WADC TECHNICAL REPORT 54-288

Cleared: December 27th, 1979
Clearing Authority: Air Force Avionics Laboratory

THE INFLUENCE OF COMPLEX TASK VARIABLES ON THE RELATIVE EFFICIENCY OF AUDITORY AND VISUAL MESSAGE PRESENTATION

The Fourth of a Series of Reports on
An Experimental Analysis of Complex Task Performance

L. STARLING REID
WILLIAM H. MORSE

UNIVERSITY OF VIRGINIA

APRIL 1955

WRIGHT AIR DEVELOPMENT CENTER

WADC TECHNICAL REPORT 54-288

THE INFLUENCE OF COMPLEX TASK VARIABLES ON THE RELATIVE EFFICIENCY OF AUDITORY AND VISUAL MESSAGE PRESENTATION

The Fourth of a Series of Reports on
An Experimental Analysis of Complex Task Performance

L. STARLING REID
WILLIAM H. MORSE

UNIVERSITY OF VIRGINIA

APRIL 1955

AERO MEDICAL LABORATORY
CONTRACT No. W33(038)-ac-21269
PROJECT No. 7192

WRIGHT AIR DEVELOPMENT CENTER
AIR RESEARCH AND DEVELOPMENT COMMAND
UNITED STATES AIR FORCE
WRIGHT-PATTERSON AIR FORCE BASE, OHIO

Carpenter Litho & Prtg. Co., Springfield, O.
100 - 19 March 1956

FOREWORD

This report is the fourth of a series covering a program of laboratory investigation of the factors determining proficiency of performance in complex task situations. The research included in the present report was conducted by Dr. L. S. Reid and Mr. W. H. Morse, under the general supervision of Dr. R. H. Henneman. This study was carried on at the University of Virginia under Project No. 7192, Task No. 71603, 'Visual Message Presentation.' The contract was administered by the Psychology Branch of the Aero Medical Laboratory, Directorate of Research, Wright Air Development Center, with James E. Smithson acting as Project Engineer.

ABSTRACT

Previous research on complex task performance has been aimed at an increased proficiency through the manipulation of certain task and operator variables. Among other findings, the results indicated that degree of practice on a patterned component and task complexity were significantly and independently related to total task proficiency, the former tending to increase proficiency, the latter to reduce it. The present study was an attempt to relate these results to those of the experiments comparing auditory and visual message presentation in which auditory presentation had been consistently demonstrated to be superior under conditions of a simultaneous distracting task.

Basically, the experiment involved the comparison of auditory and visual message reception while the subjects were simultaneously engaged in performing a visual discrimination-motor task. Experimental variables were sense channel of presentation, message length, and amount of previous practice on the visual-motor task component whose stimuli occurred in a patterned sequence. Results were measured in terms of overall proficiency of message reception and task performance combined. Practice on the motor task improved this overall proficiency, having a greater differential effect upon the longer messages combined with task than upon the shorter messages plus task. An original superiority of overall performance for the auditory presentation almost disappeared with increasing practice on the motor task. These results completely confirmed the predicted relationships based upon the previous research in both areas noted above.

PUBLICATION REVIEW

This report has been reviewed and is approved.

FOR THE COMMANDER:

JACK BOLLERUD
Colonel, USAF (MC)
Chief, Aero Medical Laboratory
Directorate of Research

TABLE OF CONTENTS

INTRODUCTION

The broad purpose of the present investigation was to relate the findings of the studies comparing auditory and visual message reception under conditions of a distracting task (1, 2) to the results of the experiments on the conditions determining the efficiency of complex task performance (3, 4, 5).

The experiments on message intelligibility during distracting task performance make obvious the interdependence of message reception and task performance (2). This being the case it has been suggested that an individual required to receive messages while simultaneously performing other tasks should be conceived of as performing a single complex task made up of a number of stimulus-response units rather than performing a number of discrete tasks (4). The importance of this conceptualization stems from a consideration of the different kinds of questions imposed by the two viewpoints. If, as in classical psychology, various segments of behavior are viewed as individual entities without due concern for the appropriate variables in terms of which the segments may be grouped, this is likely to give rise to such questions as: How many things can a person do at once? or, Is an individual able simultaneously to focus attention upon two separate activities? These are largely, if not completely, questions for which no meaningful experimental answers can be found. If, on the other hand, behavior in such complex situations is analyzed into a series of discrimination-response units (responses made to certain stimulus changes) it seems reasonable to suppose that the relations which hold among the various units provide a set of common variables which contribute to overall proficiency. In fact such a supposition is borne out by earlier research on complex task performance (3, 4, 5).

To the extent that these common variables influence overall performance in a given situation, it is not only parsimonious but theoretically more meaningful to analyze task performance in terms of them. This is not a denial that it is useful at times to segment total performance. It is necessary, however, to avoid subdividing by means of arbitrary criteria derived from response consequences, i.e., in terms of what the experimenter thinks the subject is doing. It is possible on the other hand to group individual responses into task components by utilizing the variable analysis. This accomplishes a meaningful psychological categorization by grouping together those responses that possess similar values for a given array of variables. In the original investigations of complex task performance this rationale was followed. In designing the task such variable dimensions as task complexity, temporal relations among stimuli, temporal relations between stimulus and response occurrence, stimulus duration, sequential relations among stimuli, stimulus similarity, and topographical characteristics of the required responses, were used to categorize responses into task components. The basic component, for example, involved a series of four keys which had to be pressed as spatially corresponding lights flashed on. Under one experimental condition the lights flashed on in a patterned sequence, and among other things, certain temporal relations were held constant. It was then possible to describe the influence of the component upon total task performance in terms of these variable loadings and to determine its differential influence as these loadings were changed. This led to the concept of task demandingness which is defined as the extent to which overall task performance suffers as a result of the variable values assigned the various components. Task demandingness has thus been defined in terms of these variables and the major emphasis of previous research on complex task performance has been an assessment of the conditions under which the components individually and together place greater and greater demands upon the operator and thereby reduce proficiency of total task performance. The obvious corollary of such research is a determination of the manner in which task demandingness may itself be reduced.

Underlying the decision to investigate complex task performance per se was the assumption that simultaneous message reception and aircraft operation constitute such a complex task. The several previous experiments (1, 2) expressly designed to investigate the influence of a distracting task upon the relative efficiency of auditory and visual message presentation led to the conclusions that:

1. There is an over-all superiority for auditory message presentation under conditions of both visual and non-visual distracting task. This superiority is not only reflected by better message reception but also by a lower number of errors in the performance of the distracting task.

2. There is a less pronounced auditory superiority when the messages are short and the distracting task easy to perform. There is a marked increase in its superiority, however, as the message becomes longer and the distracting task more difficult.

It is apparent, at least under the conditions specified by these experiments, that visual presentation imposes greater task demandingness than does auditory presentation. Further, the fact that distracting task performance suffers as a consequence of the greater demand imposed by visual presentation supports the position outlined above.

The major purpose of the present study was to determine whether certain of the variables previously demonstrated to influence total task performance could be utilized to improve the relative efficiency of visual message presentation by decreasing the task demandingness of the other components making up the complex task. It was an attempt to begin to relate the findings of the studies comparing auditory and visual message reception under conditions of distracting task to the results of the experiments on the conditions determining the efficiency of complex task performance.

In the complex task research the variable found to be most effective in reducing task demandingness was that of previous practice on a component in which the stimuli occasioning responses were sequentially patterned. For this reason it was the major variable chosen to be manipulated in the present study. Since, in the experiments comparing auditory and visual presentation, it had been found that longer messages increased auditory superiority, and in the complex task studies that task complexity was a significant factor influencing total task performance, it was also decided to manipulate message length. In the light of previous results the following relationships were expected to hold among these variables:

1. At low levels of practice on the patterned motor task component, performance of the complex task under the visual condition would be less proficient than under the auditory condition.

2. The effect of practice on the patterned component would be to improve differentially performance under the visual condition relative to the auditory condition.

3. The differential improvement under the visual condition of the complex task would appear at medium levels of proficiency (practice) for short messages, but would require higher levels of proficiency for the longer messages.

PROCEDURE

Subjects

The subjects were 48 male undergraduates of the University of Virginia, assigned randomly to eight groups with only the restriction that each group contain six subjects. A subject, depending upon his group, served either for 1, 2, 4, or 9 experimental sessions.

Apparatus

The motor component of the complex task used in this experiment has been previously described in detail (4). A single row of four lights was situated on a panel in front of the subject; horizontally and to the front of this panel were four response keys spatially arranged to correspond to the lights. The lights flashed on at a rate of two per second in a patterned sequence (4-2-1-3) which was continuously repeated. The subject was required to press the key corresponding to a given light within the interval the light was on.

The second component of the task involved reception of either auditory or visual messages by the subject while he was performing the motor task. The auditory messages were presented over earphones by means of an Eicor tape recorder, while the visual messages were projected on a 5-in. by 8-in. screen located 4 in. above the stimulus light panel for the motor task.

Identical sets of five- and ten-word messages were transcribed on recording tape for auditory presentation, and reproduced on 35-mm transparent slides to be projected on the screen for visual presentation. The message material consisted of phrases modified from messages actually exchanged in air operations. The ten-word messages were composed of two independent five-word phrases combined to form a logical ten-word sequence, while the five-word messages were the same phrases presented individually.

Schedules of Practice on Motor Component

Prior to being tested on the complex task, subjects were given either 0, 1, 3, or 8 days of practice on the motor component previously described. Each daily practice session on the motor component consisted of nine 2-min. trials, during which it was possible to make 240 correct responses. Subjects who received this practice were read a set of instructions on how to perform the motor task, but were given no information concerning the complex task (i.e., task plus message reception) until they were required to perform it.

Schedule of Successive Trials on Complex Task

The complex task required subjects to receive and say back the messages, which had been presented visually or aurally, while performing the motor task. An effort was made to have all subjects respond to the complex task in a similar manner by giving the following instructions:

> You are to receive and say back messages while you are performing the motor task. Always try both to say back the message correctly and to respond correctly to the flashing lights. It is more important that you receive and say back the messages correctly --- try to recite the messages without error ---, but do not stop performing the motor task. That is, keep making responses with your fingers, even though some of them may be incorrect.

Performance on the complex task was measured over a series of 24 1-min. trials during which either an auditory or visual message was presented. For half the subjects the sense modality of presentation was varied in the following prearranged order: A V A V V V A A A V V A A A V V V A V A V A A V. The sequence of auditory and visual trials was the exact reverse of this for the other half of the subjects.

Although all subjects received messages under both visual and auditory conditions, a given subject received only five-word or ten-word messages. The presentation time of the visual messages was the same as that for the auditory messages. The first five-word message was presented for approximately 2 sec. some time between 10 and 14 sec. after the trial had begun; the second message was presented some time between 22 and 26 sec.; the third between 35 and 39 sec.; and the fourth between 46 and 50 sec. The ten-word messages were presented for a duration of approximately 5 sec. between 10 and 20 sec. and between 35 and 45 sec. after the beginning of a trial.

The subjects were required to repeat the messages immediately following their presentation. A message was scored at that time by the experimenter in terms of the number of key words (articles and prepositions disregarded) correctly reproduced. During a 1-min. trial a total of 120 motor responses and approximately 17 message responses (i.e., key words) could be made by a subject.

Experimental Design

The three variables, amount of previous practice on the patterned motor component, task complexity (length of message) and sense modality of message presentation, were varied in a split-plot analysis of variance design which is shown in Table 1.

TABLE 1

Experimental Design

Days of Training on Motor Component	Message Length: 5-Word — Modality of Presentation: Auditory	Visual	Message Length: 10-Word — Modality of Presentation: Auditory	Visual
0	N = 6		N = 6	
1	N = 6		N = 6	
3	N = 6		N = 6	
8	N = 6		N = 6	

RESULTS

The results of the experiment are summarized in Table 2 which gives mean scores for the six subjects under each condition. The scores, denoting proficiency of total performance, are based upon a composite weighting of the two components of the complex task whereby the number of message responses is made equivalent to the number of motor responses. The choice of weighting is somewhat arbitrary, but because the paramount interest of the study was the auditory-visual comparison an equal weighting was decided upon. It should be added that several other methods of weighting were tried and the general trends were not changed by any of them. Of course it would have been possible to evaluate performance on the separate components individually, but this seemed inadvisable since the present study was designed to compare auditory and visual message reception in the complex task situation. Such a comparison is quite meaningless if the subjects' performance on the remainder of the task is not at the same time taken into consideration. It is interesting to note, however, that for every auditory-visual comparison the greater number of message errors is accompanied in every instance by poorer motor task performance. That is to say, the higher task demandingness provided by the visual messages not only led to poorer message reception, but also to poorer motor performance.

TABLE 2

Mean Number of Composite Correct Responses Under the Various Complex Task Conditions

Days of Training on Motor Component	Message Length: 5-Word		Message Length: 10-Word	
	Modality of Presentation		Modality of Presentation	
	Auditory	Visual	Auditory	Visual
0	106.6	95.4	107.7	90.2
1	118.4	110.8	109.4	97.4
3	118.5	117.3	111.9	106.1
8	119.1	118.8	114.5	110.2

The composite scores of Table 2 are plotted in Figure 1 to better portray the relationships that hold among the variables. Obviously the curves can be considered only suggestive as far as functional relations are concerned, but the general trends are striking and completely in line with the predictions. It can be seen that performance on the complex task improves with increasing practice on the motor component and improves more rapidly for the five-word messages. It is further evident that the effect of practice is more pronounced for the visual condition of the complex task than for the auditory condition.

The analysis of variance of these data is presented in Table 3. The F-ratios indicate that each of the three manipulated variables is significantly related to performance of the complex task at the 1% level of confidence. Significant interactions are also found between level of practice and mode of presentation, and between message length and mode of presentation. The significance of these interactions is quite likely due to the fact that performance under the five-word auditory presentation condition is very close to its asymptote after only one practice session on the motor component.

TABLE 3

Analysis of Variance of Composite Correct Responses Under Various Complex Task Conditions

Source of Variation	Sum of Squares	df	Mean Square	F
Message Length	181,047.5	1	181,047.5	8.87**
Level of Practice	346,368.9	3	115,456.3	5.66**
Length x Practice	33,044.8	3	11,014.9	----
Error	816,588.0	40	20,414.7	----
Modality of Presentation	175,702.6	1	175,702.6	74.19**
Modality x Length	18,012.8	1	18,012.8	7.61**
Modality x Practice	59,276.3	3	18,092.1	7.64**
Modality x Length x Practice	3,146.6	3	1,048.9	----
Error	94,726.2	40	2,368.2	----

** Significant at the 1% level of confidence

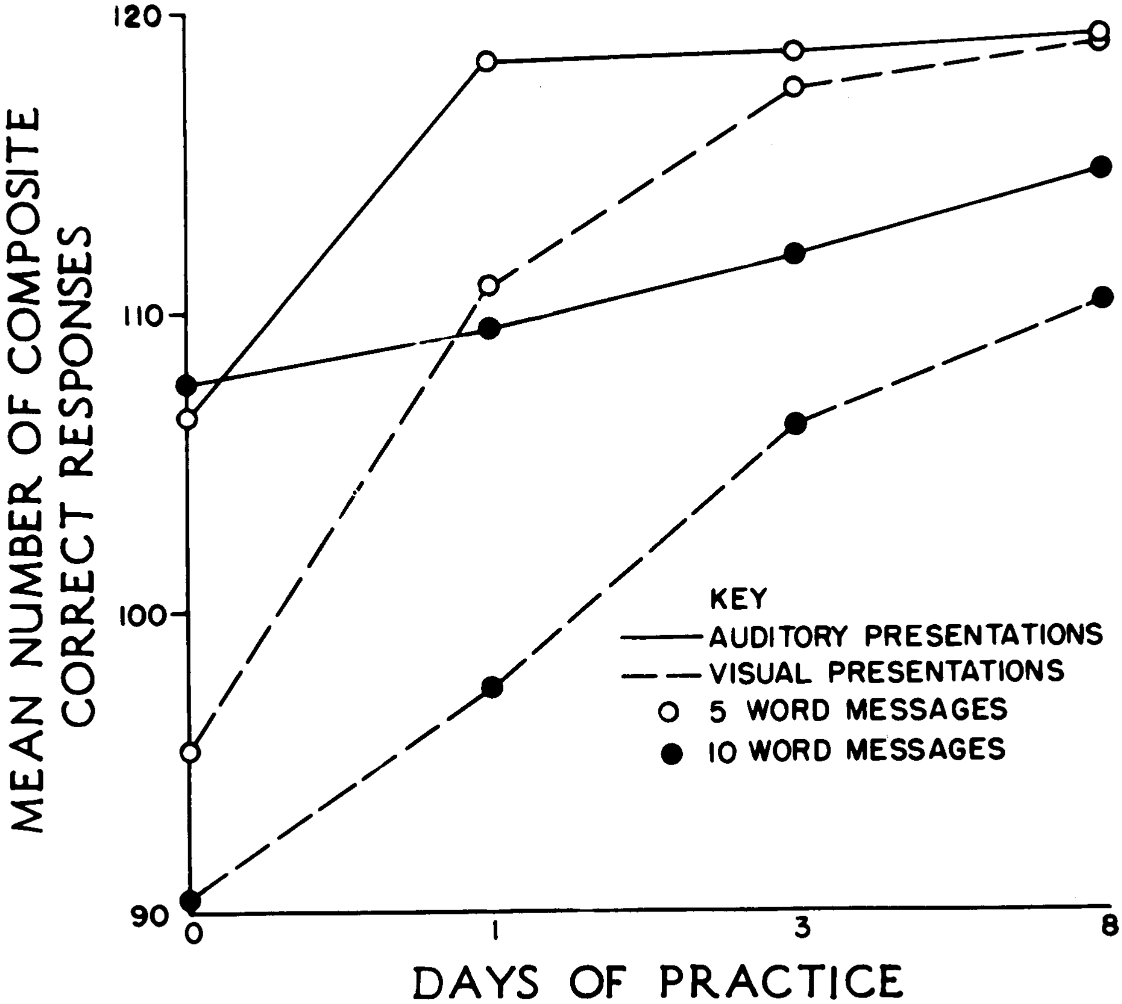

Figure 1. Mean Number of Composite Correct Responses Under Various Levels of Motor Task Proficiency (Days Practiced).

DISCUSSION

The results of this experiment may be summarized by four general statements: (1) Proficiency on a complex task, composed of the reception of auditory or visual messages and a discrimination-motor task in which the occurrence of responses is patterned, was improved by practice on the motor task. (2) Practice on the motor component had a greater differential effect upon the ten-word messages plus motor task than for five-word messages plus motor task. (3) When auditory and visual messages were presented as components of the complex task there was an original superiority in over-all performance for the auditory over the visual condition. (4) The most important finding of the present study was that the initial difference between the auditory and visual conditions almost disappears with increasing practice on the motor component. These results completely confirm the predicted relationships noted in the introduction and based upon previous research on complex task performance (3, 4), and on the research comparing auditory and visual message presentation (1, 2).

It will be remembered that any condition which increases task demandingness will decrease the proficiency of total task performance, while any reduction of task demandingness acts to increase it. From the results of complex task research it was predicted, that because its responses were patterned in their occurrence, practice on the motor component would lead to a reduction in task demandingness.

Since the longer messages increase total task complexity it also follows from the complex task research that there was initially a greater amount of task demandingness under the ten-word message condition. It was to be expected, then, that performance under this condition would more greatly benefit from practice on the motor component, i.e., there was a greater opportunity for a decrease in task demandingness to be reflected by an increased proficiency.

Similar reasoning led first to the prediction that the auditory condition of the complex task would in the beginning yield more proficient performance, and, second, to the prediction that the original auditory superiority would be diminished by practice on the motor component. The experiments comparing auditory and visual message presentation have demonstrated that visually presented messages introduce greater task demandingness into the complex task situation. This being the case the two predictions follow from the above rationale and are supported by the experimental results.

In view of the above considerations it was to be expected that performance scores for the various conditions would initially order themselves in terms of the magnitude of task demandingness and would tend to converge as task demandingness was reduced. This is exactly what was found.

SUMMARY AND CONCLUSIONS

Earlier reported studies (1, 2) comparing the intelligibility of auditory and visual messages under conditions of a distracting task have demonstrated the superiority of auditory presentation. In another area of research (3, 4, 5) it has been further shown that overall performance in certain complex task situations may be improved by the manipulation of variables related to only a segment of the total task. That is to say, a reduction of the task demandingness of a single component may lead to an increase in the proficiency of total task performance. The present study was an attempt to relate the findings of research on complex task performance to those of the studies comparing auditory and visual message reception.

The general plan of this experiment involved the comparison of auditory and visual message reception while the subject was simultaneously engaged in performing a visual discrimination motor task. In the complex task research the variable found to be most effective in reducing task demandingness was that of previous practice on a component in which the stimuli occasioning responses were sequentially patterned. For this reason it, along with message length and modality of presentation, were chosen to be manipulated in the present study.

The results of the experiment are summarized by the following statements: (1) Proficiency on a complex task, composed of the reception of auditory or visual messages and a discrimination-motor task in which the occurrence of responses is patterned, was improved by practice on the motor task. (2) Practice on the motor component had a greater differential effect upon the ten-word messages plus motor task than for five-word messages plus motor task. (3) When auditory and visual messages were presented as components of the complex task there was an original superiority in over-all performance for the auditory over the visual condition. (4) The most important finding of the present study was that the initial difference between the auditory and visual conditions almost disappears with increasing practice on the motor component.

These results completely confirm the predicted relationships based upon previous research on complex task performance and on the research comparing auditory and visual message presentation.

BIBLIOGRAPHY

1. Henneman, R. H., Lewis, P., and Matthews, T. L., The Influence of the Sensory Requirements of the Distracting Task, The First of a Series of Reports on Auditory and Visual Message Presentation Under Distracting Task Conditions. WADC Technical Report 53-309, Wright Air Development Center, Wright-Patterson Air Force Base, Ohio, November 1953.

2. Henneman, R. H., and Matthews, T. L., The Influence of Message Length and Distracting Task Complexity, The Second of a Series of Reports on Auditory and Visual Message Presentation Under Distracting Task Conditions. WADC Technical Report 54-145, Wright Air Development Center, Wright-Patterson Air Force Base, Ohio, July 1954.

3. Reid, L. S., and Holland, J. G., The Influence of Stimulus Similarity and Stimulus Rate, The Third of a Series of Reports on Experimental Analysis of Complex Task Performance. WADC Technical Report 54-146, Wright Air Development Center, Wright-Patterson Air Force Base, Ohio, May 1954.

4. Reid, L. S., and Slivinske, A. J., Rationale, Experimental Methodology, and Exploratory Investigation, The First of a Series of Reports on Experimental Analysis of Complex Task Performance. WADC Technical Report 53-310, Wright Air Development Center, Wright-Patterson Air Force Base, Ohio, December 1953.

5. Slivinske, A. J., The Factors of Task Complexity and Previous Practice on a Patterned Component, The Second of a Series of Reports on Experimental Analysis of Complex Task Performance. WADC Technical Report 53-313, Wright Air Development Center, Wright-Patterson Air Force Base, Ohio, December 1953.