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TRANSFER OF TRAINING WITH SIMULATED AIRCRAFT DYNAMICS:

III. VARIATIONS IN COURSE COMPLEXITY AND AMPLITUDE

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FOREWORD

Work covered by this report was initiated under contract by the Training Research Branch, Behavioral Sciences Laboratory, Aerospace Medical Research Laboratories of Aeronautical Systems Division. This work was part of a general program documented under Project 7197, "Human Factors in the Design of Operator Trainers," with Dr. R. L. Morgan acting as Project Scientist. Dr. M. R. Rockway was the Air Force initiator and technical monitor for this study under Task No. 71635, "Simulation Requirements of Training Equipment." The original research upon which the report is based was completed at the Aviation Psychology Laboratory of the University of Illinois under Air Force Contract No. AF 33(616)-2725, entitled "Survey and Research to Determine Simulation Requirements of Synthetic (Ground) Flight and Fire Control Training Devices." During the course of the contract Dr. A. C. Williams, Jr. and Dr. L. I. O'Kelly served as Principle Investigators.

A number of individuals contributed to the early phases of the present program, and the authors wish to extend their gratitude to Dr. A. C. Williams, Jr., Dr. M. Adelson, and Dr. L. I. O'Kelly for their guidance throughout the program.

Mr. Obermayer and Mr. Muckler are currently members of The Martin Company, of the Martin-Marietta Corporation, Baltimore 3, Maryland. Mr. Hanlon is a member of the Human Factors Group of Convair, a Division of General Dynamics Corporation, San Diego, California. Mr. Serio is a member of the Control Systems Laboratory, University of Illinois, Urbana, Illinois.

ABSTRACT

This report is the third in a series of experiments dealing with transfer of training as a function of simulated aircraft longitudinal dynamics. Subjects performed single dimension compensatory tracking with long period (phugoid) oscillatory control system dynamics. Two experiments are reported dealing with changes in course complexity and amplitude of the experimental stimulus forcing function.

Increasing course complexity was found to substantially affect transfer of training, but not training performance. Increasing course amplitude markedly affected training performance, but not transfer of training. In general, transfer effects were greater from less difficult to more difficult task conditions.

These results are superficially inconsistent with previously reported studies. However, many of the phenomena are directly attributable to the presence of complex system dynamics which were absent in prior studies.

PUBLICATION REVIEW

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I. INTRODUCTION

This report is the third in a series dealing with transfer of training as a function of simulated aircraft longitudinal dynamics. The previous reports (10, 11) have presented five studies concerned with (a) variations of period and damping terms of long-period (phugoid) oscillatory transients and (b) variations in control gain parameters.

In the present experiments, emphasis is shifted from control to display parameters. In every human tracking task a forcing function of some nature is used to provide a basic display input to the operator. In some types of tasks (e.g., compensatory tracking) the forcing function is mixed with the operator's output in order to display an error term which the operator attempts to nullify. In other kinds of tasks (e.g., pursuit tracking) the forcing function is displayed independently along with the display of the operator's actual performance output. In this case, the operator attempts to nullify the difference between the two stimulus signals. Regardless of the type of task, however, some form of forcing function is used.

There is ample evidence to indicate that variations in the nature of the forcing function may result in changes in the level of tracking and transfer performance (cf., e.g., 2, 3, 12). The present exploratory studies are an attempt to examine the effects of changes in course complexity and amplitude of the forcing function with variations in system dynamics parameters as represented by simulated aircraft phugoid responses.

II. EXPERIMENT 6: VARIATIONS IN COURSE COMPLEXITY

All of the previous studies in this series have employed a simple low-amplitude sinusoid as the basic forcing function. One variation that is immediately possible is to change the frequency of the sine wave. Another variation would be to increase the complexity of the forcing function by using combinations of various frequencies. In this study the latter method has been chosen, and transfer and training performance is compared with "simple" and "complex" course frequencies of the basic forcing function. Variation in task difficulty and system dynamics is introduced by using a number of simulated aircraft longitudinal dynamic (phugoid) responses.

Experimental Method

Experimental Task and Apparatus.* In all cases, the subject was required to perform one-dimension compensatory tracking. A horizontal stimulus line was displayed on a 5-inch oscilloscope. Using a conventional aircraft control stick, the subject attempted to keep the stimulus line centered at all times.

The subject's control stick output was fed into a computer which generated simulated aircraft long-period (phugoid) oscillatory transients with period and damping values designated by the particular experimental conditions. The signal from the computer was mixed with a signal generated by a cam, and the resultant error signal was displayed to the subject on the face of the oscilloscope.

The cam provided the basic forcing function to the subject. In the preceding experiments (10, 11), a constant course frequency was provided by a saw tooth function closely approximating a simple sine wave of six cycles per minute. Variations in course frequency provided the primary experimental variable used. The first was the six cycles per minute sine wave used in all preceding experiments, and it is here termed the "simple-course frequency". For experimental comparison, a second function was chosen from a combination of 3 and 6 cycles per minute, and it is here termed the "complex-course frequency". The two forcing functions were equated in terms of the time-on-target (TOT) scores obtained by running the cams without stick input. TOT scores of 15 ±.10 seconds were obtained for both simple- and complex-course frequencies without stick input.

Three simulated phugoid conditions were selected representing wide variations in period and damping terms: (a) Condition 1 with a period of 18 seconds and a time-to-damp-to-half amplitude of 17 seconds, (b) condition 5 with a period of 35 seconds and a damping term of 33 seconds, and (c) condition 9 with a period of 71 seconds and a damping value of 66 seconds. Previous experimentation (10, 11) has shown considerable differences in training and transfer scores with these phugoid conditions.

Experimental Design. Since two course complexity conditions and three simulated phugoid conditions were selected for this experiment, a total of six experimental conditions were used in this study as shown in Table 1.

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* A detailed discussion of the experimental apparatus, simulation techniques, and experimental procedures common to all studies in this series may be found in the initial report (10).

TABLE 1

Experiment 6: Experimental Design and Groups*

	Phugoid Condition 1	 5	 9
Simple-Course Frequency	1.1	1.5**	1.9
Complex-Course Frequency	6.1	6.5**	6.9

** Transfer Condition

Six independent groups of subjects were trained on the experimental conditions. For the transfer trials, all groups shifted to or remained on one of the two appropriate transfer conditions (1.5 and 6.5).

Subjects. A total of 60 male University of Illinois undergraduate students served as subjects in this experiment. Half of the subjects had previously served on conditions 1.1, 1.5, and 1.9 as part of the basic experiment in this series (10). The remainder of the subjects (30) were specifically assigned to the present study for conditions 6.1, 6.5, and 6.9. Subjects were assigned at random with the single exception that they were divided into 3 equal groups, 10 subjects to each condition.

Procedure. Each subject was given 30 training trials on one of the six experimental conditions. Each experimental trial was 30 seconds in length, with an intertrial interval of 30 seconds. After a 3-minute rest each subject then transferred to either condition 1.5 or 6.5 and was then given 10 additional trials. The detailed subject instructions may be seen in the first report in this series (10). Particular care was taken to insure that all procedures were identical for the simple and complex course frequency groups.

Response Measure. The response measure was TOT for each training and transfer trial. A tolerance band was allowed of ±.2 inch from the null, or center, line. The maximum possible TOT score was 30 seconds, the length of the individual training and transfer trial.

Results

The major findings in this experiment are shown graphically in figures 1 and 2. Figure 1 shows mean TOT scores for phugoid conditions 1, 5, and 9 using the simple-course frequency. Figure 2 shows mean TOT scores for phugoid conditions 1, 5 and 9 using the complex-course frequency. It should be noted that on each figure theoretical performance, with no subject stick input, is shown; that is, if the subject had done nothing he could have achieved a 15-second TOT score.

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* Report Notation. Consistent with previous studies in this series, a decimal notation has been adopted to indicate the particular experiment and the phugoid condition. The number of preceding the decimal is the experiment; the number after the decimal is the phugoid condition. It may be seen in Table 1 that half of the conditions were derived from Experiment 1, while the remainder are specific to this study.

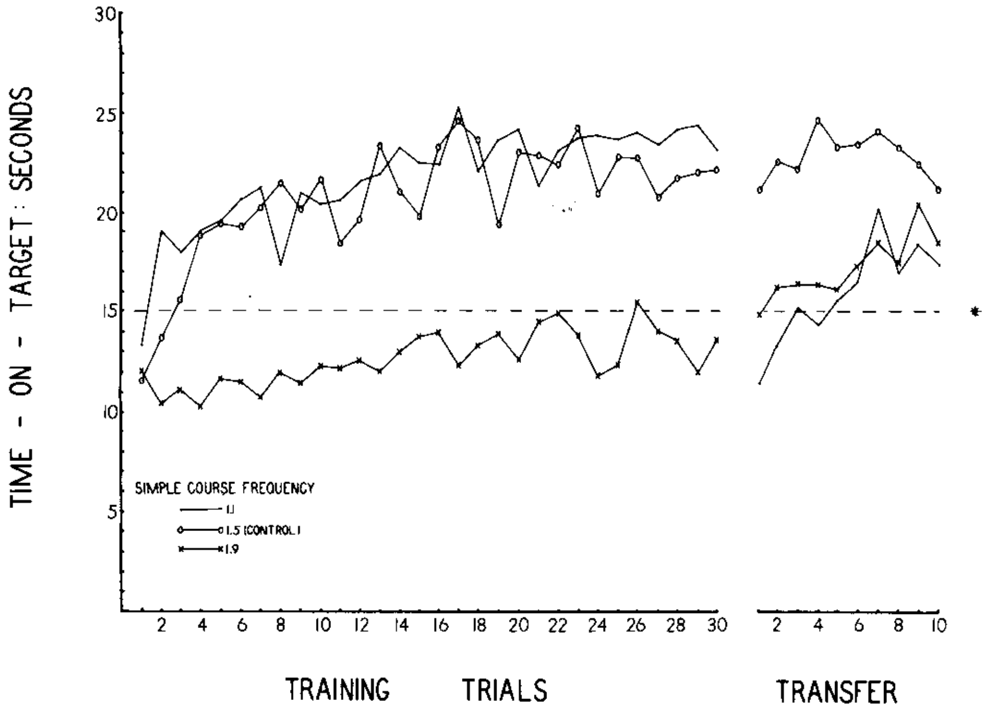

Figure 1. Simple Course Frequency: Training and Transfer Performance for Groups 1.1, 1.5, and 1.9.

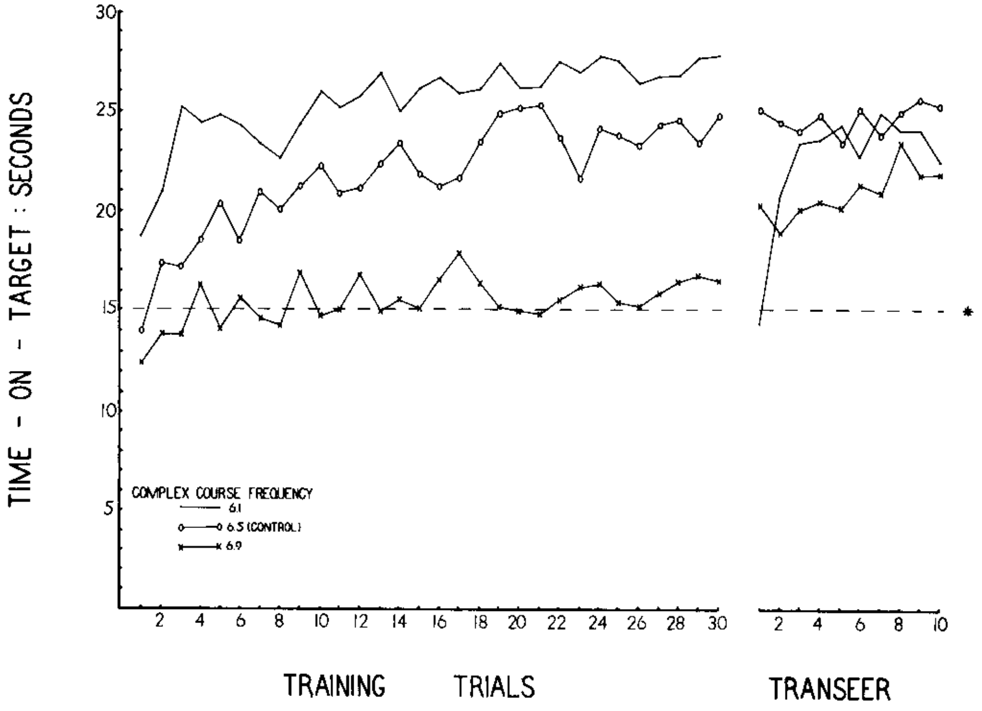

Figure 2. Complex Course Frequency: Training and Transfer Performance for Groups 6.1, 6.5, and 6.9.

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*Theoretical "performance" with no subject response.

Training Trials. Due to extreme inter-trial variability the data were blocked into groups of five trials. Means and standard deviations by blocked trials are presented in the Appendix. Using the chi-square distribution-free technique described by Wilson (14), analysis of the blocked-learning trials showed total chi-square values throughout training significant beyond the 1% level. The row (simple and complex-course frequency variations) chi-square values were not significant at any time during training. Column (phugoid conditions) chi-square values were statistically significant beyond the 1% level throughout training. There were no statistically significant interaction effects.

Separate analyses of the data for groups 1.1, 1.5, and 1.9 showed statistically significant performance differences throughout training. Analysis of the data for groups 6.1, 6.5, and 6.9 produced the same result.

Therefore, variations in simulated phugoid conditions produced reliable performance differences during training. This finding is in agreement with other studies in the present series (10,11). However, a change in the complexity of the forcing function course frequency did *not* differentially affect training performance.

Transfer of Training. In the preceding studies in this series, a distinction was made between "absolute" and "relative" transfer effect. By absolute transfer effect is meant the effect of learning a task on the *initial* learning of a second task. This is the classical question asked in studies of transfer of training (15). In the present study this concerns the effect of learning under phugoid conditions 1 and 9 on the initial learning with phugoid condition 5 for both cases of course complexity.

The term "relative transfer effect" refers to a quite different transfer question. By relative transfer effect is meant a comparison of the performance of the experimental groups (phugoid conditions 1 and 9) with the control group (phugoid condition 5) after all groups have received an equivalent number of training trials.

This distinction between absolute and relative transfer effect will be maintained in the discussion of the transfer data which follows.

1. Computation of absolute transfer effect is based on the equation proposed by Gagne, Foster, and Crowley (4):

$$\text{Per Cent Absolute Transfer Effect} = \frac{\text{Transfer Group Score} - \text{Control Group Score}}{\text{Total Possible Score} - \text{Control Group Score}} \times 100$$

Per cent absolute transfer effect is based on a comparison of the early transfer performance of the experimental groups with the early training performance of the two control groups (1.5 and 3.5). Table 2 shows these percentages computed separately for the first and second blocks of five trials for each comparison. A marked difference in the absolute transfer effect may be seen with respect to simple and complex-course frequency experimental groups. Transfer of the simple-course frequency groups resulted in negative transfer with respect to the initial training trials of the control group (1.5). On the other hand, positive absolute transfer effect was obtained in the trasnfer of the complex-course frequency groups.

TABLE 2

Experiment 6: Per Cent Absolute Transfer Effect

Blocked Transfer Trials	Per Cent Absolute Transfer Effects Simple			Complex		
	1.1	1.5	1.9	6.1	6.5	6.9
1-5	-12	50	0.3	30	54	19
6-10	-21	25	-20	32	45	10

2. The computation of relative transfer effect is based on a comparison of the experimental and control groups after all groups had received an equivalent number of training trials. Equation 3, as presented by Gagne, Foster, and Crowley (4) expresses this comparison:

$$\text{Per Cent Relative Transfer Effect} = \frac{\text{T score (trial x)} - \text{C score (initial)}}{\text{C score (trial x)} - \text{C score (initial)}} \times 100$$

Since the control group was given direct practice without change, the performance of this group is used as the base. With this equation, 100 per cent relative transfer means that the transfer gain was equal to the direct practice gain over an equivalent number of trials. Negative transfer values mean that there was a transfer loss relative to the direct practice gain over the trials block. In Table 3, per cent relative transfer effect is shown for all conditions on transfer trials 1-5 and 6-10. The 100 per cent values for the two control groups (1.5 and 6.5) are derived simply by a comparison of the control group score against itself.

TABLE 3

Experiment 6: Per Cent Relative Transfer Effect

Blocked Transfer Trials	Simple Course 1.1	1.5	1.9	Complex Course 6.1	6.5	6.9
1-5	-23	100	3	55	100	36
6-10	37	100	39	83	100	58

An over-all analysis of the performance on the blocked transfer trials showed statistically significant total, row (simple versus complex), and column (phugoid conditions) chi-square values. There was no significant interaction effect. A separate analysis of the transfer performance of groups 1.1, 1.5, and 1.9 showed statistically significant differences beyond the 1 per cent level throughout the course of transfer. This is evident from figure 1 and Table 3, which show the relatively poor performance levels of groups 1.1 and 1.9 as compared with the control group 1.5. It is obvious, however, that performance is improving for both groups as transfer progresses. Analysis of the performance of groups 6.1, 6.5, and 6.9 did not reveal any statistically significant differences except on the first transfer trial. Past the first transfer trial, however, the performance differences are not statistically significant.

In summary, these data appear to show that variations in training course frequency can affect both absolute and relative transfer of training with complex system dynamics. Training with the simple-course frequency appears to influence transfer performance to a greater extent than training with the complex-course frequency. In every case, transfer performance of the complex-course frequency groups was superior to the transfer performance of the simple-course frequency groups.

Discussion

Training. The finding that there were no significant differences in training performance between the simple and complex-course frequency groups is not in general consistent with prior investigations (cf., 2, 3, 9, 12). None of the previous studies however, used complex system dynamics, and comparisons between this study and others is not possible in the strictest sense. A visual examination of figures 1 and 2 would appear to suggest that performance levels with the complex-course frequency groups were higher than those with the simple-course frequency. As noted, however, these differences were not statistically significant.

Previous experiments (e.g., 12) would seem to indicate that variations in course complexity should be a more important variable with pursuit tracking than with compensatory tracking. By the nature of the compensatory task, the basic forcing function and the subject's output are mixed prior to display, with the result that the display movement is always "complex". In pursuit tasks, on the other hand, the forcing function and the subject's output are displayed separately, with the result, as Poulton (12) puts it, of "...an uncomplicated view of the 'stimulus' movement, and a similar direct view of the effect of control movements." It is not surprising that tracking performance differs with the two types of tasks, and it would be of interest to see whether or not differential results are obtained with the two tasks when variations in system dynamics such as those used in the present studies are introduced.

Transfer of Training. Variations in phugoid dynamics obviously produce variations in task difficulty during training. A considerable amount of experimental evidence has been published on the topic of transfer as affected by task difficulty (e.g., 2, 6), and it is of interest to examine the present data in this light. With both types of course frequencies, absolute transfer effect was greater from the less difficult phugoid condition (1.1 and 6.1) than the more difficult conditions (6.9 and 1.9); these findings are not in general consistent with most previous studies. Even more confusing is the fact that transfer with complex-course frequency groups was positive while transfer with the simple-course frequency groups was negative. There is certainly no obvious explanation for these findings, and additional experimentation would appear to be desirable.

Comparisons of these results with data from prior investigations is particularly hazardous due to the fact that most of the previous studies involved very simple output variables as compared with the present experimental apparatus and task. Perhaps the best that can be said at the present time is that the effects of task difficulty on transfer appear to differ radically, both as a function of course complexity and control system dynamics, if the present findings are found to be reliable.

Although time did not permit, it would have been interesting to compare transfer effects with (1) simple-to-complex and (2) complex-to-simple course frequency groups such as were studied, for example, by Jones and Bilodeau (6). Their data indicate that differential transfer of this sort results in greatest transfer from the complex to the simple task. Whether or not this would remain true with more complex system dynamics remains to be investigated.

Examination of the differential relative transfer effects showed that the complex course frequency groups were able to shift to the control condition with ease (except for a very transitory effect on the first transfer trial). This was not the case, however, with the simple-course frequency groups, and their transfer performance after an equivalent number of trials was significantly poorer than the direct practice (control) group. The present writers are unable to construct any simple explanation for this difference between the two-course frequency conditions. Further experimentation would appear to be in order.

III. EXPERIMENT 7: VARIATIONS IN COURSE AMPLITUDE

In addition to changes in course frequency, one of the simplest possible changes in the task forcing function is increasing course amplitude. A number of previous investigations (e.g., 1, 4, 5, 7, 8, 12) have shown that stimulus amplitude may play a role in determining level of tracking performance. The present study differs somewhat in that the increase in course amplitude is introduced in the forcing function rather than directly in the displayed element itself.

Experimental Method

Experimental Task and Apparatus. In the preceding study, variations in course frequency were studied. In the present experiment, variations in course amplitude were introduced with course frequency held constant. Given a trial with no subject stick input, the stimulus movement was ±.3 inch on the scope at the maximum amplitude of the simple sine wave pattern. This course amplitude relationship was maintained throughout all the six previous studies. For the present experiment, the course amplitude was doubled to ±.6 inch on the scope for maximum amplitudes of the simple sine wave function. Training and transfer performance were compared on the "low course amplitude" and the "high course amplitude" conditions. Thus, variations in course amplitude provided the primary experimental variable under study in the present experiment.

For control system dynamics, three simulated long period (phugoid) oscillatory transients were again selected. As was the case in Experiment 6, these were: (a) condition 1, with a period of 18 seconds and a time to damp to half amplitude of 17 seconds, (b) condition 5, with a period of 35 seconds and a damping term of 33 seconds, and (c) condition 9, with a period of 71 seconds and a damping value of 66 seconds.

Experimental Design. To investigate training and transfer effects as a function of course amplitude and simulated phugoid conditions, six experimental groups were assigned as shown in Table 4.

TABLE 4

Experiment 7: Experimental Design and Groups

	Phugoid Condition		
	1	5	9
Low-Course Amplitude	1.1	1.5*	1.9
High-Course Amplitude	7.1	7.5*	7.9

* Transfer Condition

Six independent groups were assigned to the experimental conditions. For the transfer trials, all groups shifted to or remained on one of the two transfer conditions (1.5 and 7.5).

Subjects. A total of 60 male undergraduate students from the University of Illinois provided data for this experiment. Half of the subjects had previously served on conditions 1.1, 1.5, and 1.9 as part of the basic experiment in this series (Experiment 1, 10). The remainder of the subjects were specifically assigned to this experiment for conditions 7.1, 7.5, and 7.9. Assignment of the subjects was random, with the restriction that they were equally divided between conditions. Each experimental group, therefore, consisted of 10 subjects.

Procedure and Response Measure. The same procedure was used in this study as has been described in Experiment 6. To insure validity of the comparisons between data derived here and data derived from Experiment 1, particular care was taken to insure that the only difference between the groups was with respect to the variable of course amplitude. The response measure was again TOT for each of the 30 training and 10 transfer trials.

Results

The major findings in this experiment are shown graphically in figures 3 and 4. Figure 3 shows mean TOT scores for phugoid conditions 1.1, 1.5, and 1.9 using the low course amplitude. Figure 4 shows mean TOT scores for phugoid conditions 7.1, 7.5, and 7.9 using the same phugoid transients, but with the high-course amplitude.

As usual, theoretical performance with no subject stick input is shown on each figure. Due to the fact that the amplitude relationship is changed, the TOT scores differ. For the low-course amplitude, if the subject had done nothing, he could have achieved a 15-second TOT score per trial. For the high-course amplitude condition, this figure is cut in half to 7.5 seconds per trial.

Training Trials. Again, due to extreme inter-trial variability, the data were blocked into groups of five trials. Means and standard deviations of the blocked trials for both training and transfer may be seen in the Appendix. Using the chi-square distribution-free technique described by Wilson (14) and assuming the 1% level of significance throughout, analysis of the blocked training trials showed total, row (low and high-course amplitude), and column (phugoid conditions) significant chi-square values. There was no statistically significant interaction effect. Separate analyses of the data for groups 1.1, 1.5, and 1.9 and groups 7.1, 7.5, and 7.9 resulted in statistically significant differences beyond the 1% level throughout the training trials.

Thus, both course amplitude variations and variations in simulated phugoid conditions influenced the level of training performance. It may be seen in figure 4 that training performance levels with high-course amplitude are substantially below performance with the same phugoid conditions and low-course amplitude as shown in figure 3. Over all, training performance for the high-course amplitude groups was only slightly more than half the level attained by the low-course amplitude groups over the last 10 training trials. Indeed, as may be seen in figure 4, only group 7.1 showed any evidence of improvement during training.

Transfer of Training. A distinction will again be made in the analysis of the transfer data between absolute and relative transfer effect. The computational formulae described in Experiment 6 will be used in making the absolute and relative comparisons.

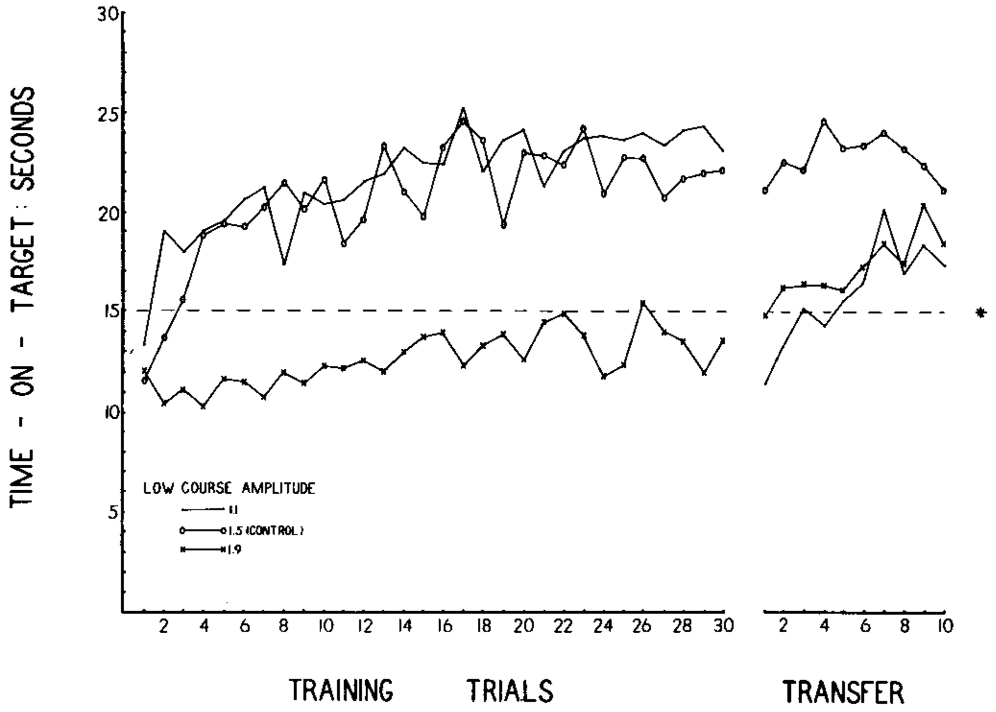

Figure 3. Low-Course Amplitude: Training and Transfer Performance for Groups 1.1, 1.5, and 1.9.

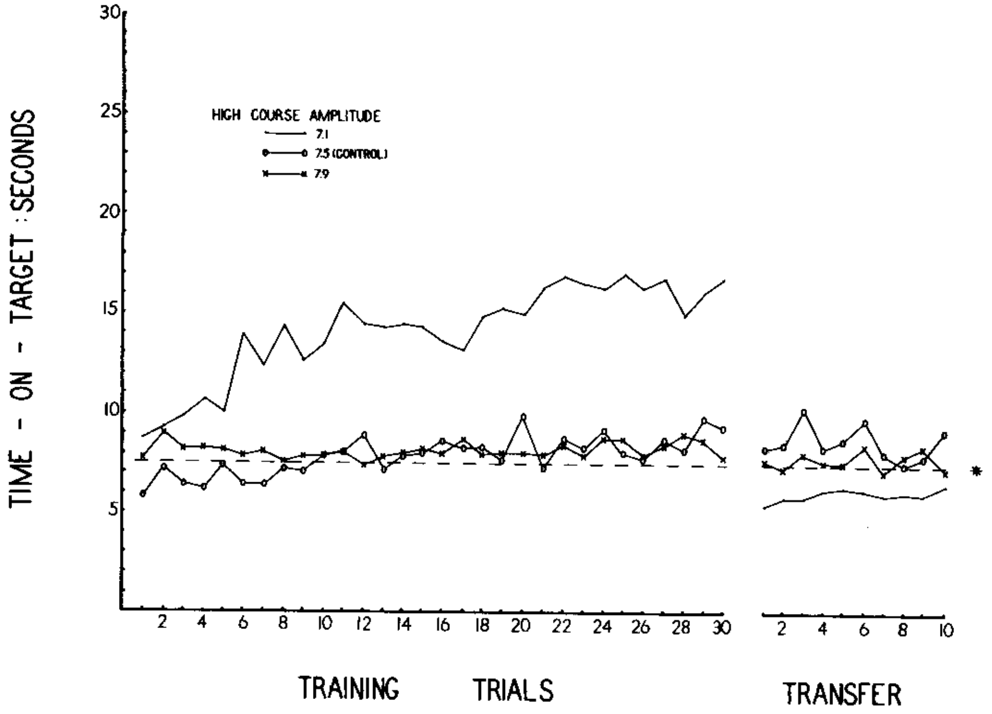

Figure 4. High-Course Amplitude: Training and Transfer Performance for Groups 7.1, 7.5, and 7.9

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*Theoretical "performance" with no subject response.

1. Table 5 shows per cent absolute transfer effect based on a comparison of the transfer performance of each experimental condition with the first 10 training trials of the control groups (1.5 and 7.5).

TABLE 5

Experiment 7: Per Cent Absolute Transfer Effects

Blocked Transfer Trials	Per Cent Absolute Transfer Effects					
	Low Amplitude			High Amplitude		
	1.1	1.5	1.9	7.1	7.5	7.9
1-5	-12	50	0.3	-3.3	9.0	-4.2
6-10	-21	25	-20	-4.4	6.2	-5.8

Analysis of the transfer data for groups 7.1 and 7.9 as compared with the first 10 training trials of control group 7.5 showed no statistically significant differences.

2. Table 6 presents per cent relative transfer effect based on a comparison of the experimental groups with their respective controls (1.5 and 7.5) after all groups had received an equivalent number of training trials.

TABLE 6

Experiment 7: Per Cent Relative Transfer Effect

Blocked Transfer Trials	Per Cent Relative Transfer Effect					
	Low Amplitude			High Amplitude		
	1.1	1.5	1.9	7.1	7.5	7.9
1-5	-23	100	3	-37	100	47
6-10	37	100	39	-36	100	95

Previous analysis of the transfer performance of groups 1.1, 1.5, and 1.9 had shown statistical significance beyond the 1% level throughout the transfer trials. A separate analysis of the performance of groups 7.1, 7.5, and 7.9 for the 10 transfer trials also produced statistical significance beyond the 1% level. As may be seen in figure 4, however, the magnitude of the differences between groups 7.1, 7.5, and 7.9 during transfer is very small. All groups are performing at about the level that could be obtained with no subject stick movement at all.

Discussion

Training Trials. Increasing course amplitude resulted in a substantial degradation of the level of tracking performance. With a high-course amplitude, only one phugoid condition (7.1) showed any evidence of learning over the 30 training trials.

It is of interest that such a simple change as increasing course amplitude should have produced such marked effects. The explanation is, however, rather simple. The increase in course amplitude required an increase in the gain of the subject's output. Due to the nature of the system dynamics and the phugoid transients, increased subject gain resulted in more frequent elicitation of transients; graphic performance records showed considerable instability and frequent complete loss of control by the subject. These data suggest the very sensitive nature of human tracking performance with complex system transients. A slight change in a system element can result in a performance shift from quite adequate operator control to no control at all. In the conduct of studies of this nature it is apparent that careful examination must be made of the various system parameters involved, particularly if extrapolation of the data to an actual man-machine system is desired. A slight change in the actual system elements might result in operator performance quite different from that predicted by laboratory experimentation.

Transfer of Training. It is difficult to discuss transfer of training in this study in any meaningful sense. Two of the three high course amplitude groups showed little learning, and transfer was to a control condition where little learning might be expected. No absolute transfer effect of any magnitude was obtained with the high-course amplitude groups, and considering the training performance levels, none should perhaps have been expected.

Nevertheless, a differential relative transfer effect was obtained. Apparently a shift from condition 1 to condition 5 after an equivalent number of training trials was made with somewhat less difficulty than a shift from condition 9 even at these very low levels of performance. The writers can offer no obvious explanation for this result.

A Final Comment. One of the objectives of human factors laboratory experiments is to provide data for extrapolation to the design of man-machine systems. While most actual systems involve very complex system dynamics, the majority of laboratory experiments have used very simple dynamics. It is suggested that extrapolation from the latter to the former may be risky indeed. It is further suggested that a great deal more laboratory experimentation is required to investigate systematically display and control variables with higher order control systems. Without these data, the only safe design choice is to limit the operator to simple subsystems. Often, however, this is neither desirable nor possible, and when the operator must be used in a complex control loop, the human factors specialist is faced with a rather acute problem in applying presently available data.

BIBLIOGRAPHY

1. Conklin, J. E. "Effect of Visual Surround on Tracking Performance." Perceptual Motor Skills, Vol 8 (2), pp 115-118, 1958.

2. Day, R. H. "Relative Task Difficulty and Transfer of Training in Skilled Performance." Psychological Bulletin, Vol 53(2), pp 160-168, 1956.

3. Fitts, P. M., Marlowe, E., and Noble, M. E. The Interrelations of Task Variables in Continuous Pursuit Tasks: I. Visual-Display Scale, Arm-Control Scale and Target Frequency in Pursuit Tracking. Research Bulletin 53-34, USAF, Human Resources Research Center, Washington, D. C., 1953.

4. Gagne, R. M., Foster, H., and Crowley, M. E. "The Measurement of Transfer of Training." Psychological Bulletin, Vol 45, pp 97-130, 1948.

5. Hartman, B. O., and Fitts, P. M. "Relation of Stimulus and Response Amplitude to Tracking Performance." Journal of Experimental Psychology, Vol 49 (2), pp 82-91, 1955.

6. Jones, E. I. and Bilodeau, E. A. Differential Transfer of Training Between Motor Tasks of Different Difficulty. Research Bulletin, USAF, Human Resources Research Center, Washington, D. C., 1952.

7. Krendel, E. S. The Spectral Density Study of Tracking Performance, Part 2. The Effects of Input Amplitude and Practice. WADC, Technical Report 52-11, Wright Air Development Center, Wright-Patterson Air Force Base, Ohio, 1952.

8. Krendel, E. S. and Barnes, G. H. Interim Report on Human Frequency Studies. WADC Technical Report 54-370, Wright Air Development Center, Wright-Patterson Air Force Base, Ohio, 1954.

9. Lincoln, R. S. and Smith, K. U. "Visual Tracking: II. Effects of Brightness and Width of Target." Journal of Applied Psychology, Vol 36, pp 417-421, 1952.

10. Muckler, F. A., Obermayer, R. W., Hanlon, W. H., Serio, F. P. and Rockway, M. R. Transfer of Training with Simulated Aircraft Dynamics: I. Period and Damping of the Phugoid Response. WADD Technical Report 60-615 (I), Wright Air Development Division, Wright-Patterson Air Force Base, Ohio, 1961.

11. Muckler, F. A., Obermayer, R. W., Hanlon, W. H., and Serio, F. P. Transfer of Training with Simulated Aircraft Dynamics: II. Variations in Control Gain and Phugoid Characteristics. WADD Technical Report 60-615 (II), Wright Air Development Division, Wright-Patterson Air Force Base, Ohio, 1961.

12. Noble, M. E., Fitts, P. M., and Marlowe, E. The Interrelations of Task Variables in Continuous Pursuit Tasks: II. Visual-Display Scale, Arm Control Scale and Target Frequency in Compensatory Tracking. Research Bulletin 53-55, USAF, Human Resources Research Center, Washington, D. C., 1953.

13. Poulton, E. C. "Perceptual Anticipation in Tracking with Two-Pointer and On-Pointer Displays." British Journal of Psychology, Vol 43, pp 222-229, 1952.

14. Wilson, K. V. "A Distribution-Free Test of Analysis of Variance Hypotheses." Psychological Bulletin, Vol 53, pp 96-101,

15. Woodworth, R. S. and Schlosberg, H. Experimental Psychology, (Revised Edition Chapter 24), New York: Henry Holt, 1954.

APPENDIX

MEANS AND STANDARD DEVIATIONS BY BLOCKED TRIALS

TABLE 7

Experiment 6

	Blocked Trials	EXPERIMENTAL GROUPS					
		6.1	1.1	6.5	1.5	6.9	1.9
Training Trials	1-5	113.81* 8.85**	88.16 20.38	86.98 19.73	78.77 10.70	69.61 12.00	55.06 13.56
	6-10	119.99 10.20	100.46 19.42	102.50 19.50	101.35 14.68	75.56 9.95	57.42 6.41
	11-15	128.32 6.74	109.69 18.21	109.00 15.60	101.72 11.97	77.02 10.07	63.01 11.31
	16-20	132.54 8.47	116.10 9.71	115.81 11.58	114.40 9.28	80.48 10.69	63.00 5.50
	21-25	135.22 5.74	115.43 10.32	117.75 11.07	112.64 14.77	77.86 7.95	66.92 9.70
	26-30	134.58 7.33	118.63 10.19	119.55 13.53	118.18 16.15	79.18 8.54	68.15 13.90
Transfer Trials	31-35	105.62 17.55	69.44 16.06	120.91 14.52	114.17 13.68	99.20 19.63	78.95 14.14
	36-40	117.62 17.55	91.17 22.82	123.98 14.15	113.64 11.20	108.44 15.72	91.64 12.70

* Mean in seconds.
**Standard Deviation in seconds.

TABLE 8

Experiment 7

	Blocked Trials	EXPERIMENTAL GROUPS					
		7.1	1.1	7.5	1.5	7.9	1.9
Training Trials	1-5	48.57* 9.79**	88.16 20.38	33.20 5.36	78.77 10.70	40.84 4.65	55.06 13.56
	6-10	66.83 11.67	100.46 19.42	35.08 6.62	101.35 14.68	39.44 5.31	57.42 6.41
	11-15	73.00 9.31	109.69 18.21	39.93 6.41	101.72 11.97	39.38 5.55	63.01 11.31
	16-20	71.84 11.80	116.10 9.71	40.93 5.80	114.40 9.28	40.66 4.49	63.00 5.50
	21-25	82.87 10.24	115.43 10.32	41.33 2.88	112.64 14.77	41.72 2.76	66.92 9.70
	26-30	80.74 10.58	118.63 10.19	43.49 4.96	111.18 16.15	41.63 2.79	68.15 13.90
Transfer Trials	31-35	29.32 5.77	69.44 16.06	43.67 8.49	114.17 13.68	38.07 5.76	78.95 14.14
	36-40	29.98 4.59	91.17 22.82	42.25 7.17	113.64 11.20	41.77 11.15	91.64 12.70

* Mean in seconds.

** Standard Deviation in seconds.