WADC TECHNICAL REPORT 52-64

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TRANSFER OF TRAINING IN MOTOR LEARNING AS A FUNCTION OF DEGREE OF FIRST-TASK LEARNING AND INTER-TASK SIMILARITY

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FOREWORD

This report was prepared by Northwestern University under USAF Contract No. AF 33(038)-11396. The contract was initiated under a project identified by Research and Development Order 694-17 and later continued under Research and Development Order 694-44. The contract was administered by the Psychology Branch of the Aero Medical Laboratory, Research Division, Wright Air Development Center, with Gordon A. Eckstrand acting as Project Engineer.

Included among those who cooperated in the study was Mr. Victor E. Montgomery of the Department of Psychology, Northwestern University.

ABSTRACT

Transfer between a first and a second task, both available on the same piece of equipment, was studied as a function of degree of learning of the first task and of degree of similarity between tasks. There were four degrees of first-task learning, defined by the number of practice trials, and three degrees of inter-task similarity, defined by the number of stimuli and responses newly paired on the second task.

It was found that acquisition of the second task was facilitated by practice on the first task, and that the facilitation increased directly with degree of first-task learning. Positive transfer also occurred with all degrees of inter-task similarity, and increased directly as similarity increased. Differential positive transfer resulting from variation of first-task learning lasted throughout all 60 acquisition trials on the second task; inter-task similarity produced differential positive transfer during only the first 30 trials.

Some forgetting of the second task was present after a 24-hour rest; the forgetting neither varied as a function of the two main variables nor was attributable to their presence. Relearning of the second task was facilitated by practice on the first task, and the facilitation varied directly with the amount of practice. Facilitation of relearning also occurred for all variations of inter-task similarity, but was significantly less for the least-similar task.

PUBLICATION REVIEW

Manuscript copy of this report has been reviewed and found satisfactory for publication

FOR THE COMMANDING GENERAL:

Robert H. Blount

ROBERT H. BLOUNT
Colonel, USAF (MC)
Chief, Aero Medical Laboratory
Research Division

TABLE OF CONTENTS

ILLUSTRATIONS

Illustrations (Cont'd)

TRANSFER OF TRAINING IN MOTOR LEARNING AS A FUNCTION OF DEGREE OF FIRST-TASK LEARNING AND INTER-TASK SIMILARITY

I. INTRODUCTION

The purpose of the study was to investigate transfer from a first to a second task in motor learning as a function of two variables: degree of first-task learning, and inter-task similarity. Both tasks consisted of different S-R (stimulus-response) patterns on the same apparatus. This type of transfer situation, in which a new task to be learned is provided by changing the S-R relationships within the same basic apparatus, has not been extensively studied, although such situations occur frequently. Machines requiring the operator to learn a fairly complex coordination, e.g., automobiles, airplanes, are constantly being modified. Such modifications often require the operator to learn a new pattern of S-R connections. The present study is an attempt to provide data on the kinds and amounts of transfer which may occur when one has to relearn the operation of the same machine because the S-R relationships have been changed.

A brief summary of the task used may help clarify the kind of transfer situation studied. The subject was required to learn to move a lever, held by the right hand, into a series of slots in response to colored-light stimuli. The task was made relatively difficult by simultaneously requiring the subject to hold another lever, grasped by the left hand, in a steady position. Different groups of subjects were taken to different levels of mastery on this first task by varying the number of practice trials. A second task was then provided by changing the pattern of pairing of lights with slots. The number of S-R pairs changed was different for different groups of subjects, thus providing various degrees of similarity between the first and second tasks. All subjects were then given the same number of trials on the second task, and 24-hours later relearned the second task. Our interest is in the learning and relearning of the second task as they are affected by transfer from the first task.

There are few studies which relate directly to the present approach. As far as is known, no studies of transfer in verbal learning have used the technique of constructing the second list by re-pairing the stimuli and responses of the first list. Perhaps the closest approach occurred in experiments in which the stimuli of the two lists were identical and the responses similar. With verbal lists, such conditions resulted in positive transfer (7, 8).

More relevant to the present experiment is the study by Lewis, McAllister, and Adams (4). In their work transfer was studied by reversing the arrangement of the controls on the Mashburn apparatus following practice on the standard arrangement. On the second (reversed) task, the subjects had to move the controls, in response to the signals, in the direction opposite to that on the first (standard) task. Following reversed practice, the subjects relearned the standard task.

Lewis _et al_ found both facilitation and interference in learning the reversed task. In comparison with a control group that had had no practice on the standard task, the experimental groups showed facilitation, indicated by a greater number of matches (of stimulus and response lights), and interference, indicated by a greater number of errors, on the first trial of reversed-task learning. In spite of the interference, the overall transfer effect was positive; the experimental groups scored higher than the control group on all reversed-task trials.

There was also some evidence that both facilitation and interference on the reversed task increased as degree of first-task learning increased, but the relationship was not clear-cut. Differences on the reversed task between successive pairs of groups that had varied in the number of trials given on the standard task were significant in some cases, but not in others. Thus, from the Lewis study we would predict that changing the direction of movement of a control will result in positive transfer.

The method in the present study of defining the similarity between tasks simply in terms of the number of S-R connections changed from the first to the second task also has precedent, in an experiment by Crafts (1). He used card-sorting with nine boxes. The boxes were arranged in the same position for the first task for all subjects. After eight trials with the standard arrangement, the positions of 0 (control), 3, 6, or all 9 boxes were changed for different groups of subjects to provide a second task. Two trials were given on the second task. The results clearly showed that the increase in sorting time on the first trial of the second task was directly related to the number of boxes with changed positions; sorting time increased as formal similarity between tasks decreased. There was some evidence of interference in the group that had all nine boxes changed; their score on the first trial of the new task was slightly higher than on the first trial of the original task. Nevertheless, all groups would probably have shown positive transfer if more than two trials had been given on the second task; this is suggested by the very steep slopes of the curves between the points for these two trials. Hence, on the basis of Crafts' results we would expect that as formal similarity decreases, initial decrement in scores on the second task will increase, perhaps even to the point of interference.

It should be noted that the meaning of the term "formal similarity" in connection with Crafts' and our experiments differs from the way the term is used in verbal learning (7). In verbal learning, formal similarity is usually varied by changing some of the letters in stimulus or response words from list to list. Thus the results from such experiments are not directly relevant to the present research.

Finally, since all subjects in the present experiment relearned the second task after a 24-hour rest, we may ask what is the proactive effect of a first task on retention of the second. Knowledge of this effect has so far been derived from studies of verbal learning. It has been argued that to find proactive inhibition with verbal lists, inter-list similarity cannot be too low; the lists must be chosen so interference will occur (6). There is no way of knowing whether similarity, as it is defined in the present study, will produce actual interference between tasks, but if so, proactive inhibition should occur and should increase as degree of first-task learning increases, as Underwood has shown (6).

II. PROCEDURE

Apparatus: Before describing the apparatus in detail, the task provided by the apparatus will be summarized. The stimuli were lights of six different hues: red, green, blue, white, orange, and purple. These were presented automatically on the same ground-glass screen, one at a time. The subject responded to each stimulus by moving a lever, held by his right hand, into any one of six radially-arranged slots. Each light was paired with one slot. Moving the lever into the slot which was correct for the particular hue appearing on the screen extinguished that light and simultaneously the next stimulus appeared; this defines a correct response. If the lever was moved a short distance into any one of the five slots which were incorrect for the stimulus being presented, a shallow error was recorded. If the lever moved further into an incorrect slot, a deep error was also recorded. Thus, the apparatus provided a relatively simple self-paced discriminative motor task containing six paired associates. The task was made more complex by requiring the subject to hold another lever, grasped by the left hand, in a fixed position. A correct response, i.e., movement of the right-hand lever into a correct slot, was not recorded and the stimulus light remained the same as long as the left-hand lever was not being held in the correct position. Total correct responses, shallow errors, and deep errors were recorded for each trial on separate counters. A clock recorded the time per trial that the left-hand lever was held in correct position. Trials were 20 sec. in length and were separated by 10-sec. rests.

The apparatus will now be described in some detail. Fig. 1 shows a front view of the apparatus. Fig. 2 is a side view showing the subject in position. The complete wiring diagram is presented in Fig. 3. The description of the apparatus may be followed more easily by reference to these figures.

Two levers made from one-fourth in. steel rod projected vertically 8-1/2 in. above the top surface of a box 37 in. long, 16 in. wide, and 8-1/2 in. deep. The levers were topped by knobs and were 21 in. apart. The right-hand lever was centered in a circular opening, 1-1/2 in. diameter, cut in the center of a steel plate 16 in. square and one-fourth in. thick. The plate formed part of the top surface of the box.

Six slots, 3-1/4 in. long, .26 in. wide, and equally-spaced 60^{o} apart, led from the perimeter of the 1-1/2 in. hole in the plate. The lower end of the right-hand lever was connected to a ball and socket joint, thus it could be moved into any one of the six slots.

Each slot carried three microswitches which were tripped by moving the lever various distances into the slot. The first switch was one-half in. from the entrance of the slot; tripping this switch upon moving the lever

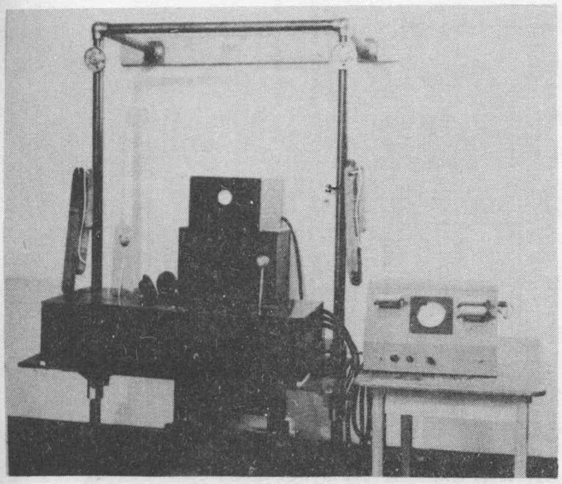

Fig. 1

Front view of the apparatus

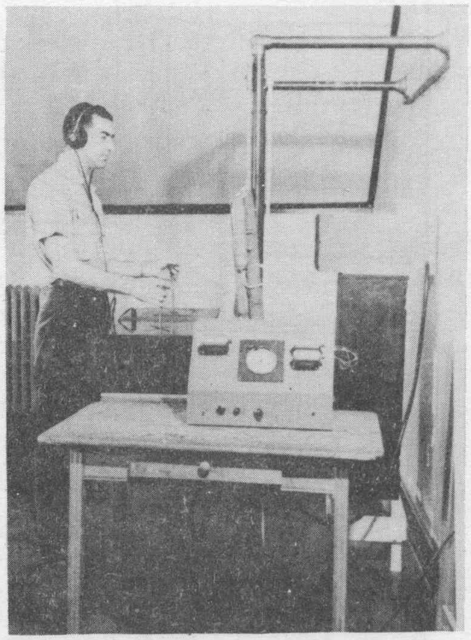

Fig. 2

Side view of the apparatus showing the subject in position

into an incorrect slot caused a shallow error to be recorded. Similarly, each slot carried a second switch, 2-1/2 in. from the entrance, which permitted recording deep errors. The third switch was at the far end of the slot; moving the lever all the way into a correct slot depressed this switch and a correct response was recorded. The error circuits were cut out for any slot whenever that slot was correct for the stimulus light showing. Correct responses and errors were recorded on Veeder-Root counters.

The left-hand lever was supported below the surface of the box by a rubber pad through which the lever passed. Mounted this way the lever could be moved in three dimensions. Attached to the lower end of the left lever was a small flexible spring which projected into a brass cup. Movements of the top of the lever of one-half in. or more in any direction except straight up made the spring touch the cup, breaking a circuit to a .01 sec. Standard Electric clock. The subject could not avoid holding the left lever steady by lifting straight up because the knob, which was fitted onto the lever by a sleeve, would come off. Thus, the left lever provided what was essentially a steadiness task. The clock recorded time whenever the lever was being held correctly.

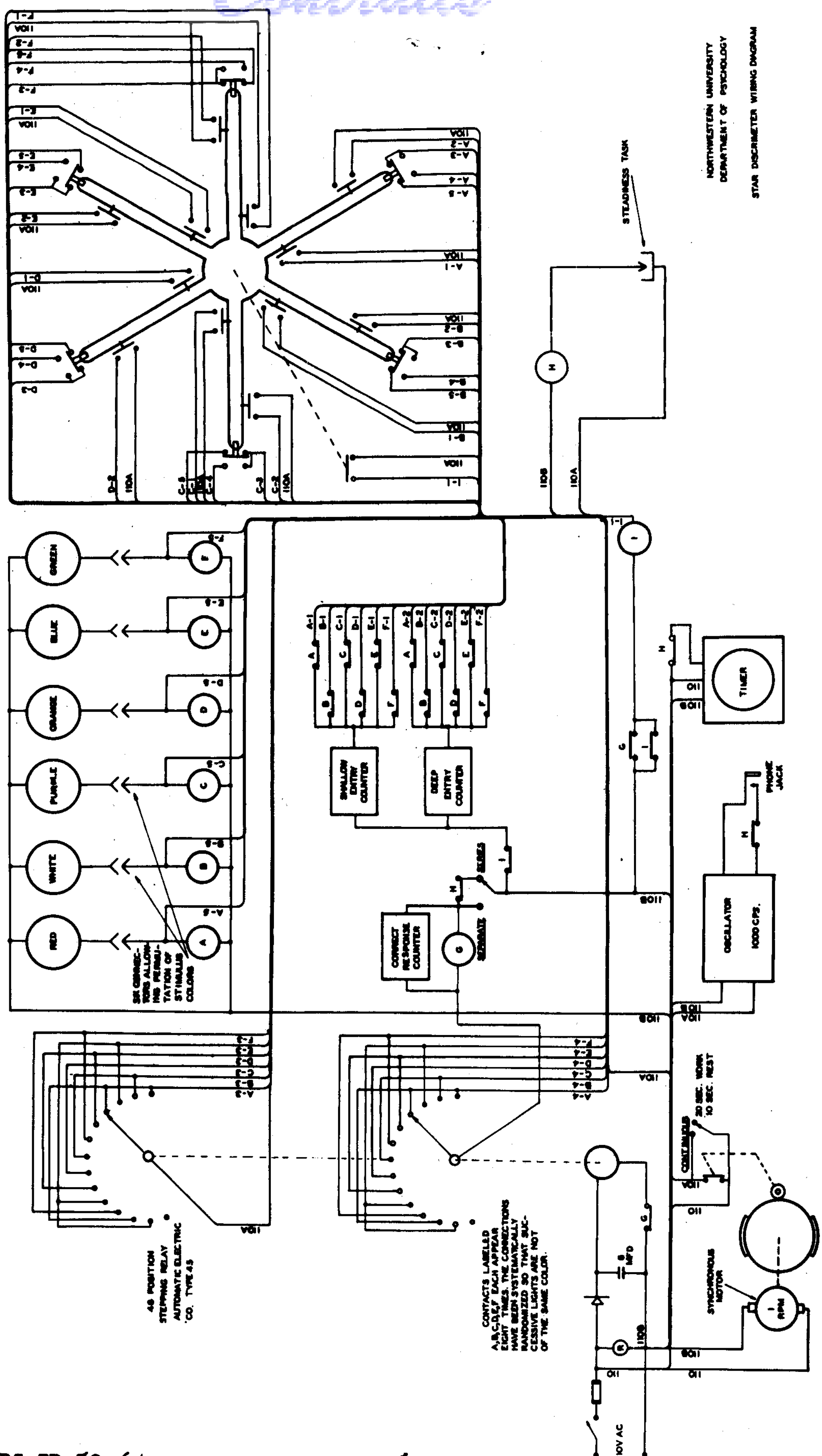

Fig. 2 Wiring diagram of the apparatus

If the lever was held incorrectly, i.e., if the spring was touching the brass cup, a circuit was completed to an ICA Model 4301 oscillator. The oscillator generated a 1000-cycle tone which was transmitted to the subject through earphones, thus informing him to correct the lever's position.

The left- and right-hand levers were connected by a circuit in such a way that correct responses were not recorded, if the left lever was out of position. At such times, depressing the correct-response microswitch at the end of a correct slot with the right-hand lever made the stimulus light flick off. But when the switch was released the same stimulus light came on again. Furthermore, a movement of the right lever sufficient to release the correct-response switch simultaneously depressed the deep-error switch. Since the deep error circuit was cut in even for a correct slot whenever the left lever was out of position, a deep error was recorded each time this switch was tripped. As soon as the left lever was returned to position, deep errors in the correct slot were no longer recorded, and depressing the correct-response switch once more with the right lever made the stimulus light change and a correct response was recorded. If desired, the circuit connecting the two levers could be cut out, making them independent.

The box containing the two levers rested on a table the height of which was adjustable by a system of pulleys and counter-weights. Thus, the height of the table could be adjusted for subjects of different heights.

The light sources for the stimuli were 50-watt projection bulbs arranged in a semicircle so that the light from each was projected onto the rear surface of the same ground-glass screen. The light from each bulb passed through a different gelatin filter, thus providing the six hues. The filters were made for the purpose and transmitted a fairly wide band of wavelengths; the brightnesses and saturations also undoubtedly varied. The six hues could easily be differentiated, however, even by subjects with some color-weakness.

The projection bulbs were contained in a box 18 in. long, 12 in. wide, and 9 in. high. Viewed from the subject's side, the stimulus box presented a black surface in the upper center of which was a circular opening 2-1/2 in. in diameter and covered by the ground-glass screen. The screen was 30 in. from the subject's eyes. The stimulus hues were seen by the subject as a diffuse color filling the whole screen.

The six stimuli were presented in eight different orders for a total sequence of 48. The same hue never appeared twice in succession. The sequence of lights was presented by means of a rotary switch with 48 positions. Even though some subjects went through the sequence many times there was no evidence of memorization.

A set of six telephone jacks permitted the experimenter to connect any stimulus light with any slot. Thus the lights could be paired with the slots in 720 different combinations and a new task could be provided for a subject within a few seconds.

A microswitch riding on a cam driven by a one rpm motor automatically timed the 20-sec. trials and 10-sec. inter-trial rests. If desired, the apparatus could also be set for continuous run.

Experimental Design: As stated in the introduction, the purpose of the experiment was to study transfer from a first to a second task as a function of two main variables, degree of learning of the first task, and similarity between tasks. There were four degrees of first-task learning and three degrees of inter-task similarity. All 12 combinations of these conditions were studied in a factorial design, shown diagrammatically in Table 1. As Table 1 indicates, there were 25 subjects in each of the 12 cells, 300 subjects in all. The notation that is used throughout the experiment is also shown in Table 1. The four groups, each containing 75 subjects, that had different amounts of practice on the first task are indicated by Roman numerals and will be called the Learning Groups.

Table 1 - The Design of the Experiment

Degree of first-task learning	Inter-task similarity		
	A(high)	B(medium)	C(low)
I (10 trials)	25	25	25
II (40 trials)	25	25	25
III (80 trials)	25	25	25
IV (180 trials)	25	25	25

The three groups, 100 subjects each, with different degrees of inter-task similarity, are denoted by capital letters and will be called the Similarity Groups. Each of the 12 subgroups can therefore be indicated by a numeral and a letter, e.g., IIB.

Table 1 shows the number of trials given each Learning Group on the first task. All subjects were given 60 trials on the second task. Twenty-four hours after the 60th trial on the second task all subjects were given 20 more trials on the second task to test for retention and relearning.

Table 2 shows the distribution of the several phases of the experiment over days. Note that in Groups II, III, and IV the last five trials on the first task were given immediately preceding the start of practice on the second task to eliminate forgetting over the last 24-hour rest.

The Tasks: With the apparatus used, the first task (or Task I) was defined as a particular pairing of the six lights with the six slots. The second task (or Task II) was defined as a different pairing of the lights and slots. Inter-task similarity was defined as the number (out of a possible six) of light-slot connections that were different during practice on the second task from what they had been on the first task. Subjects in condition A (high similarity)

Table 2 - Distribution of the Experiment Over Days. In the Table Under the Day Columns the Tasks Are Indicated by Roman Numerals, the Number of Trials by Arabic Numerals.

Group	Day 1	Day 2	Day 3	Day 4	Day 5
I	I(10), II(60)	II(20)			
II	I(1-35)	I(36-40), II(60)	II(20)		
III	I(1-40)	I(41-75)	I(76-80), II(60)	II(20)	
IV	I(1-60)	I(61-120)	I(121-175)	I(176-180), II(60)	II(20)

had two of the lights connected to different slots for the second task, therefore the other four lights remained connected to the same slots throughout both tasks. A "2-change" thus defines the second task for subjects in Similarity Group A. Subjects in condition B (medium similarity) had four of the lights paired with different slots ("4-change") for their second task, the other two remaining the same. In condition C (low similarity) all six lights ("6-change") were connected to different slots.

Although it was assumed that any one of the 720 combinations of the six lights with the six slots would be equally difficult to learn, only 25 of the combinations, chosen so that among the 25 each light was connected to each slot an approximately equal number of times, were used for Task I. Each subject within a subgroup of 25 subjects was assigned a different one of these combinations before practice began on the first task.

For each of the 25 combinations used for the first task, three other combinations were made up for use on the second task. One of these was a 2-change, one a 4-change, and one a 6-change from the Task I combination. Thus, each Task I combination had associated with it three other combinations representing the three degrees of similarity. In choosing the three Task II combinations for each Task I combination, wherever possible one of the other 24 Task I combinations was used. Thus, the Task II combination for any one subject might be a combination used by a different subject on Task I. We shall therefore assume that for the purposes of this experiment the two tasks were not only equal in difficulty but were in a sense identical.

Because of this assumption, separate control groups were not run. Instead, some of the Task I data were used to construct control curves both for learning and relearning of the second task.

<u>Controls</u>: The control curve for the learning of the second task was constructed from the data of Groups III and IV on the first task. These were the only groups given at least 60 trials on Task I, the number of trials given during original learning of Task II. This control curve (N = 150) will be shown on all graphs presented in the results showing acquisition of the second task.

The control curve for retention and relearning of the second task after 24 hours came from the data of Group IV (N = 75) on trials 61-80 of Task I. It can be seen in Table 2 that Group IV had a 24-hour rest between trials 60 and 61 on the first task. Since their first 60 trials were not preceded by practice on a different task, the data for their trials 61-80 serve as a control for proactive effects of the first task on retention of the second.

<u>Subjects and Method</u>: The subjects were 300 males from the introductory psychology classes at Northwestern University, assigned randomly to the 12 subgroups. They were rewarded with one point of examination credit for each day served in the experiment. In addition, they were told that the experiment was being done for the Air Force. From the subjects' comments it appeared that motivation was high.

When the subjects first appeared for the experiment, they were questioned concerning color-blindness. Whatever the reply, each was tested for ability to name the six stimulus hues as they were presented in the stimulus window. This color naming was continued until the experimenter was satisfied that the subject could easily discriminate the lights. Some of the subjects said they were color-blind, but if they could name the six hues they were used. One subject was rejected for inability to discriminate the lights.

Following the color naming, the subject was asked to take his place in front of the apparatus with his hands on the levers. Then the height of the table carrying the apparatus was adjusted until the tops of the levers were approximately one in. below his elbow height. Since the subjects stood up for all practice trials, this height seemed to be the least fatiguing.

The next step was to instruct the subject on the nature of the problem, the apparatus, and what he had to do. A rather lengthy set of instructions had been worked out in a pilot experiment. The gist of the instructions was as follows: The subject was told the experiment was a study in transfer of training and division of attention. Transfer was explained briefly by illustrations concerning driving one kind of car or flying one kind of airplane after having learned on a different kind. Division of attention was explained by pointing out to the subject that he could not turn off stimulus lights by movements of the right-hand lever unless the left-hand lever was being held in the correct position. The subject then put on the earphones and listened to the sound he would hear if the left-hand lever was being held incorrectly. The subject was told that he was to learn, by moving the right-hand lever into the slots, which light was connected to which slot, but it was emphasized that this was not sufficient; he was to turn off as many lights as possible during the 20-sec. trials. He was informed that during the 10-sec. rest period he would be told how many correct responses he had made, i.e., how many lights he had turned off during the previous trial.

During the 10 sec. between trials, the subject remained in position at the apparatus with his hands on the levers and the earphones on. After every block of 20 trials (on the same task) a three-min. rest was given during which the subject took off the earphones, sat down, and was permitted to smoke and talk.

When the subjects returned on subsequent days, they were told that the lights and slots were paired in the same way as before. Upon completion of the required number of trials on the first task, the subject was given a two-min. rest while the light-slot connections were being changed for his second task. The subject was then instructed that 2, or 4, or all 6 of the lights, depending on the similarity condition, were now connected to different slots, and practice was started on the second task.

III. RESULTS

The First Task

Reliability: An odd-even reliability coefficient based upon all 300 subjects was obtained by using only the first 10 trials. The two scores for each subject were the total correct responses on the five odd and on the five even trials. The obtained coefficient was .790, corrected to .883.

Another odd-even coefficient was computed from the first 40 trials, where the available *N* was 225. The scores were the total correct responses for the 20 odd and for the 20 even trials. The uncorrected coefficient was .965. Since most of the findings to be presented are based upon correct responses per trial, reliability coefficients were not computed for the other response measures. The coefficients obtained indicate sufficient reliability to permit group comparisons.

Acquisition: Since we are concerned in this report only with transfer effects on the second task, the data for acquisition of the first task are not presented in detail. It is necessary, however, to demonstrate the adequacy of matching of groups on Task I learning. This was done by performing a simple analysis of variance on the first 10 trials, which permits comparison of all 12 subgroups (25 subjects each). Each subject's score was the total correct responses on all 10 trials. Homogeneity of variance was determined by Bartlett's (2) test; the obtained chi-square was 1.92. Since chi-square for 11 df (degrees of freedom) is 19.68 at the 5% level, the variances are homogeneous. Upon analysis the variance within groups (149.62) was found to be larger than the variance between groups (108.06), thus the subgroups appear to be adequately matched.

The three subgroups within each of the four Learning Groups were also compared for adequacy of matching by four separate analyses of variance. For each of the analyses the score used was the total correct responses for all trials given that particular Learning Group on the first task. The obtained F's were less than one in Groups I, II, and III. In Group IV, F was 2.69, based on 2 and 72 df. Since F at the 5% level for 2 and 80 df is 3.11, the matching of the three subgroups within each of the Learning Groups was satisfactory.

Table 3 shows several measures of mastery at or near the end of practice on the first task. The values in the table for Group I are based on trials nine and 10, the last two trials. For the other three groups the values

Table 3 - Levels of Mastery at the End of Practice on the First Task for All Response Measures in the Learning Groups. See Text for Trials Used to Compute Values.

Group	Correct Responses per Trial	Total Errors per Trial	Steadiness Time per Trial(sec.)
I	4.63	22.91	9.67
II	9.85	12.39	12.61
III	12.99	7.83	14.42
IV	14.94	8.96	14.94
Grand Mean*	11.66	11.28	13.48

*Weighted because Group I values are based on only two trials are based on the five trials preceding the last five trials. These are trials 31-35 for Group II, 71-75 for Group III, and 171-175 for Group IV. It will be recalled that the last five trials for these groups were given after a 24-hour rest, immediately preceding the start of practice on the second task. Since there was some forgetting over the 24-hour rest, means based on the last five trials would be lower than those reported in Table 3 and would therefore not represent accurately the level of mastery attained. Table 3 also shows, in the bottom row, the grand mean for each response measure when all groups are combined.

The values given in Table 3 are those used to measure gains or losses in transferring from the first to the second task, and will be shown on the various graphs depicting acquisition of Task II.

Acquisition of The Second Task

Transfer in Terms of Correct Responses: The acquisition curves for the second task for the four Learning Groups are shown in Figs. 4-7, where correct responses per trial are plotted as a function of pairs of successive trials. Each graph includes the curves for the three Similarity Groups, labeled A, B, and C. The control curve is repeated in each figure. There is a single heavy point to the left of the break in the abscissa in each figure which shows the level reached by that particular Learning Group at the end of practice on the first task. The values for these points were obtained from Table 3.

Let us first inspect the control curve shown in Figs. 4-7. The curve shows a sudden rise from the 11th to the 12th abscissa points (trials 21-22 and 23-24), and both a drop and a rise from the 20th to 22nd points (trials 39-40 to 43-44). The drop is due to forgetting over the 24-hour rest given to Group III between the 40th and 41st trials on the first task. The rises are probably indirectly due to the rests. (It will be recalled that in addition to the 24-hour rests a three-min. rest was given after each block of 20 trials throughout the experiment.) Although we shall not present the data, there was some evidence that these rests had a complex effect; occasionally there was some forgetting, or loss of set, indicated by a slight drop in score on the trial immediately following the rest. However, on the second trial after rest there frequently was a gain (reminiscence?) larger than had been made on any previous trial; there was not only recovery from the loss but a rise to a considerably higher (relatively) level of mastery.

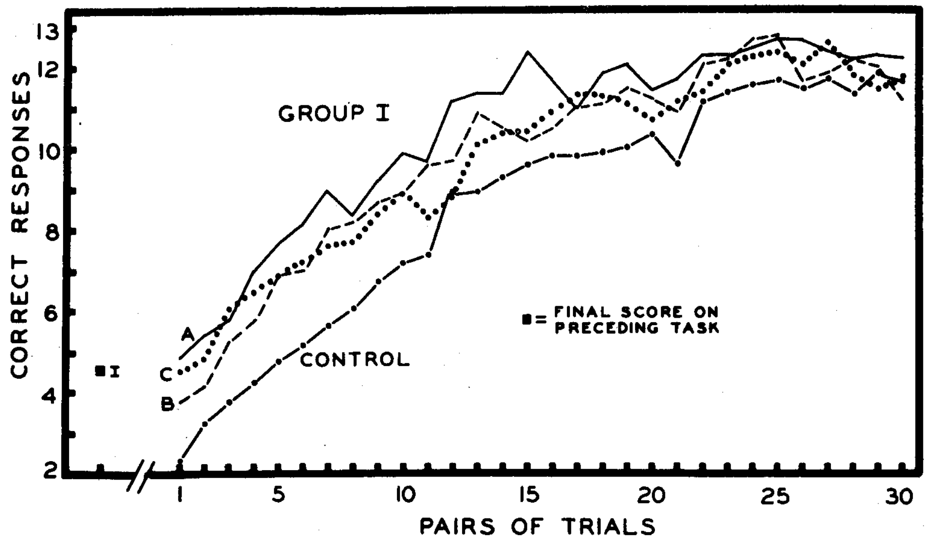

Fig. 4: Transfer to the second task for the group given 10 trials on the first task. See text for further explanation of this and the following three figures.

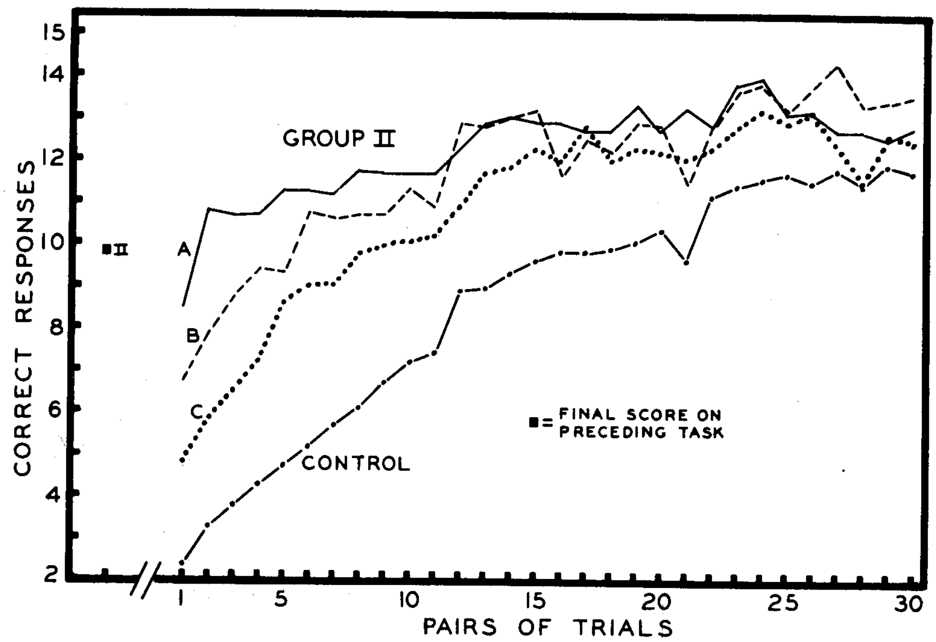

Fig. 5: Transfer to the second task for the group given 40 trials on the first task.

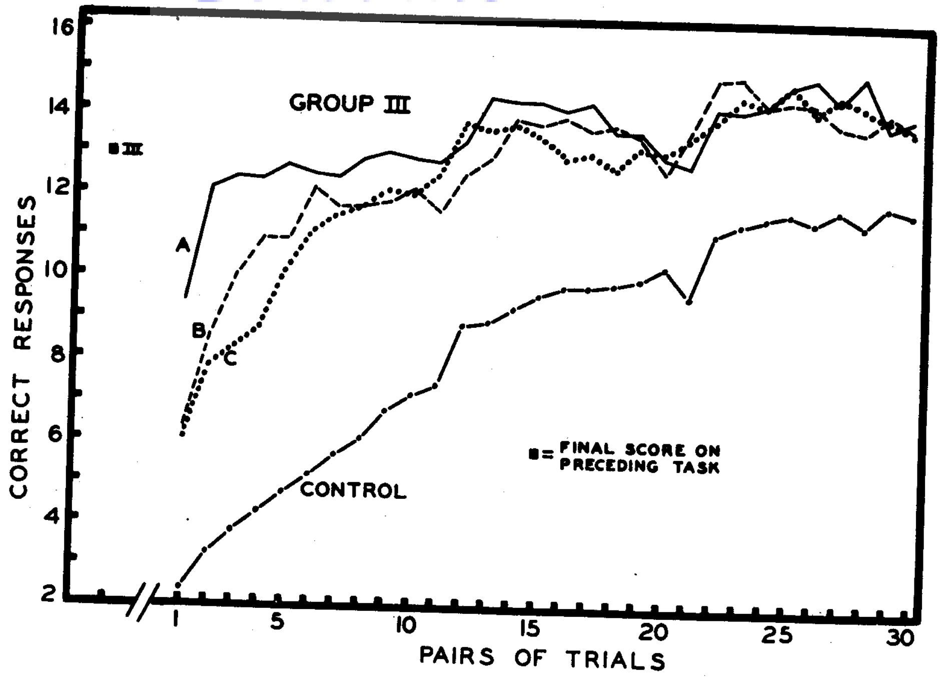

Fig. 6: Transfer to the second task for the group given 80 trials on the first task.

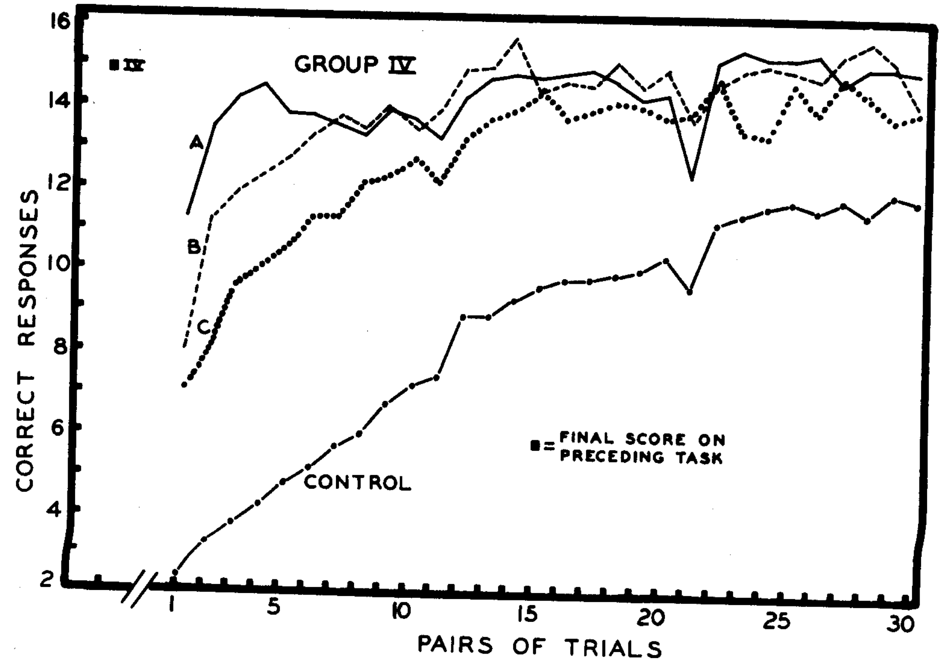

Fig. 7: Transfer to the second task for the group given 180 trials on the first task.

The transfer indicated by the curves for the experimental groups in Figs. 4-7 is much the same in kind, although varying in amount. Except in Group I, there was considerable initial decrement at the beginning of practice, shown by the drop from the end of Task I to the beginning of Task II. As is indicated by the relative positions of the curves labeled A, B, and C, the initial decrement was greater as the two tasks were made more dissimilar. The one exception to this is in Group I where subgroups B and C are reversed. The decrement was relative only since the score was higher on the first pair of trials in all 12 experimental groups than the control score at that point.

A clearer picture of the initial decrement may be obtained from Fig. 8, where the initial loss in correct responses on the second task is plotted as a function of trials on the first task. The values of points on the curves were computed by subtracting the mean of the last two trials on Task I from the mean of the first two trials on Task II, thus a loss is shown by a minus value. Since the measure of first-task learning used for Fig. 8 was the

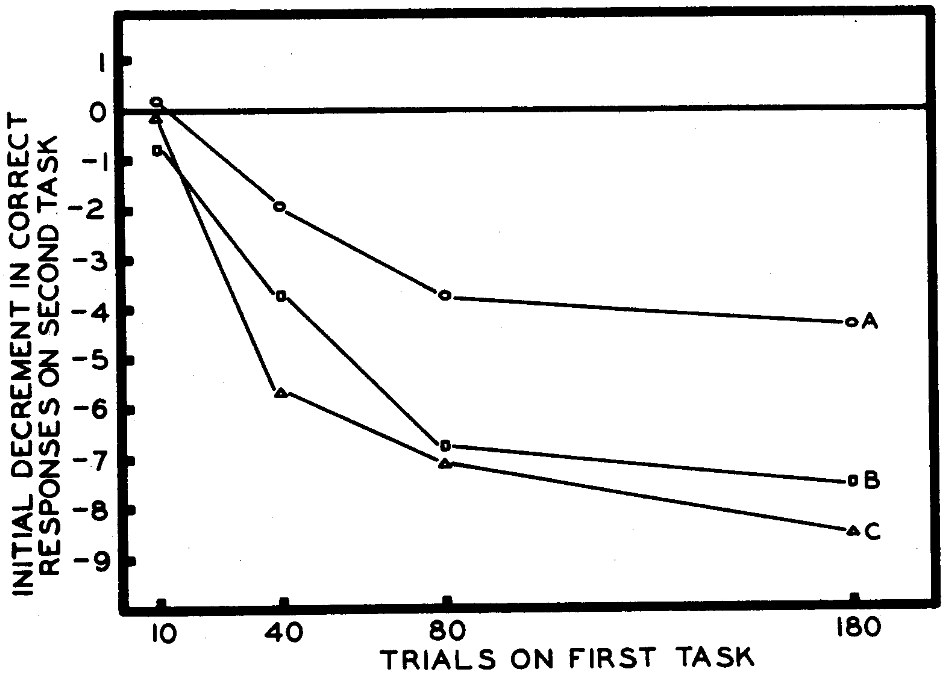

Fig. 8: Initial decrement on the second task measured as the difference between the mean of the last two trials on the first task and the mean of the first two trials on the second task.

mean of the last two trials, the amount of decrement shown for 40, 80, and 180 trials differs slightly from what would be obtained directly from Figs. 5, 6, and 7.

Fig. 8 shows that initial loss is a negatively accelerated decreasing function of degree of first-task learning. The curves for the three Similarity Groups show that the decrement increased as inter-task similarity decreased. It should be noted that we are dealing only with initial decrement. Other measures, such as total decrement, could be obtained and would vary as a function of both degree of first-task learning and inter-task similarity, but they will not be considered here.

Returning to Figs. 4-7, we see that, regardless of initial decrement, the overall transfer effect was positive; all 12 subgroup curves are clearly above the control curve. Even for Group I (Fig. 4) the control curve rises to one or another of the experimental curves at only three out of the 30 abscissa points. The positive transfer increased as degree of first-task learning increased, shown by the successively greater gains of the experimental-group curves over the control curve from Group I to Group IV. Although the graph is not presented here, positive transfer, measured as the average gain of the experimental groups over the control group, is a negatively accelerated increasing function of degree of first-task learning. A rough picture of this relationship may be obtained by comparing the average heights of the curves in Fig. 9 below.

Figs. 9 and 10 are summary graphs obtained by combining the experimental-group curves from Figs. 4-7 in two different ways. In Fig. 9 the three Similarity Groups have been combined within each of the four Learning Groups to show the effect on the second task of different degrees of learning of the first task when inter-task similarity is held constant. In Fig. 10 the four Learning Groups have been combined for each of the three degrees of similarity. The curves in Fig. 10 show, therefore, the effect of varying inter-task similarity when degree of first-task learning is constant. The control curve is repeated in both Figs. 9 and 10 and both graphs include heavy points to the left of the abscissa break representing level of mastery at the end of the first task. In Fig. 10 this heavy point is the weighted grand mean for correct responses reported in Table 3.

It may be seen in Figs. 9 and 10 that the curves for the two main variables, degree of first-task learning and inter-task similarity, are all above the control curve, except for the last two points on the Group I curve. No test of significance between experimental groups and control

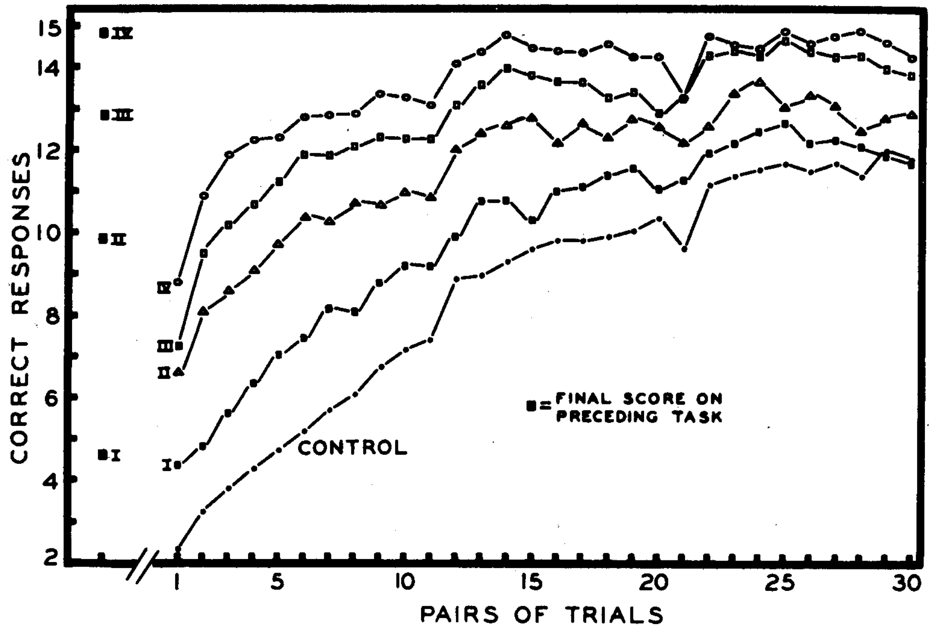

Fig. 9: Transfer to the second task for the four groups having different degrees of learning on the first task. Inter-task similarity is held constant.

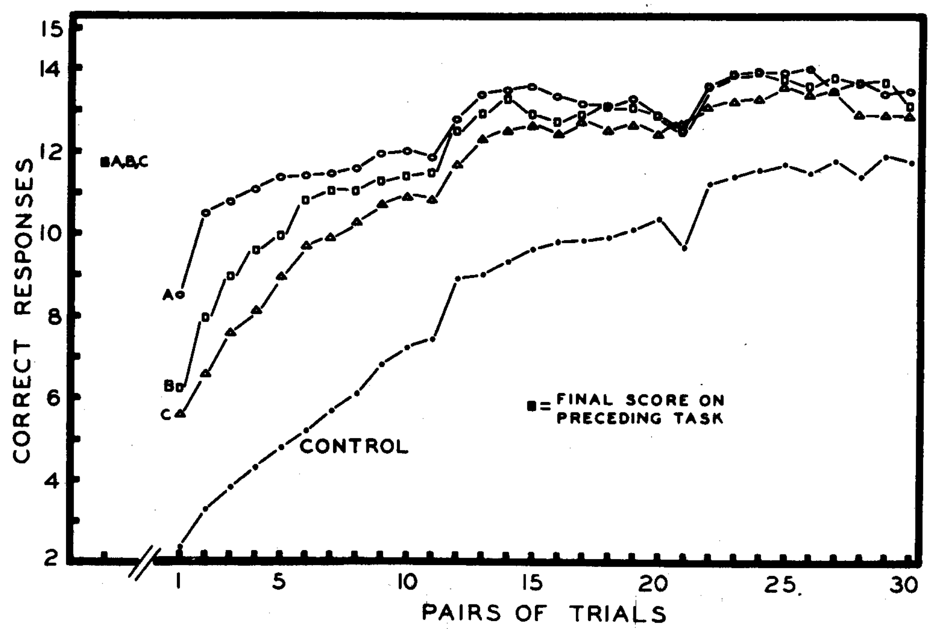

Fig. 10: Transfer to the second task for the three groups having different degrees of inter-task similarity. Degree of first-task learning is held constant.

appears necessary; it can be concluded that all experimental groups showed overall positive transfer. Put differently, transfer from the first task to the second task was positive for all degrees of first-task learning and for all degrees of inter-task similarity. Inspection of Figs. 9 and 10 shows, however, that positive transfer varied in amount as a function of both variables. We wish to know whether these differences among experimental groups are significant and whether there is interaction between the two main variables.

Double classification analysis of variance was used to test for significance of differences. The score used for each subject in the analysis was the total correct responses on all 60 trials of Task II. First, homogeneity of variance among the 12 subgroups was examined. The obtained chi-square was 7.56. Since chi-square at the 5% level is 19.68 for 11 *df*, the variances are sufficiently homogeneous to permit analysis.

A summary of the variance analysis is presented in Table 4. Interaction of degree of learning and similarity is not significant; the variance within groups was therefore used as error to test the main effects. The *F* values show that both degree of first-task learning and inter-task similarity are highly significant; significant differences in positive transfer occurred among the experimental groups.

Table 4 - Analysis of Variance on the Total Correct Responses for All 60 Trials on the Second Task

Source	df	Variance	F
Learning	3	693,260.89	39.40
Similarity	2	123,939.03	7.04
L x S	6	7,786.30	
Within groups	287	17,593.61	

F = 3.88 at the 1% level, 2.65 at the 5% level, for 3 and 200 *df*

F = 4.71 at the 1% level, 3.04 at the 5% level, for 2 and 200 *df*

The analysis of variance just presented, utilizing as it does the total score for all 60 trials, tends to mask possible changes in the effectiveness of the two variables over the course of practice. For example, an examination of Fig. 9 appears to show that differential mastery of Task I was effective throughout all trials on Task II; the curves for the four Learning Groups continue to be fairly well separated to the termination of practice. This does not seem to be true for similarity; in Fig. 10 the curves for the three Similarity Groups converge and begin overlapping considerably from approximately trial 30 onward. Perhaps the degree-of-learning variable had an effect which lasted later in practice than did the effect of the similarity variable. This possibility was tested by performing separate analyses of variance, one on the total correct responses for the first 30 trials, and one on the last 30 trials, of Task II. This division of the 60 trials into first 30 and last 30 has no theoretical basis; it was merely chosen arbitrarily from inspection of Figs. 9 and 10.

It was first demonstrated that the variances of the 12 subgroups on the first 30 trials were sufficiently homogeneous to permit analysis; the chi-square was 4.59 with 11 _df_. It was merely assumed, without testing, that homogeneity of variance also obtained for the last 30 trials.

We shall not present the summary tables for these two variance analyses. For both, the _df_, and thus the _F_'s required for significance at the 1% and 5% levels, are the same as those given in Table 4. Analysis of the first 30 trials showed that first-task learning was highly significant ($F = 60.89$), inter-task similarity was highly significant ($F = 17.26$), and interaction not significant. For the last 30 trials analysis showed learning to be highly significant ($F = 18.25$), similarity not significant ($F = 1.11$), and interaction not significant. Thus, these analyses demonstrate that the greater positive transfer produced by higher degrees of first-task learning extended later in practice on the second task than did the greater positive transfer produced by greater inter-task similarity.

Transfer in Terms of Errors: It will be recalled that the apparatus was built to permit recording of both partial entries of the right-hand lever into incorrect slots (shallow errors), and complete entries (deep errors). Deep errors were also recorded whenever the right-hand lever was in the correct slot but the left-hand lever was out of position. At such times relatively small movements of the right-hand lever were sufficient to depress the deep-error microswitch at the far end of the correct slot. The stimulus light flicked off momentarily and a deep error was recorded. Thus, the subject could record several deep errors while the right-hand lever was in the correct slot, as long as the left-hand lever was being held incorrectly. This means that the deep-error count is not a very useful measure, since it is impossible to partial out those errors made by traversing completely an incorrect slot from those made while in the correct slot.

A difficulty with recording shallow errors was also encountered. It was possible for the subject to move the right-hand lever just far enough into an incorrect slot to depress the shallow-error microswitch once and record one error. However, if he moved the lever slightly farther into the slot, he would record another shallow error as the lever again tripped the switch on the way out.

Because of these difficulties, no detailed analysis of the error data was made. Instead, shallow and deep errors were simply combined to give a total error count. Figs. 11 and 12 are summary graphs, comparable in method of plotting to Figs. 9 and 10, in which total errors per trial are shown for trials on the second task. Fig. 11 shows the four Learning Groups, where Similarity Groups are combined, and Fig. 12 shows the three Similarity Groups, where Learning Groups are combined. Both graphs show the control curve (the first 60 trials of Groups III and IV on Task I), and the points, taken from Table 3, showing the level reached at the end of practice on Task I. Note that in Fig. 11 these points for Groups III and IV are reversed; the reason for this is unknown.

In Figs. 11 and 12 the control curve does not begin to drop until after the sixth trial because, although the subjects had begun to learn which slot was connected with which light, they made many deep errors with the right-hand lever in correct slots due to insufficient mastery of the left-hand task. This initial increase in errors in the control curve, plus a slightly smaller rate of decrease than the experimental groups, results in the control curve being above the experimental curves for most of the trials. Thus, although the error curves may not be too reliable for the reasons cited above, they also show positive transfer. And again, Figs. 11 and 12 show that the positive transfer is a direct function of both degree of first-task learning and inter-task similarity.

The error curves, like those for correct responses, show that there was considerable initial decrement, again measured as the difference between the final level reached

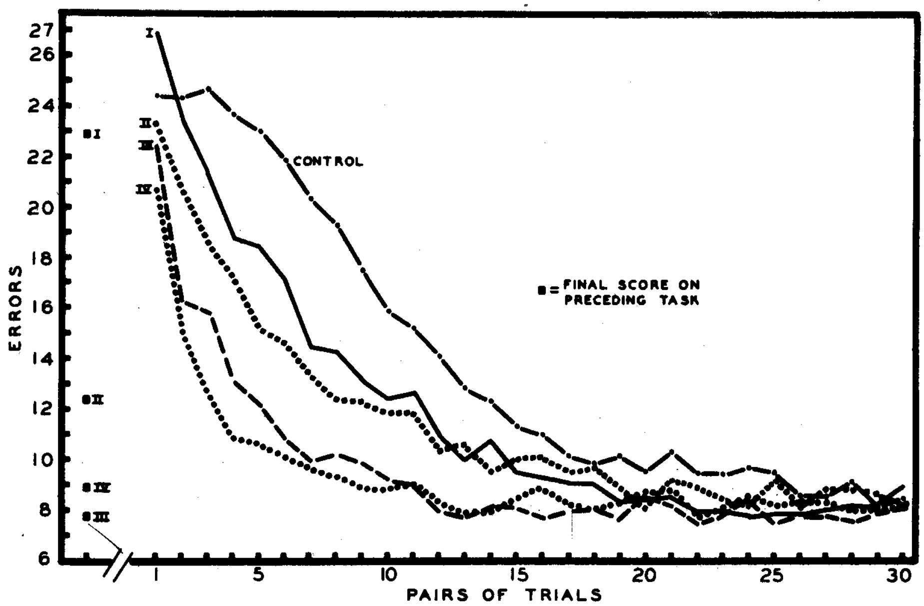

Fig. 11: Transfer to the second task in terms of total errors for the four groups having different degrees of learning on the first task. Inter-task similarity is held constant.

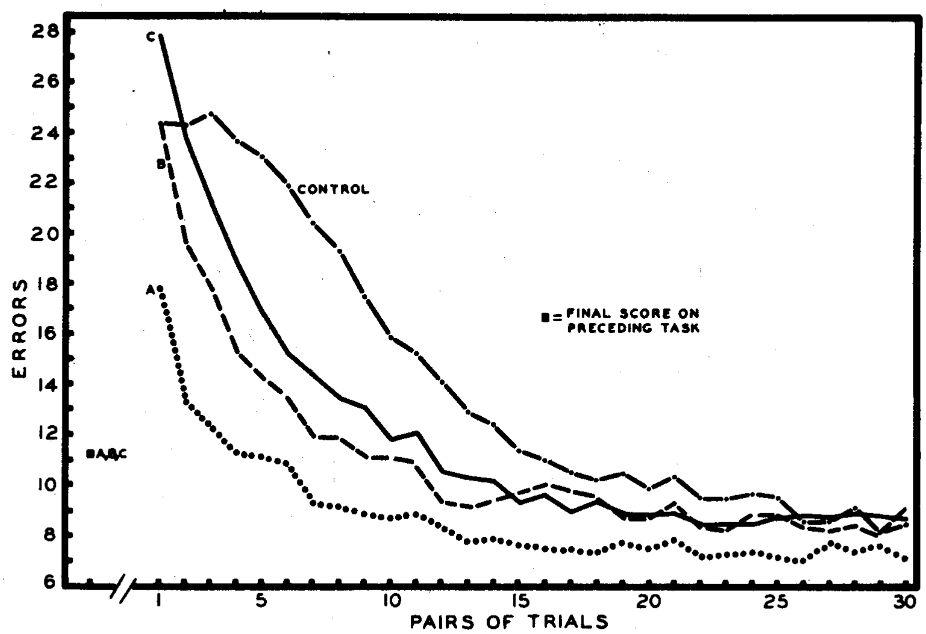

Fig. 12: Transfer to the second task in terms of total errors for the three groups having different degrees of inter-task similarity. Degree of first-task learning is held constant.

on the preceding task and the initial point on the second task. However, whereas in Group I there was little evidence of loss in terms of correct responses (Fig. 9), the corresponding error graph, Fig. 11, shows decrement for all four Learning Groups. Finally, the error graphs show two cases of interference; both Learning Group I and Similarity Group C made more errors on the first two trials than the control group.

The Left-Hand Task: The subject's task with the left-hand lever remained the same throughout all phases of the experiment, viz., to hold the lever steady in the vertical position. The effect this might have on transfer will be discussed later. It does not seem necessary, however, to present detailed data for the left-hand task. The one graph presented, Fig. 13, shows the time in seconds per trial on the second task for the four Learning Groups, similarity held constant. Again, there is a control curve shown on the graph and the points, taken from Table 3, showing the level

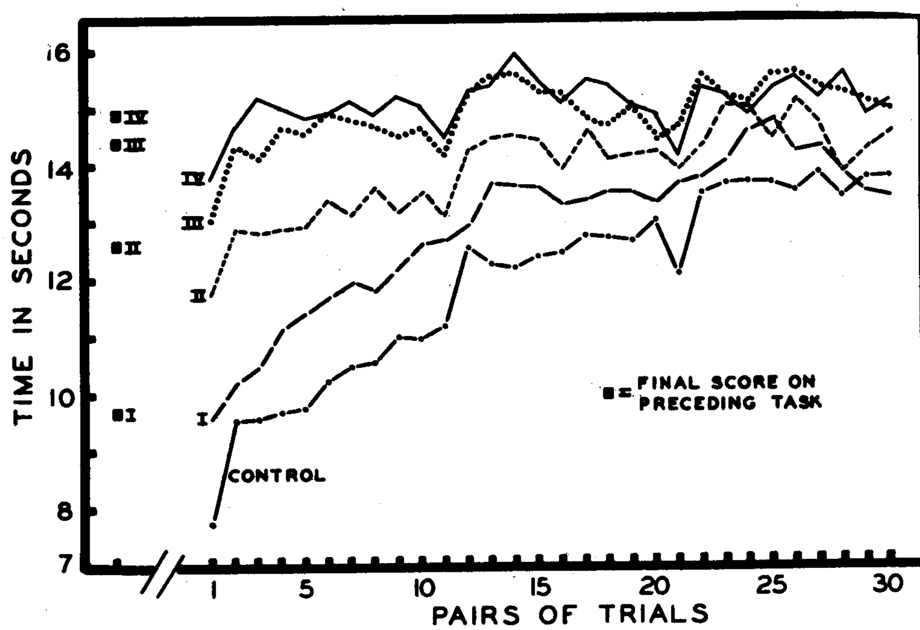

Fig. 13: The time in seconds per trial that the left-hand lever was held in the correct position during learning of the second task for the four groups having different degrees of learning on the first task. Inter-task similarity is held constant. Maximum score is 20 seconds.

reached on the first task. Fig. 13 shows that there was some loss in the time score, at least in Groups II, III, and IV, at the beginning of Task II practice. However, the loss was regained by the fourth or fifth trial. Thus the decrement demonstrated by using correct responses or errors as measures, since it lasted much later in practice than the fifth trial, was not due merely to loss of skill with the left-hand lever. It also may be seen in Fig. 13 that Groups I and II, and perhaps to some extent Group III, continued to improve in steadiness throughout practice on the second task.

Retention of the Second Task

All of the original 60 trials given on the second task were run on one day. On the following day all subjects returned for another 20 trials on the second task. The results of the retention test are shown in Figs. 14 and 15. In these graphs correct responses per trial are plotted as a function of individual trials for the various experimental groups and a control. Again, Fig. 14 shows the four Learning Groups, inter-task similarity held constant, and Fig. 15 shows the three Similarity Groups, degree of first-task learning held constant.

Both Figs. 14 and 15 include points, to the left of the break in the abscissa, showing the level of performance at the end of practice on the preceding day. These points are the means of the last 10 trials (trials 51-60) for all groups. If we take the difference between these means and the scores on the first trial on the following day for all groups, we have a measure of forgetting. The actual values of these differences are shown in Table 5.

It is immediately apparent from Figs. 14 and 15 that all groups show forgetting. Table 5 shows that the amount of forgetting was much the same for all groups. Since the value for the control differs from the value for any of the experimental groups by less than one correct response, no tests of significance between experimental groups and control are considered necessary. We conclude that there is no evidence for proactive inhibition in the experimental groups.

Although the experimental groups do not differ from the control in amount forgotten, there are differences among the experimental groups themselves. These differences are also fractional, but the amount forgotten increased, without reversal, as degree of first-task learning increased

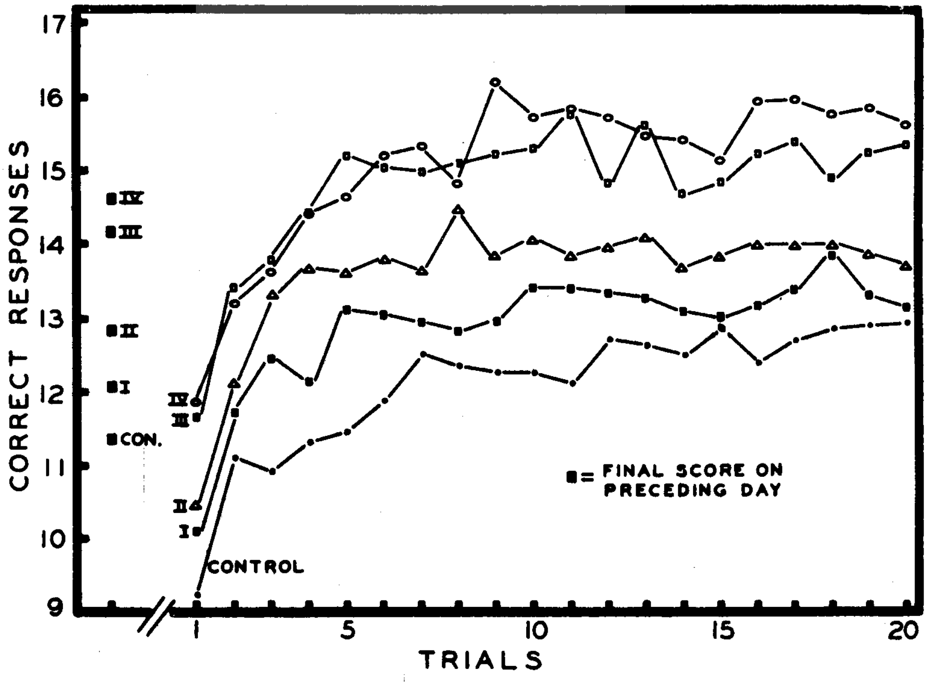

Fig. 14: Relearning of the second task after a 24-hour rest for the four groups having different degrees of learning of the first task. Inter-task similarity is held constant.

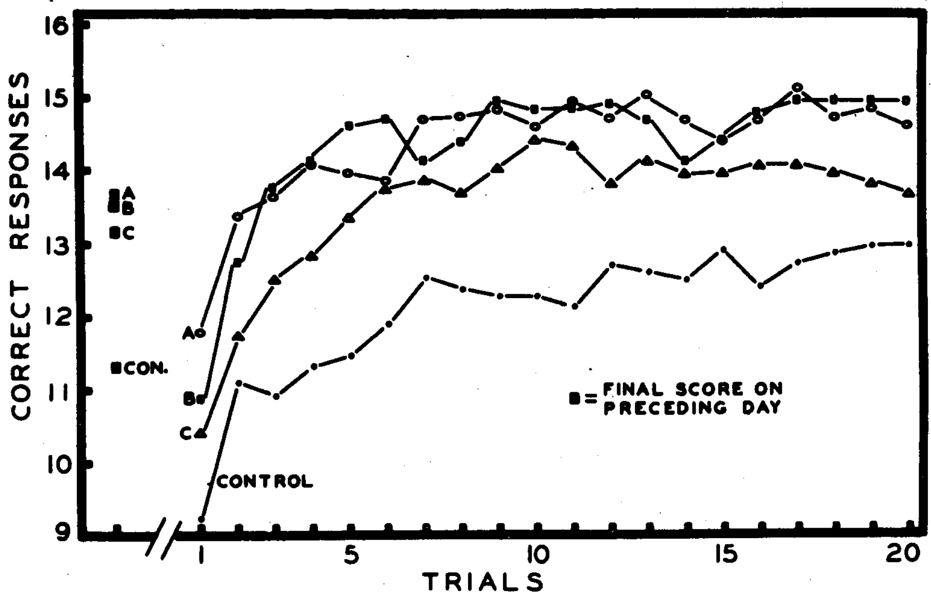

Fig. 15: Relearning of the second task after a 24-hour rest for the three groups having different degrees of similarity between the first and second tasks. Degree of first-task learning is held constant.

Table 5 - Forgetting over a 24-Hour Rest Measured as the Difference Between the Mean Correct Responses on the Last 10 Trials Before Rest and the Mean on the First Trial After Rest

Learning Groups	Mean score before rest	Mean score after rest	Difference
I	12.05	10.12	1.93
II	12.94	10.49	2.45
III	14.18	11.69	2.49
IV	14.66	11.87	2.79
Similarity Groups			
A	13.64	11.80	1.84
B	13.59	10.89	2.70
C	13.15	10.44	2.71
Control Group	11.32	9.25	2.07

and as similarity of tasks decreased. Because of the consistency of these trends, they were tested for significance by analysis of variance. In the analysis the score for each subject was the difference in correct responses between the mean of the last 10 trials before rest and the score on the first trial after rest. The analysis of variance is summarized in Table 6.

In Table 6 the interaction variance is not significant; we may therefore use the variance within groups to test the main effects. The variance table shows that neither degree of first-task learning nor inter-task similarity is significant. The conclusion is that initial forgetting of the second task after a 24-hour rest did not vary with either of the two main variables.

Returning to Figs. 14 and 15, it appears that, although initial forgetting did not vary from group to group, there was some tendency for relearning to proceed more slowly in

Table 6 - Analysis of Variance on the Difference Scores Used to Measure Forgetting of the Second Task Over a 24-Hour Rest

Source	df	Variance	F
Learning	3	8.82	
Similarity	2	26.49	1.93
L x S	6	24.09	1.76
Within groups	287	13.71	

F = 2.14 at the 5% level for 6 and 200 *df*

F = 3.04 at the 5% level for 2 and 200 *df*

low than in high degrees of first-task learning or in high than in low degrees of similarity. No detailed analysis will be made to determine if this is a reliable effect. A rough measure of the rate of relearning for each group may be obtained by noting the trial on which the group again reached or first exceeded the level of mastery it had attained at the end of practice on the preceding day. Thus, from Fig. 14 these trials are Nos. 3, 3, 4, and 5 for Group I through IV respectively, and from Fig. 15, trials 3, 3, and 5 for Groups A through C.

The most clear-cut effect shown in Figs. 14 and 15 is the continued superiority of all of the experimental groups over the control. Again, no test for statistical significance is deemed necessary; we conclude that the facilitating effect on the second task of practice on the first task continued after a 24-hour rest and that this is true for all degrees of inter-task similarity. We therefore find proactive facilitation, rather than proactive inhibition, for all conditions.

Finally, let us inspect the differences among the curves for the various experimental groups in Figs. 14 and 15. When these curves are compared to those showing acquisition of the second task (Figs. 9 and 10), it appears that the relative heights of the curves are not the same in all cases after rest as they were before rest. Group IV may be more clearly superior to Group III during original learning of Task II (Fig. 9) than throughout the 20 retention trials (Fig. 14). More clear-cut changes, however, have occurred among the three Similarity Groups. The A, B, and C curves overlap considerably for approximately the last 30 trials on the second task (Fig. 10), and it was shown that the three groups were not significantly different in total score for those trials. During relearning, however, Group C was below Groups A and B on all trials (Fig. 15).

Differences among experimental groups were tested for significance by analysis of variance on the total score for all 20 relearning trials. The summary table for this analysis is presented in Table 7.

Table 7 shows that degree of first-task learning continued to be a significant variable during relearning; the *F* ratio of 13.24 is significant at less than the 1% level. The Similarity Groups are also significantly different, since the *F* ratio of 4.00 lies between the values required for significance at the 5% and 1% levels. Thus, after a 24-hour rest, similarity has again become a differentiating variable. No *t*-tests were run between pairs of Similarity Groups because it seems clear from Fig. 15 that it is Group C (least similarity) whose curve is relatively depressed.

Although it was found that the Similarity Groups did not differ significantly among themselves over the last

Table 7 - Analysis of Variance on the Total Score for the 20 Relearning Trials on the Second Task

Source	df	Variance	F
Learning	3	31,715.26	13.24
Similarity	2	9,585.27	4.00
L x S	6	2,006.03	
Within groups	287	2,394.53	

F = 3.88 at the 1% level for 3 and 200 *df*

F = 4.71 at the 1% level, 3.04 at the 5% level, for 2 and 200 *df*

30 trials of original practice on the second task ($F = 1.11$), it can be seen in Fig. 10 that, whereas Groups A and B overlap considerably, Group C is slightly lower for 13 out of the last 15 abscissa points. The mean scores over these 30 trials are: Group A, 13.45, Group B, 13.36, and Group C, 12.97. It can also be seen, by comparing the heavy points to the left of the abscissa break in Fig. 15, that Group C was relatively lower than Groups A and B on the last 10 trials of the second task. Thus, although the slight inferiority of Group C was not statistically reliable it apparently had a significant effect on relearning after a 24-hour rest.

Corroborative information on the relatively greater effect of the least similar condition was sought by analyzing separately the shallow errors and the deep errors for both learning and relearning of the second task, and the adequacy of the matching of the Similarity Groups at the end of practice on the first task was checked. These analyses provided no clue toward explaining the lower levels of mastery attained by Group C. We can only conclude that the three degrees of inter-task similarity were not equally spaced; there was a greater difference between low and medium similarity than between medium and high similarity.

IV. DISCUSSION

The most striking result of the present study was the large amount of positive transfer obtained. Every degree of first-task learning facilitated acquisition of the second task, and the facilitation occurred for every variation of inter-task similarity. The findings of Lewis, McAllister, and Adams (4) were therefore corroborated; when the stimuli remain the same from task to task and the direction of movement involved in the responses is changed, positive transfer results.

It is believed that the finding of positive transfer both in this experiment and in that by Lewis et al is further support for that portion of the theory of transfer based on response generalization. In a recent elaboration of the theory Underwood (8) has argued that response generalization is responsible for the positive transfer typically found in learning a second paired-associate verbal list whose stimuli are identical with, and responses similar to, those of the first list. Since he has presented the theory in some detail, it will merely be summarized here. The basic assumption of the theory is that reinforcement of a response during learning of the first task or list simultaneously results in some strengthening of similar (generalized) responses. It is also assumed that there is a gradient of response generalization; the more similar responses are to the reinforced response the more they are strengthened. Thus, as a result of the "parasitic" reinforcement of generalized responses during practice on the first task, there will be some tendency to make the responses of the second task even before practice begins. The result is that learning of the second task is facilitated.

Since the defining condition of identical stimuli for the two tasks was met both in this and the Lewis study, it is only necessary, for subsuming all the results under the theory, to show that in both experiments the responses of the two tasks were similar. Although it cannot be demonstrated conclusively, it seems reasonable to assume that response similarity was present. In both experiments the responses on the first task consisted of moving one or more manipulanda in various planes of space. On the second task both the type of response and the manipulanda remained the same, only the direction of movement required for each stimulus was different. Gagne, Baker, and Foster (3) have specifically assumed that direction of movement is one of the ways responses can vary in similarity. Perhaps, although the authors do not say so, there would even be sufficient similarity between responses differing by 180 degrees in direction of movement for generalization to occur. In any case, it is believed that response generalization underlies the positive transfer found both in this experiment and in the one by Lewis, McAllister, and Adams.

In the study by Underwood (8) referred to above, it was further shown that, as predicted, positive transfer, and therefore, presumably, response generalization, increased as degree of first-task learning increased. In the Lewis study there was only partial support for this finding, but the present study corroborated it clearly.

At the same time, there was another source of positive transfer in both of these studies, that which results from "learning-how-to-learn" (5). It has been observed many times that there is a practice effect in learning successive samples of the same or similar material (see 5 and 7 for discussions of this topic). Learning-how-to-learn almost certainly occurred both in this and the Lewis study, since the subjects were naive to the tasks. One might even assume that learning-how-to-learn is more important in a more complex task (such as the Mashburn) than in a task of less complexity. There should be greater opportunity in a more complex task for the kinds of improvement usually assumed to result from learning-how-to-learn, adjustment to the situation, discovery of correct methods, etc.

In this same connection it should be repeated that in the present experiment the subject's task with the left-hand lever remained the same at all times, i.e., to hold the lever steady. Since correct responses with the right-hand lever could not be made unless the left lever was being held steady, we may have a specific case where learning-how-to-learn was required. The differences in positive transfer resulting from different degrees of first-task learning, shown in Fig. 9, were probably due in part to differences in skill with the left-hand lever, shown in Fig. 13.

Since learning-how-to-learn was not controlled in either this or the Lewis study, we cannot know how much it contributed to positive transfer and how much was due to response generalization. However, learning-how-to-learn was probably not the only source of positive transfer, since in Underwood's experiment with verbal lists (8), where it was controlled, considerable positive transfer resulted from response generalization alone.

Variation of the formal similarity between the two tasks in the present study was accomplished by varying the number of stimuli and responses newly paired on the second task. The result was much the same as that found by Crafts (1) when he changed the positions of various numbers of boxes in card sorting; as similarity decreased, positive transfer decreased. However, in the present experiment there was no evidence for interference when the measure was number of correct responses; as Fig. 10 shows, even the group practicing the least similar task (Group C) was well above the control on all trials. It is true that there was some interference, as may be seen in the error curve of Group C in Fig. 12, but it did not extend beyond the third trial.

No claim will be made here that finding transfer to vary as a function of the number of changed S-R connections is support for Thorndike's theory of transfer of identical elements (5). Superficially, the results seem to fit in well with the theory; if an S-R connection, as it is used here, is what Thorndike meant by an "element", then it is true that positive transfer increased as the number of identical elements increased. However, there has never been much agreement as to what is an element (5), so it will not be maintained here that the results support the theory.

It does seem important to emphasize the precise effect upon transfer of varying the number of changed S-R connections; within the limits of such variation obtainable here, transfer varied directly with the number of S-R connections changed. This relationship between transfer and the mere number of S-R pairs held for all degrees of first-task learning; there was no evidence of interaction between the learning and similarity variables either during acquisition or retention of the second task. There is no *a priori* reason why this should be true. Without evidence to the contrary, one could just as easily assume that in a complex task, where a high level of performance depends upon integration of several functionally interrelated components, changing even a few components would disrupt the integrated performance as severely as changing several components. That this did not occur in the present experiment lends some justification to attempts to analyze even complex tasks in terms of specific stimuli and responses.

When the second task was tested for retention 24 hours after the acquisition session, all groups showed some forgetting. However, there was no evidence for proactive inhibition from the first task; there was no difference in amount forgotten either between experimental groups and control or among experimental groups themselves. It seems likely that the reason the first task did not inhibit retention of the second was the almost complete lack of interference between the tasks. It has been argued that to find proactive inhibition with verbal lists, it is necessary that the lists be such that interference between them will occur when they are learned successively (6). If this argument may be applied to the present tasks, no proactive inhibition was found because little or no interference occurred. Evidence for the lack of interference is the finding that all experimental groups scored higher, in terms of correct responses, on the first trial of the second task than the control. Also, in terms of total errors, only Learning Group I and Similarity Group C made more errors than the control at the beginning of second-task practice, and then not beyond the third trial.

The major finding during relearning of the second task was that the rank order of the experimental groups was much the same as it was during acquisition; the levels of mastery continued to vary directly with both degree of first-task learning and inter-task similarity. The important exception occurred in the group practicing the least similar task, whose relearning curve was depressed relative to the high and medium similarity groups. Since the Similarity Groups had not differed significantly during the latter half of the acquisition trials on the previous day, an attempt was made to account for the difference during relearning by further analyses of the data. Nothing of much help was found. It could only be pointed out that, in spite of the lack of statistical significance, the group practicing the least similar task may not actually have reached as high a level of mastery as the other Similarity Groups at the end of the acquisition session. Even if such a difference did exist, it is not known why the difference was magnified, to the point of attaining statistical significance, during relearning.

V. IMPLICATIONS FOR TRAINING AND EQUIPMENT DESIGN

Due to rapid advances in engineering methods, complex equipment undergoes frequent modification in design. Rarely are the changes such that the basic function of a particular piece of equipment, and therefore the equipment itself, disappears. Much more frequently, the equipment remains fundamentally the same, at least in a qualitative sense, while changes are continually made to increase efficiency, modify the level of complexity, etc. Not infrequently such design changes require the human operator to master a skill somewhat different from that required before the change in design. Assuming that the level of difficulty of the skill remains the same, the findings of the present experiment may have certain implications for psychological problems resulting from such redesigned equipment, especially with regard to training human operators on the equipment. Within the limits of the apparatus used in the present study, the following suggestions may be made.

If the equipment is such that skilled performance can result only from the simultaneous manipulation of two or more controls, even a few changes in direction of control movement, with the visual display unchanged, are likely to result in a sudden decrement in performance. However, even on equipment where all of the responses are different, with regard to direction of movement in the horizontal plane, the operator who has been trained on the previous pattern of responses will immediately perform better than the untrained operator. This initial superiority of the trained over the untrained operator will decrease as the number of new responses increases, but these performance differences will disappear, at least temporarily, after a medium amount of training on the new equipment. The important thing to note is that the superiority on the new equipment of the operator trained on the old continues, with the result that less training will be necessary for the practiced operator to achieve mastery. In short, it is suggested that if necessary changes in equipment design can be made similar to the kind of change used in the present experiment, it will be more efficient to retrain those who have operated the original equipment than to train new personnel.

At the time redesigned equipment is introduced for general use, it may happen that among the personnel using the older equipment there will be those who have just begun training, those who are partly trained, and those who are highly skilled operators. The question arises as to what may be expected when such different groups are trained on the new equipment. The answer, again within the limits of the present study, is that even a little amount of training on the old equipment will facilitate the attainment of mastery on the new. More importantly, the greater the time spent operating the old equipment, the greater will be the facilitation of training on the new. This increasing facilitation will obtain regardless of whether the change in design requires a few or many new responses, insofar as such responses consist of variations in the direction of movement of a control. Furthermore, unlike the relatively temporary differences in performance resulting from variation in the number of new responses, performance differences due to amount of previous training may continue late in training on the new equipment. It can be said, then, that when personnel must be trained on redesigned equipment, it will be advantageous if training has been given on the equipment before the design change, and the greater the previous training, the greater the advantage.

When training on the new equipment is resumed after a rest, the results will be much the same. Previous training on the old equipment will continue to facilitate performance in comparison to the performance of previously untrained personnel, and the facilitation will continue to be greater for those who had had greater amounts of previous training. It may also be expected that the advantage of previous practice will continue to obtain regardless of the number of newly-required responses, again with the cautionary note that the present experiment does not permit predictions concerning equipment changes other than those studied.

VI. CONCLUSIONS

1. When the responses consisted of various directions of movement in the horizontal plane, positive transfer was obtained on a task defined as the differently-connected stimuli and responses of the original task.

2. Positive transfer increased as degree of learning of the original task increased.

3. As the number of stimuli and responses newly-connected on the second task increased (decreased formal similarity between the tasks), positive transfer decreased. Even when all of the stimuli and responses of the first task were differently paired on the second task, positive transfer was obtained for all degrees of learning of the first task.

4. Differential positive transfer resulting from different degrees of first-task learning was obtained throughout the entire course of acquisition of the second task. Differential positive transfer resulting from variation in inter-task similarity occurred only during the first half of the practice trials on the second task.

5. After the second task had been practiced to a high level of mastery, 24 hours without practice resulted in some forgetting. The forgetting did not vary with either first-task learning or inter-task similarity, nor was it attributable to the presence of these variables.

6. During relearning of the second task, performance was facilitated by, and continued to vary directly with, practice on the first task. Facilitation of performance during relearning also occurred for all variations of inter-task similarity, but was significantly less for the least-similar task.

VII. BIBLIOGRAPHY

1. Crafts, L. W. Transfer as related to number of common elements. J. gen. Psychol., 1935, 13, 147-158.

2. Edwards, A. L. Experimental design in psychological research. New York: Rinehart & Co., 1950.

3. Gagne, R. M., Baker, K. E., and Foster, H. On the relation between similarity and transfer of training in the learning of discriminative motor tasks. Psychol. Rev., 1950, 57, 67-79.

4. Lewis, D., McAllister, D. E., and Adams, J. A. Facilitation and interference in performance on the modified Mashburn apparatus: I. The effects of varying the amount of original learning. J. exp. Psychol., 1951, 41, 247-260.

5. McGeoch, J. A. The psychology of human learning. New York: Longmans, Green, 1942.

6. Underwood, B. J. Proactive inhibition as a function of time and degree of prior learning. J. exp. Psychol., 1949, 39, 24-34.

7. Underwood, B. J. Experimental psychology. New York: Appelton-Century-Crofts, 1949.

8. Underwood, B. J. Associative transfer in verbal learning as a function of response similarity and degree of first-list learning. J. exp. Psychol., 1951, 42, 44-53.