. Apparently, the speed of transition from one level of deprivation to another is critical.

The second major result was that changes in the distribution of responses did not initially accompany suppression of total responding. Although one S did show a lower stable rate of response, it should be noted that the two other Ss exhibited some marked pausing between periods of responding. Within this restriction, the finding seems to be at variance with the commonly accepted position. According to a Hullian interpretation, decreases in D should result in increased variability since the occurrence of a response is a function of D times the difference between that response and competing responses. If the distribution of a response is an indication of responses variability, the present finding suggests that total response strength and response variability may in part be controlled by different variables. Gorman and Miles (1964), using a less questionable measure of variability, have also found that increased variability is not a necessary accompaniment of all decreases in deprivation.

In summary, the results demonstrate that in the present instances both methods of satiation resulted in systematic albeit unexpected changes in responding, and although an ancillary problem, responding is in part controlled by the reinforcer which is
used. A consideration of possibly greater importance is that deprivation or satiation be assessed as a dynamic as well as a static variable, i.e., the transition from one degree of satiation to another should be appraised. The relevant literature is saturated with experiments in which the relationship of drive to responding, discrimination, conditioned reinforcement, etc., is examined and results interpreted as if they are findings of generality when in fact the variables have been assessed under conditions in which many of the effects of the manipulations employed may have not yet occurred.

Due to the uniqueness of some of the findings, Experiment I was more exhaustive than anticipated. The experiment, as designed, also produced two methods which are both potentially applicable to the investigation of satiation effects on conditioned reinforcement. Manipulation 2, immediate satiation, was selected to be employed in Experiment II.
EXPERIMENT II

Introduction II

Extinction is one of two general types of situations for assessing the characteristics of secondary reinforcement. In this situation, primary reinforcement is omitted, but the conditioned reinforcer is still response dependent. The second procedure is frequently referred to as the new learning method. Again, primary reinforcement is removed from the situation but unlike the previous method secondary reinforcement is estimated by either requiring a new response to produce the reinforcer or by extending the response sequence by increasing the length of a chain of responses, cf., Skinner, 1936. Responding may be compared either between groups or within subjects in both techniques.

Presumably, the rationale for an extinction test is that the reinforcing properties of a stimulus should be evaluated in a situation in which other known reinforcing events have been eliminated. Since extinction is known to produce certain effects itself, however, such tests may exclude one possible source of contamination at the expense of introducing others (Kelleher and Gollub, 1962). For example, a temporary increase in rate of response had been noted during extinction (Skinner, 1938, p. 74), and it has been found that the extinction of one response may
increase the probability of another, e.g., Reynolds, 1961. In fact, nonreward has been proposed as the defining operation of frustration (Amsel, 1958).

Further, the methodology has not been applied in an impeccable manner. Although a particular experimental procedure may involve associating a stimulus with a reinforcing event, the effectiveness of the training of conditioned reinforcement is not evaluated before the actual test. Since correlating a neutral stimulus with a reinforcing event in some instances results in a suppressing rather than a reinforcing effect (Weiss and Lawson, 1962), any given result may be a function of failing to establish a secondary reinforcer in training. Thus, for the present purpose of determining the effects of satiation on a secondary reinforcer, demonstrating the reinforcing properties of a stimulus independently of the manipulation of satiation is essential.

Recently, chaining procedures for studying conditioned reinforcement have been proposed which circumvent the above mentioned problems, (Kelleher and Gollub, 1962). In its simplest case, a chain schedule of reinforcement is a schedule in which responding in the presence of one stimulus produces a second stimulus condition under which primary reinforcement is contingent upon a similar response. Although the technique used to generate the behavior and the organism observed probably determine practical limits, a chain may consist of any number of successive stimulus changes and response requirements. The position of a particular stimulus in the sequence is denoted in reference to its distance from primary
reinforcement with $S_1$ being the stimulus in the presence of which the organism receives primary reinforcement, $S_2$ the next closest, and so on. The response characteristics of a chain may be grossly categorized according to response topographies which occur in its various components or legs. Chains involving several different responses are referred to as heterogeneous and those consisting of the same form of response, homogeneous.

Regardless of its classification, if a stimulus in a chain in part maintains the response which precedes it, i.e., if the stimulus is a conditioned reinforcer, greater response strength should occur when the stimulus is response contingent than when it is omitted from the schedule. A tandem schedule of reinforcement has the same requirements as its chain counterpart except that an external stimulus is not correlated with changes in the schedule. Thus, a comparison of responses which occur in the two schedules permits an independent assessment of the reinforcing properties of a stimulus in a chain schedule without the necessity of an extinction test. In other words, both schedules involve a response chain, i.e., a sequence of responses, in which one response is contingent upon another response. A chain schedule of reinforcement has, in addition, different external stimuli correlated with each of its components. If the presence of a stimulus increases the strength of the response which produces it, the stimulus is a conditioned reinforcer.
The purpose of this experiment was to observe the effects of immediate satiation on several complex response sequences which are partially maintained by conditioned reinforcement.

Method II

Subjects and apparatus. Ss were four hooded rats; numbers 6 and 26 had served in the previous experiment and numbers 15 and 35 were naive. Number 30 died between experiments and number 6 died during the present experiment.

The apparatus was the same as described in Experiment I.

Procedure. New Ss were magazine trained and shaped according to the procedure of Experiment I. The following conditions of reinforcement were then introduced and tested: 1) a homogeneous two-component chain schedule, 2) a homogeneous two-component tandem schedule, 3) a heterogeneous three-component chain schedule, and 4) a homogeneous three-component chain schedule. The terminal schedule of reinforcement, i.e., the VI30 or VI45, constituted each component of the above complex sechdules, e.g., an S trained originally on a simple VI45 was subsequently trained on a chain VI45VI45. Thus, the frequency of primary reinforcement was decreased and an external stimulus, i.e., a conditioned reinforcer, presented when appropriate to the schedule.

Training the above schedules was as follows: 1) the homogeneous two-component chain consisted of no illumination as S2 and 2 6w. 120v. lamps mounted in the upper wall opposite the bar as S1. The transition to the terminal chain schedule was accomplished by successively changing the program from a VI45 sec. to
a chain VR2 and/or 4 to a chain VI45VI45. In other words, the requirement in S2 was successively increased. Ss received from 12 to 17 sessions on the final chain. During one of these sessions, the two lamps were disconnected for one hour in order to assess the effect of the stimulus on responding. The schedule of primary reinforcement was not altered.

2) The two component tandem schedule was in effect following one session of tandem VI45 CRF. No illumination was correlated with both of its components. Responding stabilized within ten sessions.

3) The heterogeneous chain had no illumination, a tone of approximately 1000 cps, and house lights as S3, S2, and S1 respectively. The chain was heterogeneous in that no responding, i.e., a pause, on a VI45 with a minimum duration of 15 sec. was required to produce S1. Thus, a bar press response was required to produce the tone in the presence of which a pause, i.e., not bar pressing, on a VI45 resulted in the occurrence of the house lights. Reinforcement was then contingent upon a bar press response. The response requirements during both S3 and S2 were progressively increased until a chain VI45VI45VI45 was attained. Ss received seven sessions on the terminal schedule.

4) The homogeneous three-component chain had no illumination, 1000 cps tone and house lights associated with S3, S2, and S1 respectively. The terminal schedule was in effect from the beginning of the 11 to 15 training sessions.
After each schedule had stabilized, responding was measured on consecutive days as a function of the immediate satiation procedure described in Experiment I. Thus the sequence of deprivation, training, and testing was repeated under each manipulation. Each training condition was tested once for a given S. The order of the sequence of these manipulations and the simple VI test is presented in Table 2 for each S.

Table 2

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<tr>
<th>ORDER IN WHICH THE EXPERIMENTAL TREATMENTS WERE ADMINISTERED</th>
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Results 2

Responses on the final day of training for each of the conditions is represented in Figure 7. Total responses during each component of the schedule are shown. The upper most of the three horizontal panels displays the chain schedule data of S 6 and the result of tandem schedule training for S 35, i.e., unlike the other presentations this is a between S comparison of two Ss which had approximately the same rate of response.

The training results reveal that although total number of responses emitted during the two-hour sessions usually remained stable across conditions, responding within each component varied as a function of the schedule which maintained the behavior. Any
given schedule, however, produced essentially the same results for different Ss. Specifically, responding during each of the components of the two-leg chain was approximately equal. In comparison, the tandem schedule, a schedule in which frequency of reinforcement was the same but without a correlated external stimulus, produced differential rates with greater responding during S1. Both of the three-leg chains also showed differential responding during each of the components. For the heterogeneous chain the lowest rate occurred during S2, the delay component. The homogeneous chain, in contrast, resulted in a progressive increase in responding with S3 controlling the lowest and S1 the highest rate of response. Responding during S3 was approximately equal for both the homogeneous and heterogeneous chain. In other words, responding which produced an external stimulus was maintained in essentially the same manner regardless of the rate of response that the produced stimulus controlled. Marked pausing occurred in S3 in both of these extended chains.

The results of removing the stimulus from the two-leg chain during one of the training sessions is presented in Table 3.

<table>
<thead>
<tr>
<th></th>
<th>WITHOUT STIMULUS</th>
<th>WITH STIMULUS</th>
</tr>
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<tbody>
<tr>
<td>#6</td>
<td>1054</td>
<td>1107</td>
</tr>
<tr>
<td>#15</td>
<td>500</td>
<td>611</td>
</tr>
<tr>
<td>#26</td>
<td>544</td>
<td>585</td>
</tr>
</tbody>
</table>

For each S greater number of responses occurred when when S1 of the chain schedule was presented although the differences were small.
Figure 7. Total number of responses occurring during each of the components of the four reinforcement schedules on their final day of training.
The graph shows the number of responses for Chain, Tandem, Heterogeneous Chain, and Homogeneous Chain under different conditions labeled 6 & 35, 15, and 26. The bars represent the responses for different conditions, with S2, S1, S3, S2, and S1 on the x-axis.
In summary, the results presented in Figure 7 and Table 3 indicate that the stimuli associated with the components of the chain schedules had developed control of the behavior which occurred in their presence, i.e., stimulus control of behavior was obtained before the effects of satiation was assessed.

The results of the satiation tests are exhibited in Figure 8. Responding on nine consecutive days of satiation is presented in percentage form. The percentages were obtained from the ratio of response on any given test day to the number of responses which occurred on the day before the manipulation was initiated. Segment A of the three-horizontal panels displays the comparison of tandem and chain schedules. Of the 27 comparison days, 9 for each of the Ss, the chain schedule yielded a greater percentage of responses on 25 days. In addition, percentage of responses decreased across days for the chain, but no progressive effects occurred when the behavior was controlled by the tandem schedule, i.e., the difference between the schedules decreased across days as the chain schedule no longer maintained the behavior. Fragment B of Figure 8 shows the satiation effect on the homogeneous and heterogeneous chains. No differences between the schedules occurred. Percentage of responses under these conditions appears to be the same as that obtained for the tandem schedule.

Total number of responses during each of the components of the two-leg chain is presented in Figure 9. Responses on day 5 for S 6 were not recorded due to an apparatus failure. Ss 6 and 26 responded proportionately less during S2 under satiation (days
Figure 8. Percentage of responses for each of the four schedules of reinforcement as a function of nine consecutive days of satiation.
1-9) than before its administration (day 0), i.e., in comparison to day 0, the ratio of $S_2$ to $S_1$ responses was smaller on each of the days of the satiation tests, but $S_{15}$ did not show this effect. In general, when a shift was noted in one component, a concomitant change in strength occurred in the other.
Figure 9. Total number of responses during each of the two components of the chain schedule (training condition 1) as a function of nine consecutive days of satiation.
Discussion 2

Several experiments have yielded similar results, but all of these are either subject to another interpretation or may have confounded reinforcing effects during their tests. For instance, Seward and Levy (1953) used both food and water reinforcement and Wike and Casey (1954) permitted their subjects to manipulate food when testing satiation effects. The most comprehensive parametric study of the effects of satiation on secondary reinforcement was an experiment performed by Miles (1956). Correlating a light and a click from a feeder mechanism with reinforcement at 24 hours of deprivation, he tested rats in a bar press situation after either 0, 2-1/2, 5, 10, 20, or 40 hours. Secondary reinforcement groups were superior to comparably deprived control groups, and when compared to its corresponding control group the conditioned reinforcer was shown to exert a constant effect across hours of deprivation.

Although a classical experiment in the area, it paradoxically also contains problems which vitiate its conclusions. Since it did not independently assess the reinforcing properties of the stimulus complex, an elicitation or discrimination hypothesis rather than a secondary reinforcement analysis is equally valid. The present experiment avoided this criticism by determining the reinforcing effects of the stimulus in another situation. The results represented in Figure 8a show a clear superiority of the chain schedule of reinforcement in comparison to its tandem counterpart. The difference is maximum during the early days of satiation and declines with successive tests to a low level of responding, i.e., the difference
decreases across days. Since both the test of omitting the stimulus from the schedule for one hour and the difference between the chain and tandem schedules in training showed greater response strength in S₂ when the stimulus was present, it is concluded that S₁ was a conditioned reinforcer for responding in S₂. Thus, the efficacy of a secondary reinforcer under conditions of satiation has been demonstrated. Further, the results extend the generality of findings to individual organisms and exhibited a maintained effect for a number of days after ad lib feeding had been initiated. But, the effect wanes and the differences, if any, become negligible. Under extreme conditions of satiation, a secondary reinforcer is not effective. In contrast to the Miles study, the constant reinforcing effect was not substantiated. Since he tested his subjects only on one day after the appropriate number of hours of deprivation, failure of a relative decline in strength to occur is probably not surprising.

An unelaborate form of a secondary reinforcement analysis, however, does not seem applicable to the remainder of the data. When the chain was extended (Figure 8b) satiation resulted in infrequent responding from the onset of ad lib feeding. In fact responding was so low that the establishment of a tandem counterpart as a control procedure was not attempted, i.e., there was no effect and thus nothing to control. Of course, the stimulus may have no longer been a reinforcer, but why a secondary reinforcer should lose its effectiveness is not apparent.
One possibility is an interaction between frequency of reinforcement and the effects of satiation exists. As a consequence of a reciprocal relationship, responding might decrease at a lower frequency of reinforcement. Although there is some experiment support for this position (Carlton, 1961), Clark (1958) did not find an interaction when he used several values of VI schedules in which frequency of reinforcement was both more and less stringent than the chain schedules in this experiment. Secondly, when the chain schedule in the present experiment produced its greatest number of responses under satiation, the comparable tandem schedule was apparently maximally suppressed. An interaction hypothesis is not a cogent interpretation.

Consideration of the training data suggests an alternative conception. Those instances which revealed the least amount of responding under conditions of satiation showed the highest differential rates of responding in training, i.e., although total number of responses under the different schedules remained fairly constant, the number of responses in the components of the schedules varied. The chain schedule which was resistant to changes in deprivation, however, exhibited the most comparable rates in its two components during training. Possibly, the conditions in training and maintenance of a response which produce the most homogeneous rates in a behavior sequence results in its resistance to increased satiation. Specifically, rate of response may be used as a measure of response strength. Since the schedules in the various segments were equivalent, with the exception of the delay
component of the heterogeneous chain, rate in a particular component is an index of strength of that segment. In the present experiment, satiation exerted its greatest suppression effect on a sequence of behavior which was contingent upon a low probability response and its least effect on a sequence of approximately equal and higher strength components. The suppression effect on the former schedules may have been a consequence of eliminating a response sequence by reducing an already low strength response existing early in the chain, or in reference to the latter, the superiority of the equal strength sequence was a function of its constituent parts existing in considerable strength and thus requiring greater degrees of satiation to suppress the entire sequence.

In summary, a differential strength of response conception has been advocated as an interpretation of the results. Even if the stimuli in the extended chains were not conditioned reinforcers, the proposed analysis may still be valid since it also predicts the outcome. The advantage of a differential strength of response conception is its additional generality. It may be applied to a response sequence irrespective of the reinforcing properties of an exteroceptive stimulus, i.e., it is applicable to behavior not controlled by external stimuli. For example, recent experimental evidence has shown that response sequences without correlated stimuli may have higher rates than comparable behavior with explicit corresponding events (Thomas, 1964). By definition, the stimuli

\[\text{component o f t h e h e t e r o g e n e o u s c h a i n , r a t e i n a p a r t i c u l a r c o m p o n e n t i s a n i n d e x o f s t r e n g t h o f t h a t s e g m e n t. I n t h e p r e s e n t e x p e r i m e n t, s a t i a t i o n e x e r t e d i t s g r e a t e s t s u p p r e s s i o n e f f e c t o n a s e q u e n c e o f b e h a v i o r w h i c h w a s c o n t e n g e n t a u n p o w e r l y }\]

\[\text{r e s p o n s e r e s p o n s e } \text{and } \text{i t s l e a s t e f f e c t o n a s e q u e n c e o f a p p r o x i m a t e l y e q u a l a n d h i g h e r}

\[\text{s t r e n g t h c o m p o n e n t s. T h e s u p p r e s s i o n e f f e c t o n t h e f o r m e r s c h e d u l e s m a y h a v e b e e n a c o n s e q u e n c e o f e l i m i n a t i ng a r e s p o n s e s e q u e n c e b y}

\[\text{r e d u c i n g a n a l r e a d y l o w s t r e n g t h r e s p o n s e e x i s t i n g e a r l y i n t h e}

\[\text{c h a i n , o r i n r e f e r e n c e t o t h e l a t t e r , t h e s u p e r i o r i t y o f t h e e q u a l}

\[\text{s t r e n g t h s e q u e n c e w a s a f u n c t i o n o f i t s c o n s t i t u e n t p a r t s e x i s t i n g}

\[\text{i n c o n s i d e r a b l e s t r e n g t h a n d t h u s r e q u i r i n g g r e a t e r d e g r e e s o f s a t i a -}

\[\text{t i o n t o s u p p r e s s t h e e n t i r e s e q u e n c e .}

\[\text{I n s u m m a r y , a d i f f e r e n t i a l s t r e n g t h o f r e s p o n s e c o n c e p t i o n}

\[\text{h a s b e e n a d v o c a t e d a s a n i n t e r p r e t a t i o n o f t h e r e s u l t s . E v e n i f}

\[\text{t h e s t i m u l i i n t h e e x t e n d e d c h a i n s w e r e n o t c o n t i n e d r e i n f o r c e r s, t h e p r o p o s e d a n a l y s i s m a y s t i l l b e}

\[\text{v a l i d s i n c e i t a l s o p r e d i c t s t h e o u t c o m e . T h e a d v a n t a g e o f a d i f f e r e n t i a l s t r e n g t h o f r e s p o n s e c o n c e p t i o n i s i t s a d d i t i o n a l g e n e r a l i t y . I t m a y b e a p p l i e d t o a}

\[\text{r e s p o n s e s e q u e n c e i r r e s p e c t i v e o f t h e r e i n f o r c i n g p r o p e r t i e s o f}

\[\text{a n e x t e r o c e p t i v e s t i m u l u s , i . e ., i t i s a p p l i c a b l e t o b e h a v i o r n o t}

\[\text{c o n t r o l l e d b y e x t e r n a l s t i m u l i . F o r e x a m p l e , r e c e n t e x p e r i m e n t a l}

\[\text{e v i d e n c e h a s s h o w n t h a t r e s p o n s e s e q u e n c e s w i t h o u t c o r r e l a t e d s t i m -}

\[\text{u l i m a y h a v e h i g h e r r a t e s t h a n c o m p a r a b l e b e h a v i o r w i t h e x p l i c i t}

\[\text{c o r r e s p o n d i n g e v e n t s ( T h o m a s , 1 9 6 4 ) . B y d e f i n i t i o n , t h e s t i m u l i}

\[\text{1 A f t e r t h e t e r m i n a t i o n o f E x p e r i m e n t I I , a c h a i n s c h e d u l e d e v e l o p e d}

\[\text{b y c o r r e l a t i n g S 1 w i t h c o n t i n u o u s r e i n f o r c e m e n t b e f o r e e s t a b l i s h i n g a}

\[\text{c h a i n V I 5 V I 5 p r o d u c e d r e s u l t s s i m i l a r t o t h o s e r e p o r t e d b y T h o m a s . U n f o r t u n a t e l y , s a t i a t i o n t e s t s c o u l d n o t b e p e r f o r m e d w i t h t h e s e t w o}

\[\text{s u b j e c t s .} \]
in the Thomas experiment were not conditioned reinforcers. The effect of satiation in such cases is not apparent. Thus, the usefulness of a secondary reinforcement hypothesis seems to be limited to those instances in which the reinforcing properties of an external stimulus have been demonstrated. The proposed hypothesis, however, predicts increased resistance to increments in satiation as a function of greater relative response strength of the incipient components of any response sequence.
SUMMARY

This study investigated the successive effects of food satiation on an established operant response which was maintained by simple and complex schedules of reinforcement. Experiment I was devoted to an examination of the former schedules, and Experiment II explored the latter types. The purpose of these experiments was to develop a technique which would permit an assessment of varying degrees of satiation on the behavior of individual organisms and then employ the procedure in an evaluation of conditioned reinforcement, i.e., secondary reinforcement.

In Experiment I, variable interval responding was established under conditions of deprivation and the effect of gradual increments of satiation measured in one series of tests and immediate ad lib feeding in another. Gradual increases in satiation produced a step function decrease in total number of responses, but proportionately the distribution of responses within a session, i.e., within session variability, did not accompany the initial decline. Immediate free feeding resulted in a progressive decrease in total number of responses and a terminal distribution of responses which appeared only after a number of days. A comparison of the two manipulations revealed greater total response strength at all equivalent body weights under conditions of gradual satiation. Thus, the satiation procedures yielded two different response functions, and apparently rate of satiation is a determining variable.
Secondary reinforcement was assessed in the second experiment under conditions of satiation in which immediate free feeding was administered. A conditioned reinforcer was established in a chain schedule of reinforcement. The reinforcing properties of the stimulus were determined independently of the satiation tests. Responding, which was in part maintained by conditioned reinforcement, was superior to its comparable control on 25 of 27 comparison days. When the chain was lengthened, however, no resistance to satiation was observed. In other words, no reinforcing effect occurred following the establishment of extended chain schedules. The apparent contradiction was discussed in terms of the differences which were noted during training. It was suggested that resistance to satiation was in part a positive function of response strength of the incipient components of a response sequence.
Sucessive changes of body weight in grams as a function of consecutive days of test condition 1. The vertical lines correspond to the arbitrary divisions displayed in Figures 1 and 2.
BODY WEIGHT IN GRAMS


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AUTobiography

I, Carl Merrill Danson, was born in New York City on May 1, 1939. I received my secondary school education at Walden School in Manhattan, New York, and my undergraduate training at The Ohio State University. After obtaining my Bachelor of Arts degree in 1960, I enrolled in the Department of Psychology at Ohio State where I majored in experimental psychology under Dr. Reed Lawson. While in residence at Ohio State I held a research assistantship under Dr. Reed Lawson on two different occasions; a research assistantship under Dr. Samuel Corson; a teaching assistantship; and a National Institute of Health Training Fellowship. I received my Master of Arts degree at Ohio State in 1963.