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INFLUENCE OF FIRST TASK PRACTICE AND INTERTASK SIMILARITY ON TRANSFER OF TRAINING IN A SYMBOL SUBSTITUTION TASK

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FOREWORD

This report represents a portion of the basic research program of the Technical Training Branch, Training Research Division of the Behavioral Sciences Laboratory, Aerospace Medical Research Laboratories. The report was prepared under Project 7183, "Psychological Research on Human Performance," Task 718306, "Research on Human Learning and Related Methodology."

The experiment was conducted several years ago under Contract AF 33 (038)5474 with the Ohio State University Research Foundation. Dr. Delos D. Wickens was the Principal Investigator for the contract, and Dr. Armand N. Chambers supervised the collection of the data. The research was planned by Dr. Marvin Levine and Dr. Ross L. Morgan. The final manuscript was prepared by Mr. Alan Neiberg, with assistance from Dr. Morgan and Dr. Levine.

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This technical report has been reviewed and is approved.

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ABSTRACT

This experiment investigated the effects of degree of learning of a first task and degree of similarity between two tasks on the transfer of training from the first to the second task. The basic relationship between the two tasks was such that learning the first might well interfere with learning the second. Twelve groups of 15 college students learned a symbol substitution task to one of four levels of mastery. They were then transferred to a task where the symbols in task I were rearranged to permit three degrees of intertask similarity. Extensive and persistent negative transfer was obtained. During the initial stages of learning task II, negative transfer seemed to decrease as the degree of learning of task I increased. However, during the later stages of task II, negative transfer seemed to increase with an increase in the degree of learning of the first task, especially with the higher degrees of learning of task I. The intertask similarity variable appeared to be significant only during the early stages of learning the second task. These findings differ from previous findings in the extent and persistence of negative transfer and in the tendency for it to increase with higher degrees of first task mastery. The present findings question the generality of existing transfer principles derived from slowly paced tasks involving relatively few discrete stimuli and responses.

SECTION I

INTRODUCTION

From both a practical and a theoretical standpoint, transfer of training is one of the most important aspects of human learning. Educational programs, almost without exception, have their foundations in the premise that knowledge accrued in one situation can be applied to performance in a different situation. A major problem is to determine what factors govern the transfer from one situation to another. The present research is relevant to this problem.

The formal discipline approach to education, perhaps the predominant approach until about 1930, was based on a belief in the very broad transfer of mental skills. It was thought that intellectual ability developed through intellectual exercise could be used in performing mental feats much the same as muscular ability developed through physical exercise can be applied to many physical tasks. With this approach, a student studied Latin, Greek, and mathematics, not because they were valuable in their own right, but because they exercised the basic mental faculties and thereby made the student more adept at any subsequent intellectual task.

Thorndike and his associates at Columbia University were among the first to question the formal discipline approach and to systematically investigate the conditions that influence transfer from one situation to another (ref 1). He formulated the concept of identical elements, ie, transfer is dependent upon identical response elements in the two situations. Thus, learning to drive an automobile facilitates learning to fly an airplane because some of the responses present in airplane flying are also present in automobile handling. According to Thorndike's view, the amount of transfer is a direct function of the number of identical behavioral elements in the two tasks.

Thorndike's concept of identical elements has been further elaborated and refined. Many studies of the influence of intertask similarity on transfer of training have been made. The relationship between transfer of training and intertask similarity has been summarized in graphic form by Underwood (ref 2).

Diagrams such as figure 1 are useful, but they do not cover all cases. In continuous tasks, for example, it is difficult to isolate discrete stimulus and response units. This inability makes it difficult to predict transfer among continuous tasks using diagrams such as figure 1. Relationships such as those pictured in figure 1 have been derived primarily from research using tasks that have discrete stimuli and responses. For example, in verbal learning, the stimulus might be the appearance of a word in the left window of a memory drum, and the response might be the subject's pronunciation of the word that will appear in the right window (pronouncing the word before it appears).

Another significant aspect of the tasks used in much research on transfer of training is that they are relatively slow paced. For example, in verbal learning tasks, the subject is allowed some time, usually 2 seconds, to make an overt

response. This may seem like a very short time, but during this time, a practiced subject can consider several responses and select one. The events ensuing in the 2 seconds are not measured. This is not true with either a continuous task, or a subject paced task, where the measurement taken is the amount of work per unit time. Where these measures are employed, any delay on the part of the subject influences his score. Thus, scores from continuous tasks or subject-paced tasks may be more sensitive to transfer effects than scores on more slowly paced tasks. For this reason, some of the principles of transfer derived from slowly paced, discrete stimulus and response tasks, as in figure 1, may not be applicable to all types of tasks.

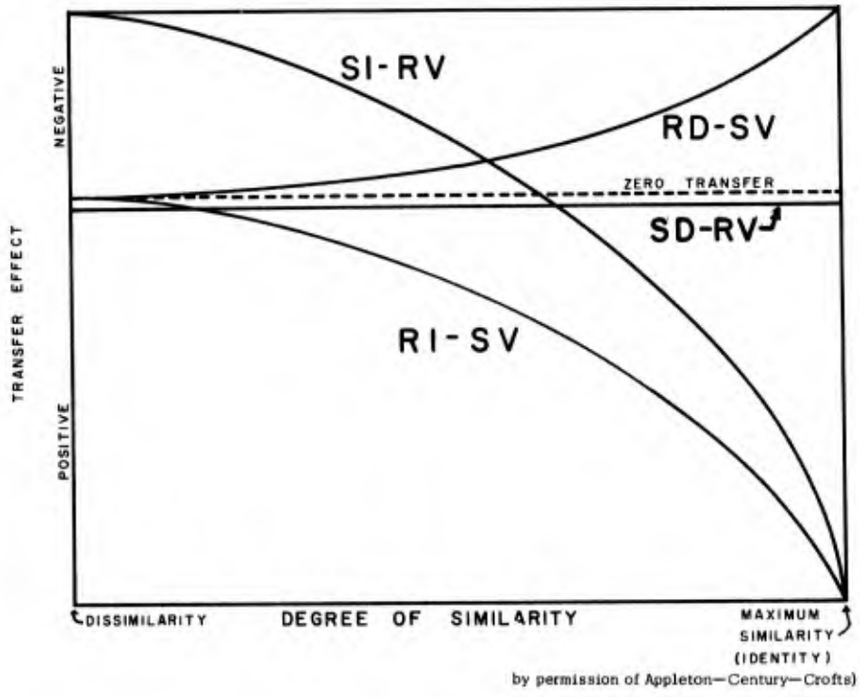

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Figure 1. Theoretical Relationship Between Similarity and Transfer of Training (after Underwood, ref 2)

SI-RV: Hold the stimuli identical in both tasks and vary the degree of similarity of the responses.

RI-SV: Hold the responses identical and vary the degree of similarity of the stimuli.

RD-SV: Make the responses markedly different and vary the similarity of the stimuli.

SD-RV: Make the stimuli completely different and vary the similarity of the responses.

The degree to which the subject has mastered the first task is another important variable in transfer studies. When the degree of first task mastery has been considered, Underwood (ref 2) and McGeoch and Irion (ref 4) agree that the conditions yielding negative transfer do so only when the first task is learned to a low level of mastery. When the first task is mastered at a high level, positive transfer probably will be obtained. In a negative transfer situation, then, as first task mastery increases, there will be initial negative transfer followed by positive transfer. Most data on this problem, however, have been obtained with relatively simple discrete stimulus-response tasks where the subject is given some time between the presentation of the stimulus and the demand for the response.[1]

The present experiment represents an effort to obtain data on the effect of first task mastery and intertask similarity on the transfer of training between learning tasks that are subject paced.

SECTION II

EXPERIMENTAL MATERIALS

A symbol substitution task was employed as an example of a subject-paced learning task. The experimental materials were bound into booklets, a typical page of which appears as figure 2.

At the top of the page is the key, sixteen letters associated with sixteen symbols. The rest of the page contains these symbols randomly distributed across eight rows but without the associated letters. The subject's task was to write the appropriate letter in the space beneath each symbol. There were two sets of such pages. The first constituted the materials for the training task and varied in the number of pages, depending upon the amount of training that the subject was to receive. The other set constituted the materials for the transfer task and always contained eight pages. Other pages in the booklet consisted of test and instruction pages. A test page presented symbols as in figure 2, without the key. Single test pages were placed first after the pages for the training task and again after the pages for the transfer task. The instruction pages contained directions for the succeeding portions of the experiment, and were placed before the training task test page, again before the transfer task pages, and finally before the transfer task test page. The total

1. Although the present experiment is no exception, in most experiments on transfer of training, the total transfer to the second situation is the sum of both specific and nonspecific transfer between the two tasks. Theoretical analyses usually consider only that transfer which is based on specific stimulus and response relationships and neglect nonspecific factors such as warm-up, learning how-to-learn, set, etc. Usually nonspecific transfer is positive and may well cover considerable interference or negative transfer based on specific stimulus-response relationships.

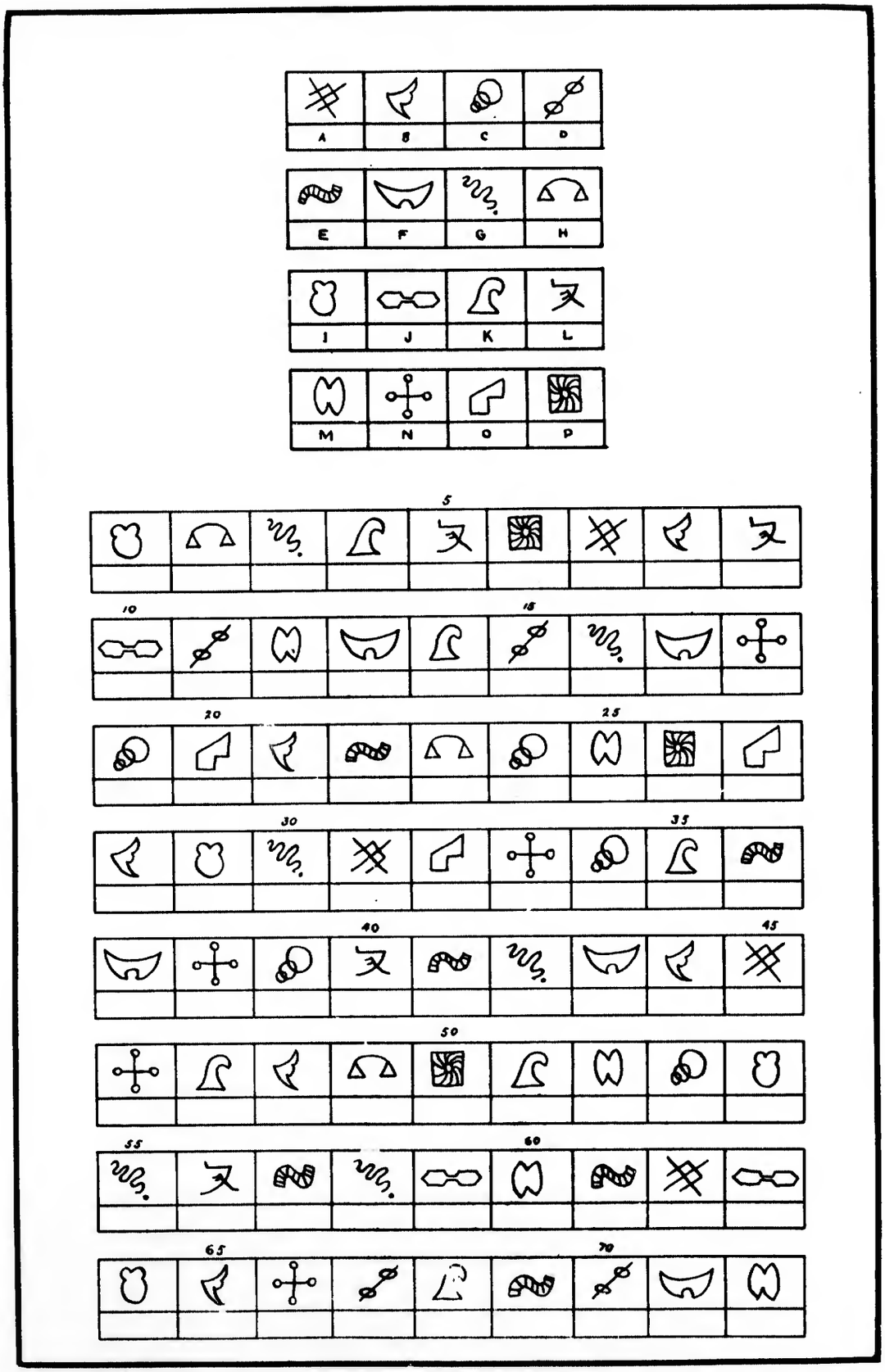

Figure 2. A Typical Page of Symbols Employed During Each Task.

number of pages in the booklet varied with the length of the training task. The letter symbol associations in each key depended on whether the page was for the training or transfer task, and the degree of similarity between the tasks.

SECTION III

DESIGN

The experiment was designed to investigate two variables: the amount of practice on the training task and the degree of similarity between the training and transfer task when the change between the tasks involved rearranging the symbols and letters in the key. The experimental design is represented in table I.

TABLE I

EXPERIMENTAL DESIGN

INTERTASK SIMILARITY	SUBJECT GROUP	PERIOD OF TASK I PRACTICE			
		2 min	4 min	8 min	16 min
	Group A (High)	15	15	15	15
	Group B (Medium)	15	15	15	15
	Group C (Low)	15	15	15	15

As this table shows, 180 subjects were distributed equally over four degrees of practice on the training task and three degrees of similarity. The varying degrees of similarity were obtained by varying the number of spaces across which symbols in the key were shifted for the transfer task. For group A, all the symbols were shifted one space; for group B, half the symbols were shifted one space, and half the symbols were shifted two spaces; for group C, all the symbols were shifted two spaces. For all degrees of change, any two symbols that were adjacent in task I were not adjacent in task II.

Although task I and task II used identical letters and symbols, the assignment of letters to symbols differed in the two tasks. Since some letter-symbol associations might be easier to learn than others, each of the two sets of letter-symbol associations for a given condition was used as task I for about half of the subjects and as task II for the remaining subjects. This potential factor was not perfectly counterbalanced (ie, about half rather than exactly half) because subjects had to be discarded in order to match the groups. Precise matching was considered much more important than perfect counterbalancing of any slight difference in difficulty of sets of letter-symbol associations.

All subjects received both the training and the transfer tasks. It is customary in transfer of training research to ask the question, "How does the performance of the experimental groups on the transfer task compare with the performance of a group which has had no training?" That is, "How much has the training augmented (or interfered with) performance on the transfer task?" To answer this question, usually a control group, which receives no training, performs the transfer task alone. However, no special control group was run in this experiment. Because of the general likeness of tasks I and II, performance scores from task I served as a control comparison to the data collected in task II.

SECTION IV

PROCEDURE

There were 180 college students that took part during the experiment and approximately 30 subjects performed during each session. All the subjects at any one session received the same degree of training, but all three degrees of similarity were administered during every session. Each subject received a booklet. The experiment was started by having the subject read the instruction page preceding task I. He was then given 1 1/2 minutes to practice on a demonstration task, the purpose of which was to show what the task was like. The demonstration task involved the same letters and symbols used in task I and task II, but the letter symbol associations were different. Task I was then performed for the preassigned periods of 2, 4, 8, or 16 minutes. The test of task I was then presented for 1 minute. This was followed immediately by task II, which was always 10 minutes in length. A 1-minute test of task II was performed and this concluded the experiment. Except for the 16-minute group, no rests were given except to read the instructions before the tests and before task II. Reading the instructions required about 1 minute. The 16-minute group was given a 2-minute rest after the eighth minute of training.

The subjects were instructed to make the letter responses as rapidly and accurately as possible and to learn the associations. They were further directed to cross out the symbol on which they were working whenever the experimenter called "mark." The experimenter announced the work "mark" every 30 seconds during the tasks. This procedure yielded a record of the number of letter responses per 30 seconds and provided a means for comparing the groups.

SECTION V

RESULTS

PERFORMANCE DURING TASK I

A greater number of subjects per cell were run than were required so that the groups could be matched on the basis of their performance during the first 2 minutes of task I. The means and standard deviations of the groups during the first 2 minutes of performance are shown in table II. An analysis of variance of the data during this portion of the experiment yields a between-groups F and an interaction F of less than 1, indicating that no reliable differences existed between the groups.

TABLE II

MEAN NUMBER OF SYMBOLS SUBSTITUTED ($\bar{x}$) AND THE STANDARD DEVIATIONS FOR EACH GROUP DURING THE FIRST TWO MINUTES OF TASK I.

SUBJECT GROUP		DEGREE OF PRACTICE ON TASK I			
		2 min	4 min	8 min	16 min
Group A	$\bar{x}$	47.5	47.9	49.4	52.8
	σ	7.9	6.4	4.7	10.4
Group B	$\bar{x}$	49.7	48.6	48.4	49.0
	σ	8.1	6.4	7.4	5.1
Group C	$\bar{x}$	46.6	49.6	48.2	47.1
	σ	5.9	9.6	6.0	8.2

Performance during the first task is shown in figures 3 and 4. Each curve in figure 3 represents the data from subjects having the same degree of training regardless of the degree of similarity. Figure 4 shows the converse each curve is based on the data from

subjects having the same given degree of similarity, regardless of the degree of task I training. All degrees of practice on task I are represented in the first 2 minutes of figure 4, while only the 16-minute group is represented in the data beyond 8 minutes. The two figures indicate that, not only were the groups matched during the first 2 minutes of task I, but that this matching tended to endure at least across the main variables throughout task I. However, in spite of the apparent goodness of match, it will later be shown that the groups were not matched in all ways and the importance of this fact will be discussed.

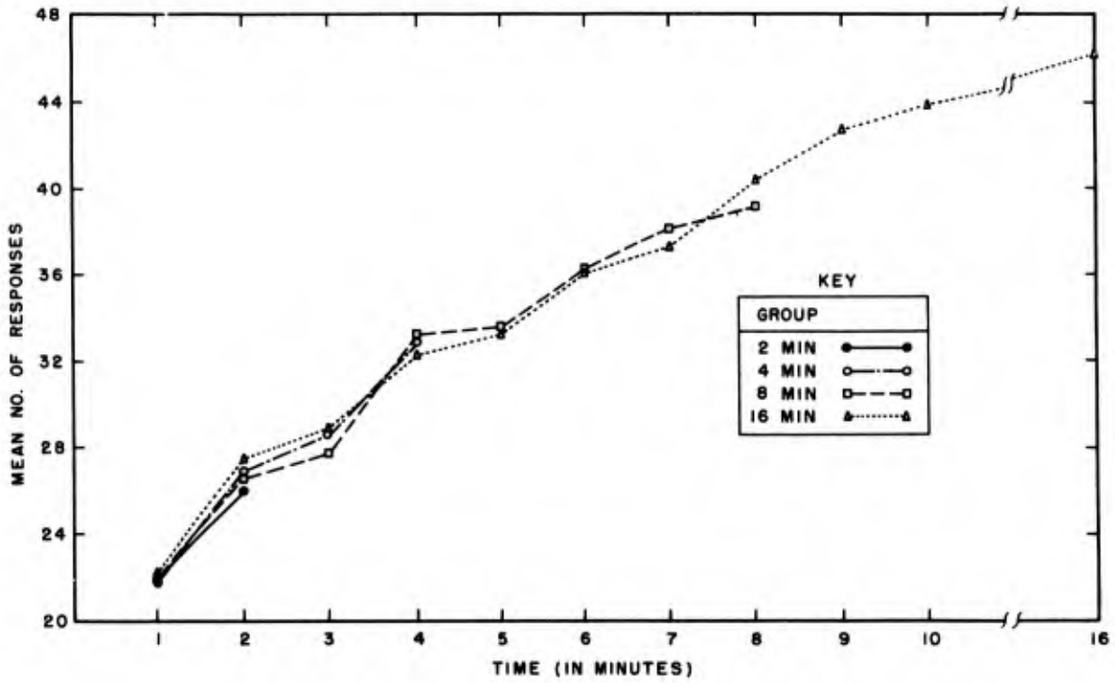

Figure 3. Number of Letter Responses Per Minute During Task I. The Parameter is Amount of Practice on Task I.

PERFORMANCE DURING TASK II

The performance curves for task II are presented in figure 5. This figure shows the performance curves for each task I practice group compared with a control curve. The control curve is based on the mean number of symbols substituted per minute by all subjects in task I. As was pointed out earlier, such a curve indicates learning performance with no prior training. The control curve is always higher than the other curves. This indicates that task I training hindered performance on the second task.

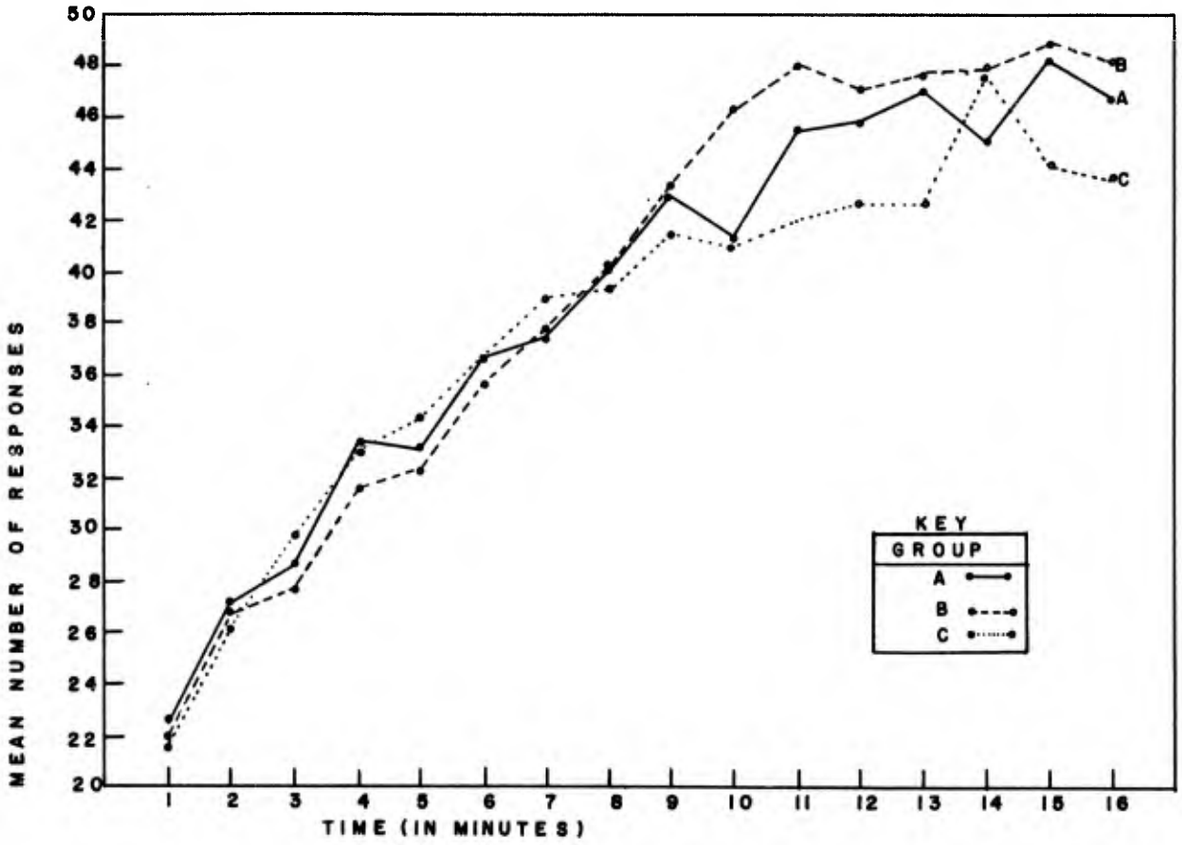

Figure 4. Number of Letter Responses Per Minute During Task I. The Parameter is Degree of Similarity.

An analysis of variance of the total number of symbols substituted during task II yielded no evidence that either degree of learning or degree of similarity produced differential transfer. Figure 5 shows why this might occur when in fact there are real differences among the groups. An inversion of the four practice groups occurred between the third and fifth minute. Those groups that were high during the early part of task II were low during the latter part and vice versa. Addition of these two portions of task II would cause the differences to cancel each other. Thus, the decision was made to perform two separate analyses of variance, one for the first 3 minutes, the other for the last 5 1/2 minutes of task II.

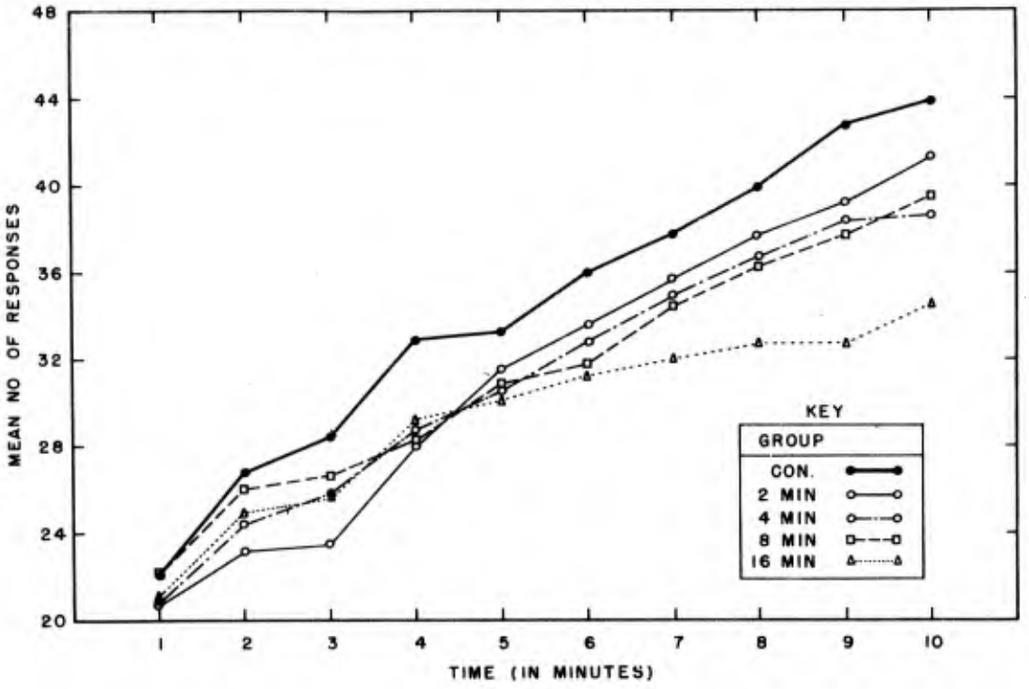

Figure 5. Number of Letter Responses Per Minute During Task II. The Parameter is Amount of Practice on Task I.

The results of the analysis for the first 3 minutes are presented in table III. This table shows that the effect of the degree of similarity and first task practice duration were statistically significant. Table III also shows that the interaction between the two variables was not significant.

TABLE III

ANALYSIS OF VARIANCE: TOTAL NUMBER CORRECT SYMBOL SUBSTITUTIONS DURING THE FIRST THREE MINUTES OF TASK II.

SOURCE	df	SS	MS	F	P
Similarity	2	1878	939.0	6.24	0.01
Task I Time	3	1565	521.7	3.47	0.05
Interaction: Similarity x Task I Time	6	1278	213.0	1.41	NS
Within	168	25244	150.3		
Total	179	29965			

The analysis for the last 5 1/2 minutes gave contrasting results. Table IV shows that during this portion of task II the degree of similarity was not statistically significant, whereas the effect of differential practice during task I was significant at the .05 level. Figure V shows that, during the last 5 1/2 minutes, the groups were ordered inversely to degree of task I practice, ie, the more the subjects practiced on task I, the poorer they performed during the latter part of task II. However, more important than the ordering of the groups is that the differences between the 2-, 4-, and 8-minute groups are small in relation to the difference between these three groups and the 16-minute group (see fig. 5). According to t-tests none of the differences among 2-, 4-, and 8-minute groups are statistically significant, while the 16-minute group is significantly different from each of the others at better than the .01 level. It is reasonable, therefore, to

TABLE IV

ANALYSIS OF VARIANCE: NUMBER CORRECT SYMBOL SUBSTITUTIONS DURING THE LAST FIVE AND ONE-HALF MINUTES OF TASK II.

SOURCE	df	SS	MS	F	P
Similarity	2	2796	1398	1.006	NS
Task I Time	3	14342	4781	3.442	0.05
Interaction: Similarity x Task I Time	6	19834	3306	2.38	0.05
Within	168	233334	1389		
Total	179	270306			

conclude that the significant F for the practice variable (see table IV) is due chiefly to the difference between the 16-minute group and all of the other groups. In order to be more confident about the existence of this difference, an additional group of 15 subjects underwent essentially the same procedure as the original 16-minute group. There was but one difference in the procedure between the two groups: whereas the earlier group had received a 2-minute rest after the eighth minute of task I, the new group received no such rest. The results for both groups were almost identical. As figure 6 shows, the second group had a slightly lower performance curve during task II.

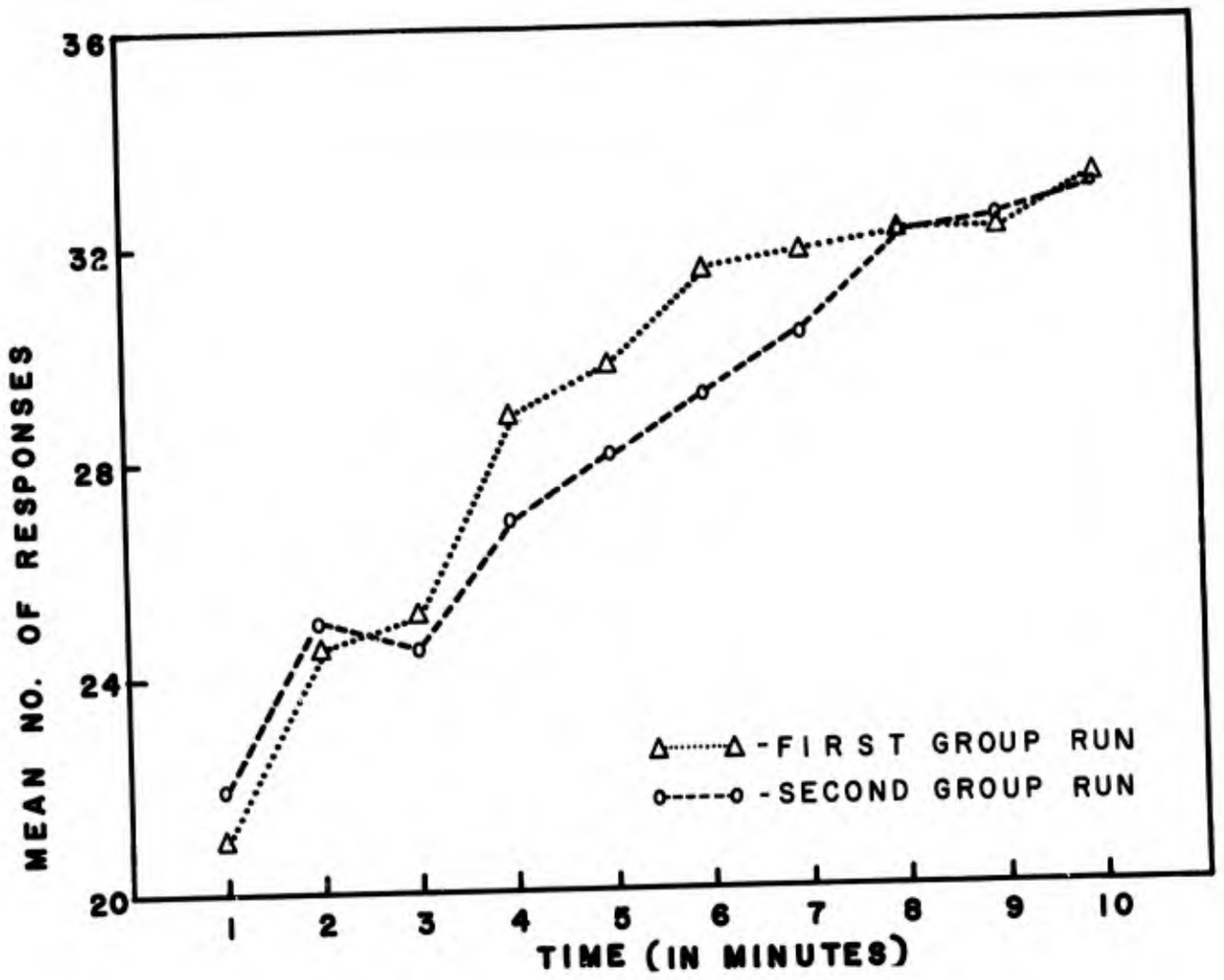

Figure 6. Mean Number of Letter Responses Per Minute by the Two 16-Minute Groups During Task II.

These results — that during the last 5 1/2 minutes, there was little difference between 2-, 4-, and 8-minute groups, but that the 16-minute group was significantly poorer — are not without exception. As table IV shows, the interaction between the two variables is significant at about the .05 level. The nature of the interaction is apparent in figure 7. Here it will be seen that while the relationships described above among the four practice groups held for groups A and C, strikingly contrasting results were obtained from group B.

Close examination of the experimental results suggests some possible reasons why the interaction occurred. Although there is no obvious a priori basis for expecting it, the B degree of similarity (moving half the symbols one space, half two) may not be on the same dimension, at least by these behavioral criteria, as the A and C degrees of change (moving all the symbols one space, or all the symbols two spaces).

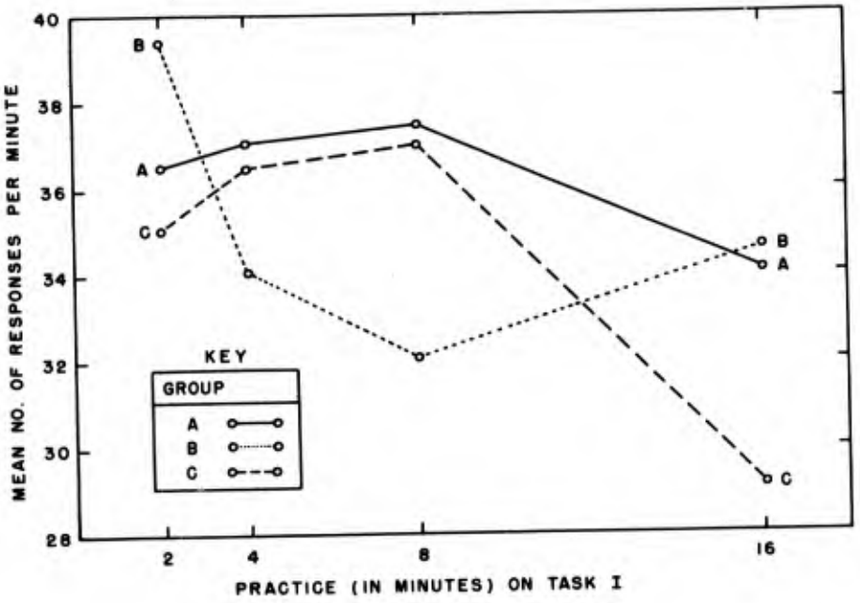

Figure 7. Mean No. of Letter Responses Per Minute During the Last 5 1/2 Minutes on Task II as a Function of Degree of Practice on Task I. The Parameter is Degree of Change Between Tasks.

Also, reinspection of task I data suggests another source of the interaction. For the 8- and 16-minute groups in figure 7, group B has a low 8-minute group and a high 16-minute group, while the reverse is true for the other two groups, particularly for group C. Figure 8 shows that there was a corresponding difference among these groups during the first 8 minutes of task I. Apparently, matching on the basis of performance during the first 2 minutes of task I did not assure equivalence of all groups after 8 minutes of practice on the same task. An analysis of variance of the data represented in figure 8 yielded an F of less than 1.0 for both of the major variables (one would expect this after studying figures 3 and 4), and an F for the interaction term which is significant at the .05 level. At least part of the interaction that occurred during task II was, no doubt, produced by initial differences among some of the groups.

After task I, and again after task II, each subject was tested to determine how many of the letter-symbol associations they had learned. Performance on the test after task II is summarized in figure 9. These data offer further evidence that learning task II was increasingly hampered by increasing practice on task I.

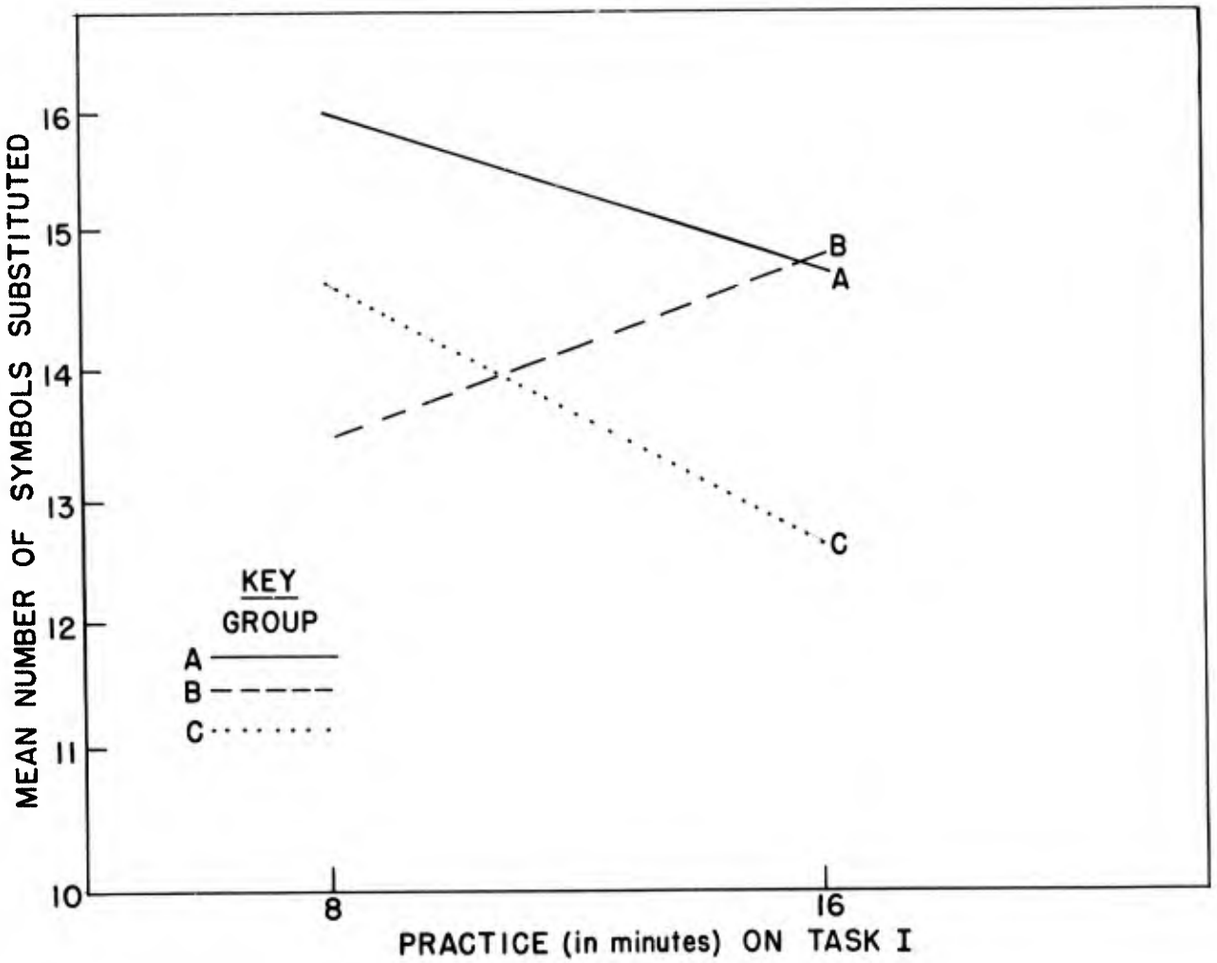

Figure 8. Mean Number of Symbols Substituted in Eight and Sixteen Minute Groups During First Eight Minutes on Task I.

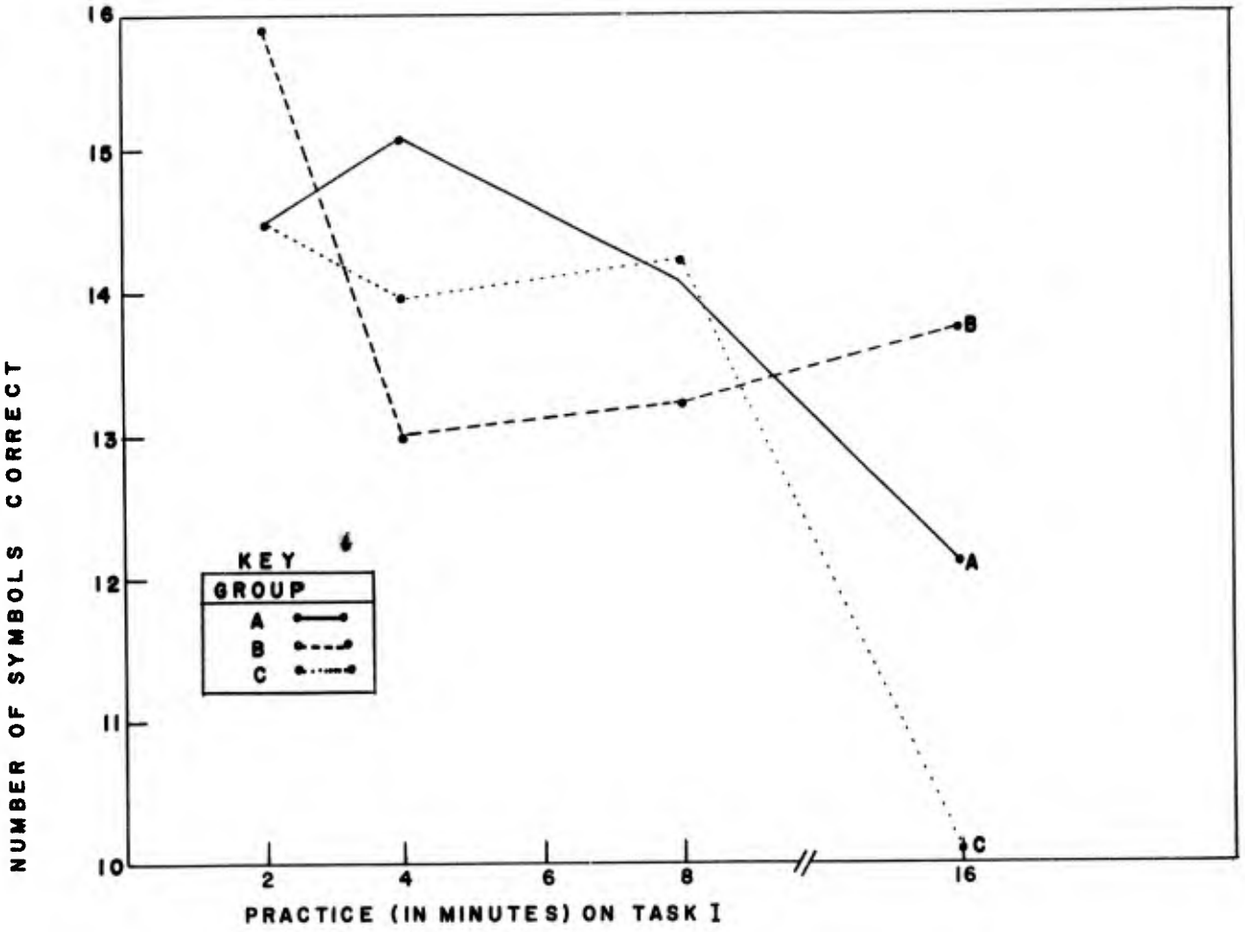

Figure 9. Task II Test Scores as a Function of Practice on Task I; the Parameter is the Degree of Change Between Tasks (A=Low; B=Medium; C=High).

SECTION VI

DISCUSSION

Perhaps the most striking finding of this experiment was that all groups showed extensive and persistent negative transfer. Also, interesting results were observed in regard to the influence of the degree of first task learning on negative transfer, and especially the importance of the point in task II at which transfer was measured. When measured during the first 3 minutes of task II, negative transfer tended to decrease somewhat as the degree of practice on task I increased from 2 to 4 to 8 minutes. This trend seemed to be halted or reversed with 16 minutes of practice on task I. When measured during the last 5 1/2 minutes of practice on task II, negative transfer tended to increase as the degree of practice on task I increased. When measured during the last 5 1/2 minutes on task II, negative transfer was especially great after 16 minutes of practice on task I. In general, the trends during the first 3 minutes of task II are consistent with earlier conclusions (ref 4, ref 6). However, the trends during the last 5 1/2 minutes of task II are quite contrary to earlier studies. Undoubtedly, some of these differences among studies of transfer are due to the nature of the tasks used, the relative degree of learning of the first task, and the point in task II at which transfer is measured. It is believed that 16 minutes of practice on task I represents a relative higher degree of learning on task I than that used in most previous studies.

Similarity between task I and task II was achieved in a manner that was considerably different than that used in most experiments. Variations in similarity seemed to have an effect on transfer only during the first three minutes of task II, but the differences seemed not to follow a consistent pattern.

The persistent negative transfer occurred in spite of a number of factors that would be expected to produce positive transfer. Warm-up, stimulus predifferentiation, learning how-to-learn, and other nonspecific factors would support positive transfer in this situation. Since negative transfer was obtained, there were evidently some powerful forces acting to depress performance during task II.

One factor that would depress performance on task II is the inhibitory effect of massed practice. Performance tends to be relatively depressed by long and constant practice. That such an effect has taken place here is undoubtedly true, particularly for the 16-minute group.

Massing must not be the only factor that tended to produce negative transfer, because this was also shown among the shorter practice groups. In view of the several factors tending to produce positive transfer in the present experiment, it would be exaggerating the effects of massing to propose that the addition of 2 minutes, or even 4 minutes of performance would produce such sustained negative transfer. Also, although performance on the test after task II probably was relatively free of any decrement attributable to massing, performance on this test (fig 9) seemed to decrease quite steadily with increasing practice on task I. The relative influence of massed practice could be investigated by either distributing practice on task I or allowing a longer interval between the two tasks.

The nature of the task suggests other sources of negative transfer. Even for group A, that group having the highest degree of intertask similarity, task II was considerably different from task I. First, although the symbols and letters were the same in both tasks, the associations between the letters and the symbols were changed. Evidence indicates that such a change is more likely to produce negative transfer than is substituting new items for old ones. In addition, all rather than just a portion, of the associations were changed. Duncan et al (ref 3) have reported that positive transfer decreases as the proportion of changed stimulus-response associations increases, being minimal when all the associations are changed.

Also of importance seems to be the number of stimulus-response items in the task, as well as the proportion that are changed. Duncan and Underwood (ref 3), changing a maximum of six stimulus-response associations, found positive transfer throughout; Crafts (ref 6), changing a maximum of nine associations, found zero transfer under the maximum condition; Porter and Duncan (ref 5), changing twelve associations, provided a single instance of negative transfer; the present experiment, with sixteen stimulus-response associations changed, yielded negative transfer conclusively. Admittedly, because of many differences, comparison of these experiments cannot be expected to yield confident conclusions; but the comparison is suggestive. In all likelihood, transfer of training is a function of the proportion of stimulus-response associations which are changed. Furthermore, when all of the stimulus-response relations are altered, measured transfer may well change from positive through zero to negative transfer as the number of associations increases.

Another point worth noting regards the task used in the present study. As was noted earlier, the typical verbal learning tasks allow a short time between the stimulus and the response. Response conflict during this period is not observed. In the task used in the present study, response conflict presumably decreases the response rate and directly influences the subjects' score. In some ways, then, the symbol substitution task is more sensitive to transfer effects than the conventional verbal learning tasks.

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Aerospace Medical Research Laboratories Aerospace Medical Division, Air Force Systems Command, Wright-Patterson AFB, C

13. ABSTRACT

This experiment investigated the effects of degree of learning of a first task and degree of similarity between two tasks on the transfer of training from the first to the second task. The basic relationship between the two tasks was such that learning the first might well interfere with learning the second. Twelve groups of 15 college students learned a symbol substitution task to one of four levels of mastery. They were then transferred to a task where the symbols in task I were rearranged to permit three degrees of intertask similarity. Extensive and persistent negative transfer was obtained. During the initial stages of learning task II, negative transfer seemed to decrease as the degree of learning of task I increased. However, during the later stages of task II, negative transfer seemed to increase with an increase in the degree of learning of the first task, especially with the higher degree of learning of task I. The intertask similarity variable appeared to be significant only during the early stages of learning of the second task. These findings differ from previous findings in the extent and persistence of negative transfer and in the tendency for it to increase with higher degrees of first task mastery. The present findings question the generality of existing transfer principles derived from slowly paced tasks involving relatively few discrete stimuli and responses.

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