A FREE-OPERANT TEST OF RESPONSE TRANSFER

DISSERTATION

Presented in Partial Fulfillment of the Requirements for
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By

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* * * * * * *

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INTRODUCTION

An animal's behavior is a function not only of present conditions but also of other conditions to which he has been exposed. This fact, behavioral interactions, is so obvious that it was recognized early in the history of psychology. Most early studies of interaction were those of the transfer type—so called because in these studies it is often convenient to think of behavior in one learning situation as "transferring" to another learning situation.

Thorndike and Woodworth (1901a, 1901b, 1901c) did a series of studies which led them to postulate the theory of identical elements. According to this theory, in order for transfer to occur there must be identical elements in the two behavioral situations.

As a significant branch of psychology grew more analytic, researchers and theoreticians gradually began teasing out relationships between stimuli and responses which could lead to interactions between two situations. The importance of stimulus similarity or stimulus generalization in producing response transfer from one stimulus to another was soon recognized. Yum (1931) presented an experiment and an argument which were important developments in this direction. He taught Ss lists of paired associates in which the stimulus items were nonsense syllables, words, or visual patterns, and the response items were words. Since he found in the subsequent test that a new
stimulus similar to one of the original stimuli tended to elicit the latter's response, he argued that similarity between two stimulating situations facilitated transfer from one to the other. A study by Gibson (1940) was also a landmark in the development of stimulus generalization as an important concept in behavioral interactions.

The principle emerging seemed to be that the more similar two behavioral situations are, the more performance in one will facilitate performance in the other. This came to be called positive transfer to distinguish it from negative transfer in which two behaviors interfered with each other. But a number of investigators were finding that in some cases stimulus similarity also produced interference.

McGeoch and McDonald (1931) and McGeoch and McGeoch (1937) in their studies found that, to the degree that two learning situations are similar, later learning will inhibit the recall of prior learning. This phenomenon, called retroactive inhibition, is usually differentiated from transfer because it involves a recall rather than a learning test. Gibson (1941) also performed an experiment in which stimulus similarity between tasks increased interference, demonstrating in this case both negative transfer and retroactive inhibition.

Osgood (1949) was the first to appreciate clearly the apparent paradox, and he proposed a resolution. If $S_1 - R_1$ is a typical stimulus-response connection in one behavior pattern and $S_2 - R_2$ is a typical stimulus-response connection in a second behavior pattern, Osgood's resolution may be stated: As $S_1$ and $S_2$ become more similar, interaction between the two behaviors increases; this interaction is facilitory as $R_1$ and $R_2$ become more similar, inhibitory as $R_1$ and $R_2$
become more antagonistic, and neutral at some middle point or when \( R_1 \) and \( R_2 \) are unrelated. This formulation fitted all of the existing data up to that time. The paradox appeared to be resolved by distinguishing response similarity from stimulus similarity. The three-dimensional theoretical curve which Osgood used to illustrate interaction as a joint function of stimulus similarity and response similarity has been called the Osgood transfer surface.

Osgood's theory has been beneficial in focusing attention on the analysis of stimuli and responses in interaction situations. But the difficulty of measuring stimulus and response similarity, particularly the latter, has made the theory difficult to employ. Moreover, in some instances it seems difficult to find stimuli relevant to Osgood's theory. Barlow's (1949) work on learning sets still defies analysis in terms of the Osgood surface. So do findings concerning discrimination reversals (e.g., Dufort, Guttman, and Kimble, 1954).

Many studies have attempted to test Osgood's theory. Often the results have been inconsistent with one another. Bugelski and Cadwallader (1956), varying response similarity, did not get the results predicted by the theory. But Dallett (1962), in a similar experiment, did obtain the predicted results. Bugelski and Cadwallader (1956) found positive transfer of responses from one set of stimuli to similar stimuli, confirming Osgood's theory. But Twedt and Underwood (1959), Postman (1962), Jung (1962), and Dallett (1962) found that the same situation produces negative transfer, clearly contradicting the theory.
Perhaps part of the difficulty lies in the level of analysis used in most of these studies. Generally the learning tasks are lists of complex stimuli and responses, such as verbal material. These may be too complex—i.e., composed of too many different interacting units—for basic relationships to be seen clearly. Inter-list interactions, for example, are difficult to determine and control. Moreover, it is difficult at present to control fully an S's history pertaining to the S-R material used in these experiments. The effects of such history are, for the most part, unknown.

An alternative analysis of behavioral interactions is provided by the free-operant situation. Its use of a simple, continuous behavior makes it valuable in depicting changes in rate of responding as a function of various manipulations. The basic purpose of the study presented here was to test one aspect of the Osgood paradigm in the free-operant situation. It was hoped that this would lead to a useful methodology for studying the problem of transfer.

To my knowledge, there have no previous free-operant studies of transfer. However, there are studies of other types of interactions in the free-operant situation; the present experiment was also to help integrate their findings with those of transfer of training studies.

Reynolds (1961a, 1961b, 1963) and Catania (1961) have shown that decreasing the rate of reinforcement in one component of a two-component multiple or concurrent schedule causes an increase in rate of responding in the other; and, conversely, increasing rate of reinforcement in one component causes a decrease in responding in the other. This phenomenon is called behavioral contrast.
Surprisingly, it appears that aside from contrast, different components of either multiple or concurrent schedules are highly independent of each other—as long as superstitious (i.e., adventitiously reinforced) response chains from one concurrent component to the other are not allowed to develop. Catania (1963) programmed a concurrent VI VI schedule on two keys (Ss were pigeons). By presenting a stimulus on one key shortly before a reinforcement on that key was due, he lowered the rate of responding almost to zero on that key. This had no effect on the rate of responding on the other key. Extinguishing on the first key, however, caused a marked increase in responding on the second key. In another study, Catania (1962) showed that on a concurrent FI VI, the VI responding remained fairly steady throughout the gradual increases in rate of FI responding that occurred as the time for a reinforcement in each fixed interval approached. In the concurrent schedules investigated by Catania many of the stimuli are similar; yet no transfer was shown.

The question asked by the present experiment is: Does transfer occur if the stimuli are identical?

Two bars were used, and a bar light over each bar indicated when VI reinforcement could be obtained on that bar. A tone was then associated with an extinguished component on bar A. Two other components occurred separately during bar light A: a clicker and the bar light only. VI reinforcement on bar A was associated with both. The clicker was used to test for generalization between stimuli on the same bar. Then tone and clicker were also presented separately when bar B light was on. For some Ss they were presented on bar B while extinction was
taking place during the tone on bar A; for other Ss, they were not introduced during bar light B until after extinction had already occurred for the tone on bar A.

It will be seen that in terms of the Osgood surface, this is a test for transfer where the stimuli in the two situations are identical and the responses are antagonistic. That is,

- $S_1 = \text{tone} + \text{bar light A}$
- $S_2 = \text{tone} + \text{bar light B}$
- $R_1 = \text{extinction on bar A}$
- $R_2 = \text{VI responding on bar B}$

According to the Osgood surface, this should result in a good deal of interference—i.e., negative transfer. However, a rather subtle distinction between the present and the usual interpretation of the transfer surface should be pointed out: $R_1$ and $R_2$ (above) technically do not represent responses but rather rates of responding. This constitutes a fundamental difference between the present study and previous studies on transfer, which were concerned with the probability of a discrete response event.
METHOD

Subjects and Apparatus

The Ss were six male Long Evans hooded rats whose ages were between 100 and 120 days at the beginning of the experimental procedures.

The apparatus was a standard operant conditioning box (Foringer Co., Rockville, Maryland). It contained a test chamber 9 7/8 in. wide x 10 5/8 in. long x 11 3/4 in. deep. Two metal bars protruded 5/8 in. from the front wall and were located 1 7/8 in. from either corner. Each bar was 3 1/4 in. above a grid floor. A force of 10 gms. applied to either bar operated a micro-switch. A food trough was located 2 in. above the floor, 1 3/4 in. from the left-hand bar (bar A) and 3 5/8 in. from the right-hand bar (bar B). It was supplied by a feeder capable of dispensing P.J. Noyes Lab Rat Food Tablets, 4 mm. x 3.3 mm. x 45 mg.

Above each bar was a small, white jewel light with a GE-1819 d.c. bulb. A tone (ranging from 1000 cps to 11000 cps) and a clicker (ranging from 46 pps to 60 pps) were presented through a speaker in the chamber. A house light consisting of two 6-w bulbs illuminated the chamber.

The apparatus was located in a small, darkened room adjacent to the room housing the rats and programming equipment. An air
conditioner in the apparatus room helped control the temperature. However, for several consecutive sessions near the end of the study, the air conditioner was out of order, as will be noted later. When the air conditioner was working, the temperature in the apparatus room ranged from 68° to 75° F. The temperature in the room housing the Ss ranged from 68° (in the winter) to 98° F. (in the summer).

Other units in the apparatus room made extraneous noises, including tones. However, since each box was partially soundproof and the relevant stimuli were close to the Ss, the extraneous tones probably did not seriously affect the experimental results. Moreover, the fan of the air conditioner and an exhaust fan in the operant conditioning box made continuous masking noises.

Procedure

Deprivation

Initially, six 100 day old Ss were fed ad lib. for 33 days. The "100% weight" for each rat was calculated by taking the mean of the S's weight over the last four days of ad lib. Then each S was reduced by food deprivation to 80% of his 100% weight over a period of 14 days. Shaping was begun immediately thereafter. Three of these Ss died very early in the experiment leaving only S-2, S-3, and S-6 of this initial set having data to be reported.

Another two Ss (S-7 and S-8) were 110 days old when obtained 60 days after the above Ss as replacements for the ones that died. They were fed ad lib. for 17 days. Their 100% weights were calculated on the basis of the last five days of ad lib., and they were reduced by
food deprivation to 80% of that weight over a period of approximately 14 days. For these Ss shaping was begun about 21 and 76 days later respectively.

A final S (S-9), also a replacement, was 120 days old when obtained 305 days after the initial set of Ss. He had been on ad lib. feeding when obtained. Three additional days of ad lib. feeding were used to calculate his 100% weight, and he was also reduced to 80% of that weight in 11 days. Shaping followed immediately.

Ss began the experimental procedures at different times mainly to provide replacements for ones that died so that a sufficient number of Ss would have been given the experimental treatments.

Since Ss did not get enough food in the apparatus to maintain 80% weight, they were given additional food (either Rockland Mouse Diet or Purina Laboratory Chow) in their home cages after each session. The amount given was weighed carefully in order to have them at about the 80% weight level at the beginning of the next session. Ss were given sessions almost every day usually within one hour of the time of the previous session. On days when they were not run they were given extra food in their home cages.

Training

The essential objective of training was to teach Ss to press bar A when its light was on, to press bar B when its light was on, and to make relatively few errors. Partly convenience, but mainly that experience in training Ss led to better techniques, caused
different training procedures to be used for later Ss. In fact, the
procedure originally attempted proved ineffective. Aspects of training
which differed among Ss will be detailed in separate sections. First,
however, an over-view of the modified procedure that eventually proved
effective will be given. This will help impress on the reader the
aspects of training common to all Ss, and it will also help make the
ensuing sections easier to follow.

Training may be divided into two phases: early-training and two-
bar training. The early-training sessions were usually about an hour
long (although occasionally they were as short as 1/2 hr. or as long
as two hrs.). S-9 is an exception, as will be explained later.

Initially, Ss were given several sessions of shaping, followed
by a few sessions of CRF and VI training. During these conditions
both bars were operative and the house light illuminated the chamber.
The original plan was to develop VI\textsubscript{75} as the final response require-
ment on either bar for all Ss. Due to difficulties in maintaining
the behavior of S-2, S-3, S-6, and S-7—as will be described in the
appropriate sections—this was changed to VI\textsubscript{45}. When VI\textsubscript{45} responding
was obtained, a DRO (differential reinforcement of other responses),
signaled by darkness, was introduced. That is, during the DRO the
house light was off, and no reinforcement could be obtained on either
bar, and the DRO remained in effect until no responses on either bar
had been made for a set period of time (termed the DRO time interval).
After the DRO time interval had expired, the house light came back on;
and reinforcement could again be obtained. The DRO alternated with
the house light, coming on after the house light had been on for two
min. When DRO training was begun, the DRO time interval was set at 5 sec. Gradually, over a number of sessions, it was increased to two min.

When Ss were making relatively few responses during the two min. DRO—much less than 10% of the responses during the house light—the two-bar phase of training was begun. The house light was no longer used. Bar light A came on to begin each session and alternated with bar light B every nine min. Each bar light was on for a total time of 5½ min. Ss were reinforced on VI 45 for responding on the bar whose light was on and were not reinforced for responding on the unlighted bar. At the end of 108 min. of bar light time, bar light B went off, the session was completed, and the chamber remained dark until S was removed. Ss were generally removed within half an hour after the end of their sessions.

During this phase of training the DRO no longer occurred automatically. However, an incorrect response—i.e., a response on the unlighted, non-reinforced bar—produced the DRO. The time during which the DRO was in effect did not count as part of the nine-min. period of the bar light which was on just before the DRO. The DRO time interval in this phase of training started at five sec. and again was gradually increased to two min. When the number of incorrect responses on each bar was less than 10% of the number of correct ones on each bar, the DRO was disconnected. For all Ss except S-9 it was still used (set at one minute) occasionally—every third session or so—to prevent a tendency for incorrect responses to increase over sessions. This proved unnecessary for S-9 and might have been unnecessary for the other Ss as well.
The above procedure proved effective in establishing the desired two-bar behavior. Now, as promised earlier, a more detailed description of training for different sets of subjects will be given.

**S-2, S-3, and S-6**

After $S_2$, $S_3$, and $S_6$ had reached 80% weight they were given magazine training and shaping in two sessions. CRF was given for four sessions, VI$^{45}$ for three sessions, and VI$^{75}$ for ten sessions. The VI$^{75}$, as mentioned above, was later abandoned. But, since $S$s were responding at a rapid and stable rate at this point (though making from 4 to 20 times more responses on bar A than on bar B), two-bar training was initiated. This was done in a manner similar to the procedure described above. Bar A light alternated with bar B light every nine minutes, and each light was on for a total of 54 minutes during each session. Each bar light indicated that reinforcement on VI$^{75}$ could be obtained only on that bar. This condition lasted for 12 sessions, at the end of which $S$s were emitting a considerable number of responses, almost half or more of which were incorrect.

In the next 26 sessions much difficulty developed. After every two min. of reinforcement time the DRO came on; that is, the box was dark and no response was reinforced until no response had been made for 5 sec. on either bar. As it was gradually increased, the number of responses became quite variable, and eventually started decreasing—especially on bar B. Also, the number of errors stayed well above 10% of the number of correct responses. After various efforts to recover the behavior proved futile, I concluded that the trouble was
caused by the double-discrimination problem with the high VI as a complicating factor. Therefore, training was begun again, using the modified procedure described earlier.

Ss were given six sessions of CRF with both bars operative, three sessions of VI20, five sessions of VI^5. Then came the DRO, such that the VI^5 schedule (with both bars operative), signaled by the house light, was on for two min. followed by the DRO. The DRO time interval was 5 sec. for one session, 10 sec. for one session, 15 sec. for five sessions, 20 sec. for four sessions, 30 sec. for three sessions, 40 sec. for two sessions, 50 sec. for two sessions, and 60 sec for seven sessions. At the end of DRO training, the number of responses made on bar A during the DRO was less than 10% of the responses made on bar A during the VI^5. The responses made on bar B during the DRO were generally more than 10% of the bar B responses during the VI^5. (This was probably due to the strong preference for bar A leading to an increase of responding on bar B during the extinction condition imposed by the DRO.)

Next, two-bar training was begun. As before, each bar light alternated with the other every nine minutes. An incorrect response produced the DRO. The DRO time interval was five sec. for two sessions, 10 sec. for two sessions, 20 sec. for two sessions, 30 sec. for one session, 40 sec. for two sessions, 60 sec. for three sessions, and two min. for 12 sessions. At the end of this training Ss were responding well on both bars and making very few errors on either bar—much less than 10% of the total of correct responses on that bar.
The next 38 sessions were devoted to testing whether the bar lights had indeed acquired good stimulus control. The DRO was disconnected, and the amount of time each bar light alternated with the other was varied from session to session. The bar lights still indicated reinforcement on VI45 on that bar. The range of alternation time was varied from one and a half to 54 min. The session time remained 108 min. The total number of correct and incorrect responses on either bar was quite stable.

Continuing the same test series, three test sessions in which only bar light A was on were followed by three test sessions in which only bar light B was on. Again, rate of correct responding remained about what it was during the other sessions. For some Ss there was an increase in errors. Then came two sessions in which both bar lights were on and VI45 reinforcement was available on either bar. I thought this might produce either a summation of subtraction effect. However, results among Ss were not consistent.

After this testing, Ss were returned to the original training schedule without the DRO for six sessions. Then each nine minutes on each bar was divided into three three-min. segments. During each three-min. segment, one of three stimulus conditions could occur: bar light A or B only (AL or BL); bar light + tone (AT or BT); bar light + clicker (AC or BC). A randomized sequence of presentation for these conditions would have been desirable; however, due to apparatus limitations, the following sequence was used every session:

AL, AT, AC, BL, BT, BC, AT, AC, AL,
BT, BC, BL, AC, AL, AT, BC, BL, BT.
In this notation of the stimulus conditions, the first letter indicates which bar light was on (A or B); the second letter indicates whether the tone (T), the clicker (C), or only the bar light (L) was present. For example, BL indicates that bar light B was on and the clicker and tone were not present; AT indicates that bar light A was on and the tone was present. This sequence was run through twice every session. These conditions were to be used later during the Transfer Test when AT would signal extinction. They were introduced now to test whether the tone and clicker in themselves influenced rate of responding. So far as could be detected, they did not. However, differential responding in these segments occurred before the tone and the clicker were used. For example, segments to be occupied by AL tended to have a lower total number of responses per session than the segments to be occupied either by AT or AC.

From the introduction of the tone and clicker until the Transfer Test, the DRO (set at one min.) was used only occasionally---no more than once every third session. It was not used during the Transfer Test.

During 1/4 of the tone-and-clicker sessions, mechanical difficulties made bar A unreliable. Each time the difficulty was discovered, S was removed from the apparatus and the other Ss were not run until the bar was fixed. Eventually, on the 36th session after the introduction of the tone-and-clicker, a permanent solution to the problem was found. After eight "good sessions," Ss were given the Contrast Test.
S-7

S-7 (the replacement for S-1, who died) began training when the above Ss were being given their first exposure to DRO training. Since he was shaped very rapidly, teaching him the two-bar discrimination was tried almost immediately. The bar lights alternated every nine minutes, and he was given CRF on the lighted bar for two sessions. This was increased to VI20 for seven sessions, and VI45 for 11 sessions. Until the last two sessions of VI45, this S was showing fairly good discrimination—errors were less than 10% of correct responses on bar A and less than 20% on bar B. His rate of responding was low, however—between seven and ten responses per minute on bar A and between four and seven responses per minute on bar B. During the last two sessions on VI45 his behavior drastically deteriorated. At this point training was modified and re-initiated for S-2, S-3, and S-6. Henceforth training for S-7 was identical to that of the first Ss, and comments in the preceding section concerning the latter portion of training also apply to S-7.

S-8

When training was re-initiated for S-2, S-3, S-6, and S-7, another subject, S-8, who had not been exposed to the original abortive training efforts, was added. S-8 therefore, after one session of shaping and three sessions of CRF on either bar, received the same training as the above Ss when their training was re-initiated.
S-9, as mentioned earlier, started much later in the study as a replacement for S-2, who died just before the Transfer Test. With both bars operative and the house light on, S-9 received one session of shaping, two sessions of CRF, two sessions of VI25, and three sessions of VI45. Then the DRO was introduced as before; after two min. of VI45 with the house light on, the DRO came on and alternated with the house light until the session's end. The DRO time interval was set at 5 sec., 10 sec., 30 sec., 40 sec., 50 sec., 60 sec., and 90 sec. for one session each. Then it was set at two min. for four sessions. The above sessions, from CRF to the end of DRO training, varied but averaged five hours. Since S-9 was the only S then being trained, extra long sessions were convenient.

Next, two-bar training was carried out in the standard way—bar A light indicating VI45 on bar A, and bar B light indicating VI45 on bar B. The DRO was made contingent on incorrect responses as described previously. The DRO time interval was set at 5 sec., 10 sec., 20 sec., 30 sec., 60 sec., and 90 sec. for one session each. Then S was given eight sessions during which the DRO time interval was two min.

After this, the DRO was discontinued. S was making far less than 1% incorrect responses. S then had five training sessions without the DRO before the Contrast Test.

**Contrast Test**

Since during the Transfer Test one component (AT) of a multiple schedule was to be extinguished, it was thought that behavioral
contrast might be an important factor in what happened in the transfer test sessions. For example, if contrast does affect one bar when extinction occurs on the other, the BT component might show either most or least of the effect. The Contrast Test was performed to help determine the role behavioral contrast might have during the Transfer Test. The same conditions that were in effect at the end of training continued except that Ss were extinguished on bar A. Rate of responding on bar B was examined as a function of this manipulation.

All Ss were given seven sessions of extinction on bar A. S-6, S-7, and S-8 were then returned to the regular training schedule, with occasional DRO, for 23 sessions. Then they began the Transfer Test. S-9 was put back on the regular training schedule for six sessions before beginning the Transfer Test. About 15 sessions of the regular training schedule after the Contrast Test S-2 and S-3 both became ill. Despite penicillin treatment, S-2 had to be destroyed. S-3, however, showed gradual signs of improvement and returned 42 days after leaving the experiment. Four days later S-3 became sick again and had to be left out of the experiment for three days. He then continued on the regular training schedule for four sessions and then started the Transfer Test.

**Transfer Test**

S-6, S-7, and S-8 were the first to begin the Transfer Test. The AT component was extinguished while all other conditions were the same as before the test. How this affected the rate of responding during BT, as compared with BL and BC, was closely observed. The Transfer Test continued for 48 sessions at which time extinction appeared to be
progressing very slowly—especially for S-6 and S-7. It was hypothesized that Ss' being reinforced on BT resulted in a transfer effect from BT to AT. To test this, for S-6 both the tone and clicker were discontinued during bar B light (called the bar-B-light-only condition) while all other conditions remained the same.

For convenience in exposition I shall speak of the bar-B-light-only (BLO) condition as part of the Transfer Test even though Ss receiving it were not actually being tested for transfer, but were serving as controls.

The BLO condition for S-6 and the continuation of the condition with tone and clicker during bar B light for S-7 and S-8 were carried out for 59 sessions. This made a total of 107 sessions since the beginning of the Transfer Test.

When S-3 and S-9 began the Transfer Test, they also were put on the BLO condition because: (1) the speed at which they extinguished on AT, in comparison with that of the other Ss, would give some indication whether reinforcement on BT was retarding extinction on AT; (2) recording the responses during the time intervals of the BLO that corresponded to BL, BT, and BC would provide a control for any differences in number of responses in the time segments regardless of whether the tone and clicker were present; (3) transfer to BT after completing extinction on AT could be tested without the complicating factor that Ss had already been trained to respond on BT while being extinguished on AT.

S-3 became sick again on the tenth session of the Transfer Test. He was kept out of the experiment for four days. He then continued on
the BLO condition for 39 more days when he became ill again and had to be destroyed.

S-9 received 42 sessions of the BLO condition. Unlike the other Ss, S-9's first exposure to the tone and clicker was during the Transfer Test. Several as-yet-unmentioned events took place during the preceding phase of the Transfer Test. A few apparatus failures are not included in the total numbers of sessions expressed above. Also not in those totals are four tests for stimulus control by the tone on bar A, and a bar-preference test. The stimulus control tests consisted of twice (i.e., for two sessions) not extinguishing on AT and twice not presenting the tone during the extinguished component on bar A. These sessions were not consecutive. Stimulus control by the tone on bar A was demonstrated. However, this will not be discussed in the Results section because better evidence is shown in a later phase of the Transfer Test.

The bar-preference test consisted of three consecutive sessions in which tone and clicker alternated with each other every minute for a total session time of about 108 min. In the first session the bar lights were off, and no reinforcement was available. During the second session, both bar lights were on throughout the session, and no reinforcement was available. For the third session both bar lights were on simultaneously, and reinforcement on VT45 was available on either bar.

The above test was to show: (1) what degree of stimulus control the tone had over responding on bar A, (2) what effect the tone had on
bar B responding, and (3) whether S's preferred responding on bar B during the tone, rather than on bar A.

The bar-preference test took place after the 43rd session of the Transfer Test for S-6, S-7, and S-8; after the 39th session of the Transfer Test for S-3; and after the 28th session of the Transfer Test for S-9.

Twelve sessions before the end of this phase of the Transfer Test the air conditioner stopped working, and the temperature (in June) reached 98° F. Responding was very low during these sessions, and data for them is not presented in the Results section. Eight sessions later the air conditioner was replaced; and, to make sure that S's responding was back to normal, they were given four additional sessions of this phase of the Transfer Test. Responding did increase during these sessions, but still was not as high as before. It is probable that the heat continued to affect the results since the room where Ss were housed was not air conditioned.

In the second phase of the Transfer Test S-6 and S-9, who had been on the BLO condition, were switched to the one with tone and clicker presented during bar light B for six sessions. S-7 and S-8, who had been on the condition with tone and clicker on bar B, were switched to the BLO condition. (S-3, as mentioned, had been discarded because of illness.) This was to discover the effect (if any) of adding the tone to bar B and of removing it after extinction during the tone had already taken place on bar A.

Next all Ss were given two sessions with tone and clicker presented on bar B. The third phase of the Transfer Test consisted of
no longer extinguishing during AT. In other words, VI45 was in effect during all segments, including AT. The condition in which tone and clicker was presented during bar light B was also still in effect. This was carried out for 18 sessions.

There had been a general decline in responding on both bars throughout previous portions of the Transfer Test. This last phase of the Transfer Test was designed to determine whether the decline was due to a generalization of the effects of extinction during AT to other components on either bar. If so, it seems that resuming reinforcement on AT would reverse this process; and responding on all components would increase to about the original level.

This phase also demonstrated the degree of control the tone had on rate of responding on bar A during AT when AT was being reinforced. Thus it provided a good comparison for rate of responding on bar B during BT since BT was always reinforced. Further, it allowed one to observe the effect (if any) that reconditioning on AT had on BT and the other components.

In summary, it must be emphasized that, although the Transfer Test seems complex, essentially there was one independent variable and one dependent variable. The independent variable was extinction in the presence of the tone on bar A. The dependent variable was rate of responding in the presence of the tone on bar B.

Rationale for testing Ss that differed in training procedure

The fact that Ss were not given exactly the same training conditions was, of course, not originally planned. It was largely due, as
has been explained, to various problems which arose in attempting to produce satisfactory two-bar behavior. This kind of variation in procedure which is prohibited in statistical studies is quite common in free-operant research where each S is closely observed. Sidman (1960, p. 111), in his widely used textbook on free-operant research, even argues that such variation is often desirable.

But this involves a risk, as Sidman quickly points out. It may therefore be wise to resort to evidence from the literature that differences in procedure would not differentially influence the results. There are at least three major uncontrolled variables which could have produced intra-subject variability in the Transfer Test: (1) amount of training, (2) variety of training procedures used, and (3) age. To my knowledge, there are no data on transfer or generalization in mature rats as a function of age. However, the effects of the other two variables can be documented to some extent.

A number of maze studies (e.g., Reid, 1953; Capaldi and Stevenson, 1957; Pubols, 1956; Bruner, Mandler, O'Dowd, and Wallach, 1958; Stevenson and Weir, 1959) and a number of verbal learning studies (e.g., Underwood, 1951; Mandler and Heinemann, 1956) have shown that degree of original training affects transfer. Similarly, it has been shown that degree of prior familiarization with the S and R components of a given task influences later learning of the task (e.g., Underwood and Schulz, 1960). In the present experiment the amount of training varied considerably and could have caused differences in transfer during testing. But it should be noted that even S-9, the S with the least amount of training, was given over 42 hours of training on the
two-bar problem. Thus S-9 had made thousands of responses on the two-bar problem before the beginning of the Transfer Test. If the effects of overtraining on transfer have a finite asymptote, as many of the above studies suggest, it seems likely that the Ss of the present experiment had all been trained to points near that asymptote.

Ss also differed with respect to variety of training procedures. Because of the problems which arose, S-3, S-6, and S-7 had more variable training procedures than did S-8 and S-9. Duncan (1958) has shown that variety of previous tasks increases positive transfer to similar tasks. The function is asymptotic; and since all Ss in the present study were exposed to a large variety of conditions, it is possible that transfer effects for all Ss were near asymptotic level with regard to this variable.
RESULTS

Contrast Test

Figure 1 shows the results of the Contrast Test in which extinction was carried out during bar light A. It will be noted that there are four separate curves plotted for each S: (1) correct responses on bar A, (2) incorrect responses on bar A, (3) correct responses on bar B, and (4) incorrect responses on bar B. Each of these curves was constructed in the following manner. Means of responses for nine (five for S-9) sessions before, seven sessions during, and seven (six for S-9) sessions after the Contrast Test were obtained separately for each curve. These three means were then summed, and each mean is expressed on the ordinate of Figure 1 as a percentage of that total.

The contrast effect appeared in all Ss except S-7. Actually one could argue that even he showed some contrast if one were to consider only the last two sessions of extinctions on bar A. During the other five sessions there was first a decrease in responding on bar B (an "induction" rather than a contrast effect) which, when averaged with the increase, canceled it out. The other S's did not show this initial induction effect.

Also interesting is the effect extinction had on incorrect responding. The extinction of correct responding on bar A apparently generalized to incorrect responding on bar A. In some cases both
Figure 1.--Contrast Test. Percentage of mean numbers of correct and incorrect responses before (B), during (D), and after (A) extinction on bar A. The number near each point represents the mean number of responses before being converted to a percentage (see text).
COMBINED SESSIONS: BEFORE, DURING, AND AFTER EXTINCTION.
correct and incorrect responding on bar A showed almost proportionate decreases. On the other hand incorrect responding on bar B showed a very strong contrast effect. In all but one case (that of S-2) the effect was considerably stronger, proportionately speaking, on incorrect than on correct bar B responding.

A one-tailed t test on the proportionate increase in bar B responses during, as opposed to before, the Contrast Test is significant with \( t = 4.29, \) \( df = 5, p < .005 \). A two-tailed t test on the proportionately greater increase in incorrect, as opposed to correct, bar B responses during the Contrast Test is significant with \( t = 3.09, \) \( df = 5, p < .05 \).

Thus it was possible under these conditions to obtain a strong interaction between bars. It proved to be less easy to do during the Transfer Test.

Transfer Test

It will be recalled that the components AL, AT, AC and BL, BT, BC did not occur in a random sequence. Since response rate was not uniformly distributed over a session, there was differential responding in the time intervals corresponding to these components. Figure 2 shows the mean correct response distributions in the time intervals corresponding to each component. These means for each S (except S-9) were obtained for 57 sessions prior to the Transfer Test, not including sessions of the Contrast Test or sessions in which there were apparatus or recording failures. For S-9 these means were obtained for 25 sessions prior to the Transfer Test.
Figure 2.--Response Distributions before the Transfer Test. Mean correct responses on bar A and B during light (L), tone (T), and clicker (C)—or their corresponding time intervals—before the Transfer Test (see text).
MEAN RESPONSES ON BAR A.

MEAN RESPONSE ON BAR B.

STIMULUS COMPONENTS: LIGHT, TONE, CLICKER
Figure 2 should also be referred to when it is desired to compare rates of responding for different Ss since they maintained their same relative positions during the Transfer Test.

Before describing the results of the first phase of the Transfer Test, it will be helpful to review briefly some of the procedure. In the first phase of the Transfer Test extinction was given during the tone on bar A (AT). This manipulation was to permit observation of its effect on bar B responding during the tone on bar B (BT). Also the generalization (if any) of the effects of extinction on AT to the clicker on either bar was of some interest.

At the onset of the first phase of the Transfer Test, only S-6, S-7, and S-8 received the tone and clicker during bar light B. S-3, S-9, and (after 48 sessions) S-6 were on what is termed in the procedure section the bar-B-light-only (BLO) condition, meaning that they did not receive tone and clicker presentations during bar light B. These Ss served as controls for the possibility that there would be differences in responding in the bar B light only (BL), bar B light plus tone (BT), and bar B light plus clicker (BC) components irrespective of the tone and clicker, for, as stated, these components did not occur in a random sequence.

Figures 3-6 show the data for correct responses during Transfer Test as well as, for comparison purposes, a number of sessions before the Transfer Test. Means for each component were obtained over six-session blocks, beginning 12 (six for S-9) sessions before the Transfer Test. These means were then divided by the means of their respective components obtained over the 57 (25 for S-9) sessions during which all
Figure 3.—Transfer Test for S-3 and S-6. Correct responses during each component for S-3 and S-6 before, during, and after extinction on tone, bar A. Each point represents a mean for six sessions expressed as a percentage of the mean number of responses during the corresponding time intervals before AT extinction (see text).
Responses on Bar A. →

Responses on Bar B. →

Tone and Clicker are Presented

Bar B Light Only

All Components Reinforced

Extinction during Tone on Bar A.

Blocks of Six Sessions

Extinction

All Components Reinforced

Tone and Clicker are Presented

Bar B Light Only

All Components Reinforced

Extinction during Tone on Bar A.
Figure 4.—Transfer Test for S-7. Correct responses during each component for S-7 before, during, and after extinction on tone, bar A. Each point represents a mean for six sessions expressed as a percentage of the mean number of responses during the corresponding time intervals before AT extinction (see text).
Tone and Clicker are Presented.

Bar B Light Only

All Components Reinforced.

Extinction during Tone on Bar A.

Blocks of Six Sessions.
Figure 5.—Transfer Test for S-8. Correct responses during each component for S-8 before, during, and after extinction on tone, bar A. Each point represents a mean for six sessions expressed as a percentage of the mean number of responses during the corresponding time intervals before AT extinction (see text).
Tone and Clicker Are Presented.

Tone and Clicker Are Presented.

Bar B Light Only

Extinction During Tone on Bar A

Blocks of Six Sessions

All Components Reinforced
Figure 6.—Transfer Text for S-9. Correct responses during each component for S-9 before, during, and after extinction on tone, bar A. Each point represents a mean for six sessions expressed as a percentage of the mean number of responses during the corresponding time intervals before AT extinction (see text).
Components binding "0 Reinforced Tone on Bar A. Blocks of Six Sessions."

Responses on Bar A.

All Components Reinforced

Extinction

Bar B Light Only

Tone and Clicker are Presented

Responses on Bar B.
components were reinforced (the data of Figure 2). Thus each point
in Figures 3-6 represents for a particular S the mean of his responding
during a given component, expressed as a percentage of his responding
during the time intervals corresponding to that component before
extinction.

Not all of the sessions held during the Transfer Test are repre­
sented in Figures 3-6. Besides apparatus failures and recording
difficulties, sessions near the end of the first phase when the air
conditioner was out of order are excluded. If at the end of a phase
fewer than six sessions were left, they were excluded. Such a block
of sessions occurred just before S-6 was switched to the BIO condition
during the first phase, and is excluded. Also not represented in these
figures are the four stimulus control tests and the bar-preference
test which, as mentioned in the procedure section, took place during
the first phase. With these exceptions all sessions of the Transfer
Test are represented in the figures.

As Figures 3-6 show, extinction during AT occurred very slowly
and did not reach a very low level. There was an initial rise in AT
responding with a concomitant suppression of the other two-bar A com­
ponents for all Ss except S-9. Actually S-9 also showed a slight rise
in AT responding on the first session of the Transfer Test, but the
succeeding five sessions in the first block cancel it out. Suppression
on the other two A components did not occur at all for him. In addi­
tion S-9 extinguished more rapidly on AT than did the other Ss and
to a greater extent.
It is not clear whether the slow rate of extinction on AT is correlated with the occurrence of reinforcement on BT. S-3 also has a very low rate of extinction, and he was on the BLO condition. However, his chronic illnesses may have contributed to his failure to show much extinction. The change to the BLO condition for S-6 is correlated with an almost immediate drop in response rate on AT. However, S-7 also had a large drop in AT responding at about the same time, and S-8 had begun to show the drop sometime before. Both of these Ss were still receiving tone and clicker presentation during bar B light.

On bar B there is very little evidence of transfer. It is possible that there was a slight transfer effect for S-6, but if so it begins quite some time before extinction starts to appear on AT. S-8 may also have had a slight transfer effect; and, if so, it seems to have begun at about the time that extinction began taking place on AT. But S-7 shows no indication of transfer whatsoever. If transfer from AT to BT took place during the first phase of the Transfer Test, it was weak for two Ss and did not occur for a third.

Note that differences during the various time intervals are shown by the BLO condition. However, the bar light B time intervals corresponding to the other two components. This provides added evidence that the slight, apparent transfer effect shown for S-6 and S-8 was not artifactual. Particularly was this true for the data obtained when S-6 was switched to the BLO condition during the first phase of the Transfer Test.
The results of the bar-preference test were not very conclusive either and so will be described only briefly. As has been explained, this test consisted of three sessions in which the tone alternated with the clicker every minute. In the first session neither bar light was on, and reinforcement was not available. In the second session both bar lights were on, and reinforcement was still not available. In the third session both bar lights were on, and reinforcement was available on VI45 on either bar.

S-6, S-7, and S-9 showed more responding on bar A during the clicker than during the tone throughout all three sessions. S-8 responded more on bar A during the clicker than the tone in the first and third sessions but responded more on bar A during the tone in the second session. S-3, however, showed no apparent discrimination on bar A.

The status of the discrimination on bar B is much more ambiguous during this test. S-3 made more responses on bar B than on bar A, and more responses during the clicker than the tone on bar B during all three sessions. S-6 made very few responses on bar B during the first session, but apparently showed a transfer effect during the second and third sessions. S-9 made very few responses on bar B, and perhaps for this reason did not show a discrimination between tone and clicker on bar B. Since S-7 and S-8 had been on the condition with tone reinforced during bar light B for the 43 prior sessions of the Transfer Test, it was thought that they might show a strong preference for bar B during the tone. However, this did not materialize. Nor was
there apparent discrimination on bar B between tone and clicker for these Ss.

The second phase of the Transfer Test consisted of six sessions (see Figures 4 and 5) in which those Ss (S-7 and S-8) who had been on the condition with tone-and-clicker presentations during bar light B were switched to the BLO condition; and those Ss (S-6 and S-9, see Figures 3 and 6) who had been on the BLO condition were switched to the condition with tone-and-clicker presentations during bar light B. Again it is possible that S-6 showed a transfer effect when the tone was re-introduced during bar light B. But S-9, who in these sessions was receiving his first exposure to the tone during bar light B, clearly showed no such effect. The results of this phase seem to point once again to the weakness of the transfer effect if it existed.

One unexpected aspect of the results is that all Ss, except possibly S-7, showed over blocks of sessions a general decline in correct responding during all conditions on both bars. This is unexpected because it seems to contradict the results of the Contrast Test. There are several hypotheses which might account for this decline—one of which led directly to the next phase of the Transfer Test. It will be convenient to mention some of the others first. One is that the decline is due to aging. However, S-9, who was the youngest S, also showed it. Another more plausible hypothesis is seasonal changes since the Transfer Test took place as summer approached and the room housing Ss was not air conditioned. The hypothesis which led to the next phase of the Transfer Test is that extinction during tone on bar A generalized to all conditions
irrespective of the presence of the tone. That is, the hypothesis
states that there was an "induction" rather than a contrast effect.

If the last hypothesis is correct, then it seems that the trend
should have been reversible. Thus, the third phase consisted in making
VI\textsuperscript{45} reinforcement available on AT so that all components were rein-
forced. During this phase one could also observe the stimulus control
the tone had acquired on bar A responding since the operation of
extinction no longer differentiated the A components. This is import-
ant since the paucity of transfer might suggest the absence of stimulus
control by the tone on bar A. In addition, this final phase provides
an interesting comparison with bar B responding because it too can be
viewed as a transfer test—viz., the transfer from AT—extinction to
AT—VI\textsuperscript{45}, just as the main test was one of transfer from AT—
extinction to BT—VI\textsuperscript{45}.

The third phase (see Figures 3-6) of the Transfer Test was
restricted to 18 sessions. This was perhaps not enough time to assess
fully its effects on response rate on all components. However, as
can be seen from Figures 3-6, the available evidence indicates no
tendency for response rate to return to its pre-extinction level.
There is a slight increase for some Ss, but this could easily be due
to weather changes. It will be noted that in the beginning of the
third phase all Ss responded less on bar A during AT, but none did so
on bar B during BT.

Looking at the results of the Transfer Test as a whole, one might
infer that S-6 and S-8 may have shown a slight degree of transfer,
whereas S-7 and S-9 showed none at all. If this is a real difference,
is there any a posteriori reason that might account for it? S-7 and S-9 were much lower responders than S-6 and S-8 (see Figure 2) but it is difficult to see how this would have much bearing on the question. Another possibility is that the degree of the discrimination between bar light A and bar light B would be relevant. For each S the ratios of total correct responses on bar A to total incorrect responses on bar A (CA/IA) and of total correct responses on bar B to total incorrect responses on bar B (CB/IB) were computed for 15 sessions (six for S-9) prior to the Transfer Test. Sessions where the DRO occurred and where there were apparatus failures were excluded.

The results of these calculations were as follows:

- S-6: CA/IA = 18.1; CB/IB = 33.4
- S-8: CA/IA = 16.6; CB/IB = 25.8
- S-7: CA/IA = 14.4; CB/IB = 77.4
- S-9: CA/IA = 51.3; CB/IB = 87.8

It is very clear that by this measure S-9 shows the best discrimination. It is somewhat more difficult to interpret the results for the other Ss. They are very close in their bar A discriminations, but S-7 shows a much better bar B discrimination.
DISCUSSION

The Contrast Test demonstrated a strong interaction; the Transfer Test did not. No definite conclusions can be drawn from the Transfer Test because of the possibility that it was not sensitive enough to detect differences had there been any. But if future research substantiates this lack of transfer across operants, Catania's (1962, 1963) findings of "reinforcement interaction and response independence" will have been further extended. And the transfer surface, which has been so often under attack, will meet further difficulties.

In either case it seems that contrast is a much easier phenomenon to produce than is transfer. Osgood's theory could not have predicted this. One curious feature of the Transfer Test is the general decline in responding that most Ss showed in all conditions. As mentioned earlier, this may have been artifactual. But, if due to extinction during tone on bar A, it represents not a contrast but an induction effect. This would oppose other work on contrast. In particular, Catania (1962) showed that when a multiple VI extinction schedule was programmed on one key concurrent with a VI schedule on the other, the rate of responding on the second key remained steady throughout both the extinction component and the VI component on the first key. But contrast did occur in the amount
appropriate to the average rate of reinforcement on the first key. Thus, extinguishing during a specific time segment on one bar (in the present study) should produce a contrast effect on the other bar. Evidently this did not occur. Perhaps Catania's above results are specific to concurrent schedules.

The Contrast Test, and perhaps the general decline over sessions, help validate that the test conditions of this study were sensitive to interaction. This lends credence to the argument that the Transfer Test would have detected transfer if any existed. Transfer within the same operants would further support this argument. Hence the clicker; but, as will be noted from Figures 3-6, no transfer to the clicker was demonstrated either. However, possibly the clicker and the tone were not similar enough to permit transfer from one to the other in this situation.

On the other hand, if correct and incorrect responses on one bar may be considered parts of the same operant, then transfer within each operant appears to have been demonstrated in the Contrast Test (Figure 1). Also interesting is the almost proportionate decline in correct and incorrect responses on bar A in comparison to the proportionately greater increase of incorrect over correct responses on bar B. There is no immediate explanation for these differences. The fact that during two-bar training failure to receive reinforcement on bar A meant reinforcement was available on bar B if the DRO was not present could have caused these results. This should be investigated by future research.
Another instance of transfer within an operant was demonstrated in the third phase of the Transfer Test when VI 45 reinforcement was again presented during the tone on bar A (Figures 3-6). For a number of sessions responding during the tone on bar A remained lower than during the other two bar A components, but this effect was still not shown on bar B.

The results of the present study, taken at face value, appear to contradict most of the more traditional studies testing the same portion of the transfer surface. For example, using human Ss with paired associates as the learning tasks, Bugelski (1942), Bugelski and Cadwallader (1956), Twedt and Underwood (1959), Postman (1962), Jung (1962), and Dallett (1962) all obtained negative transfer when S₁ and S₂ were identical, and R₁ and R₂ were different. Using rats in a T-maze, Hunter (1922) found negative transfer when R₁ was turning right and R₂ was turning left. But Bunch (1939), also using rats in a T-maze, failed to show transfer (negative or positive) when R₁ and R₂ were different turns in the maze.

Several factors could be involved in the present failure to show transfer from bar A to bar B. First, Ss had had many hours of training and hundreds of reinforced responses before the Transfer Test. By the standard of more traditional kinds of experiments, this constitutes a tremendous amount of "overlearning." A number of experiments have shown that overlearning in the first situation can reduce the amount of negative transfer in the second situation. Specifically, it has sometimes been found that if rats are trained to go in one direction in a T- or Y-maze, and then the reinforced
direction is reversed, Ss who have had the most training beyond mastery of the original task will learn the reversal quickest. In some cases, a large degree of overlearning has actually resulted in positive rather than negative transfer. Studies illustrating this point have been done by Pubols (1956) and Bruner, Mandler, O’Dowd and Wallach (1958). There are also many studies that have been unable to find any overlearning effect.

On the other hand, if overlearning had eliminated the tendency for negative transfer in the present study, it seems there should have been no negative transfer when the tone on bar A was reinforced during the third phase of the Transfer Test. But negative transfer did occur within the same operant during this phase.

A second possible explanation for the failure to demonstrate transfer between operants may be the high degree to which Ss had learned the discrimination between the two operants. If bar light A was highly differentiated from bar light B, then adding the tone to bar light B may not have altered the control that bar B light had over responding on bar B. In other words, the differentiation between the bar lights insured that tone + bar light A was a different stimulus complex from tone + bar light B. The tone itself did not control behavior; behavior on bar A during the tone was controlled by the stimulus complex (tone + bar light A) of which the tone was a member. The fact that Ss were never extinguished on bar B (during bar light B) helped strengthen this differentiation.

Continuing this line of argument, it might even be said that generalization between two identical stimuli had been reduced by
"stimulus predifferentiation." Perhaps more relevant, however, are studies and theories concerning "background" (or "situational" or "contextual") stimuli. The bar lights would be the background stimuli, and the tone would be the specific task-related stimuli in this conceptualization. For example, Greenspoon and Ranyard (1957) in a retroactive inhibition test found that there was less interference between two lists of paired associates if each were learned in a different room. The specific stimuli were the stimuli members of the paired associates, and the background stimuli were all the stimuli in the two rooms.

Jean Barnes McGovern (1964) in a study in transfer and recall examined the function of background stimuli from a theoretical point of view. She argued that background stimuli elicited the "free recall" of response items but had no effect on the ability to associate them with specific stimuli. Her prediction that when $S_1$ was different from $S_2$ and $R_1$ different from $R_2$, retroactive inhibition would occur in the free recall of $R_1$ but not in associating it with $S_1$, was verified.

But if the discrimination between bar lights did cause independence of operants during the Transfer Test of the present study, it remains unclear why interaction between operants occurred during the Contrast Test.
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