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EFFECTS OF STRESS ON PERFORMANCE IN A DOMINANT AND A NON-DOMINANT TASK

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FOREWORD

This experiment was conducted at Antioch College as part of the work accomplished under U.S. Air Force Contract No. W33-038 ac-19816, R & D Order No. 694-31. Dr. Charles W. Simon was project director on the contract at the time the study was conducted, in 1951, and Major Edward Cole was project engineer.

Dr. William C. Biel, of the Psychology Branch, Aero Medical Laboratory, gave considerable aid in formulating the problem and made numerous suggestions in the design of the experiment and apparatus. Dr. Paul M. Fitts, of Ohio State University, offered valuable suggestions in the design, analysis, and writing of this paper. Mrs. Dian Simon ran a majority of the subjects and did most of the analysis of the data. Considerable aid was obtained from numerous Antioch students working for the project. Additional subjects were obtained through the splendid cooperation of the administration at Wittenberg College, Springfield, Ohio, who provided the space and facilities required to perform the experiment there.

ABSTRACT

Considerable research has been expended to discover instrument designs requiring for their successful operation a response pattern used most frequently by the majority of the population. Substituting such designs, for others on which operators apparently perform at a comparable level only after extensive training, has usually been justified by the hypothesis that under stress, operator performance tends to retrogress less when dominant response patterns are required. The hypothesis was tested in the experiment reported here.

Eighty male college students were divided into four equal groups. One group practiced for 96 trials on a "dominant" task; the remaining groups practiced for 96 trials a day for one, two, or three days respectively on a "nondominant" task. The task -- proper positioning of a light in an arc of lights by turning a rotary knob -- was termed "dominant" when a clockwise movement of the control moved the light clockwise. The task was termed "nondominant" when a clockwise movement of the knob moved the light counterclockwise. Following the practice session, an experimental stress period was introduced. One half of each group worked under mildly stressful conditions in which they were required to perform a compensatory pursuit task while responding at intervals to the positioning task. The other half worked under more severe stress, performing the pursuit task while simultaneously solving simple arithmetical problems.

Stress as defined above resulted in more reversal errors for subjects performing on the originally nondominant task than for those performing on the originally dominant one, although both groups had practiced to an apparently equal performance level previously. Response time and individual response time variability, only indirectly related to the original dominance measure, reflected this tendency under mild stress only, while overshoot errors showed no differential effects of stress. Additional practice on the nondominant task was insufficient in this experiment to decrease the disruptive effects of stress on performance. The results are discussed in terms of current learning theory. The concept of "dominance" was more precisely defined.

PUBLICATION REVIEW

This report has been reviewed and is approved.

FOR THE COMMANDER:

Jack Bollerud

JACK BOLLERUD
Colonel, USAF (MC)
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1. INTRODUCTION

With the development of modern complex machines and equipment, simple mistakes can often be fatal. Designing display and control equipment to make its use easier for the average individual under normal conditions is not sufficient. It has become apparent that a good design is not merely one the human can handle under routine conditions. Instead, it is in the stress situation that the need for well designed equipment becomes most critical.

Fitts (8) summed up the general viewpoint on this issue by writing: "It has been assumed by some writers that even if an individual greatly overlearns a response that is contrary to an earlier learned habit, he will frequently revert to the population stereotype under the stress of an emergency. There is no experimental evidence to show that this hypothesis holds for the interpretation of instruments or the operation of controls, although anecodotal reports appear to support it"(p. 36).

Fitts had suggested the term "population stereotype" for the commonly observed behavior pattern since it implied "...only the notion of frequency of occurence with no implication that the response is learned or innate" (p. 36). The present writer has used the word "dominant" in much the same manner as Fitts used "population stereotype" to avoid the tongue-twisting difficulties involved in saying the multi-syllabic "non-population-stereotype" and to avoid the specific connotations which the latter term has already acquired with certain stimulus-response motion relationship problems.

The following definitions will be used throughout this paper:

1. A dominant response is that one of a number of alternative responses which is made by the greatest proportion of the population in a free situation.

2. A dominant task or design is one in which the dominant response is the correct one.

3. Nondominant responses are the ones not freely made by the greatest proportion of the population when a number of alternative responses is provided.

4. A nondominant task or design is one in which a nondominant response is the correct one.

Although these operational definitions make use only of data for normal situations, we might also expect a better performance under stress with a dominant task than with a nondominant task. This follows if we hypothesize that there is a tendency to return to the dominant response under stress, and accept, by definition, that this is the correct response for the dominant and the incorrect one for the nondominant task. This generates a second hypothesis which may be stated more precisely in this manner:

> Though apparently performing at comparable levels with either task under ordinary conditions, under conditions of stress, operators working with what was originally a nondominant task will tend to retrogress more in performance than those working with the dominant task.

In one study, Vince (25) tested this hypothesis but felt that her results failed to support it.

The present experiment is an attempt to retest the hypothesis on a task somewhat different from the one used by Vince and with two levels of stress. A second hypothesis was also examined:

> Additional practice on the nondominant task will tend to reduce the disruptive effects of stress.

II. APPARATUS

The apparatus used in this experiment consisted of the following six major parts (see Figure 1):

- A Mock-up cockpit
- B Primary task (intermittent positioning)
- C Subordinate task (continuous pursuit)
- D Dual pursuit apparatus for pursuit task
- E Experimenter's control panel and kymograph
- F Wire recorder and play-back unit

The mock-up cockpit (A), a stripped down C-3 Link Trainer fuselage disconnected from its base, served only to eliminate external environmental disturbance during the experimental period and to provide "atmosphere" for subject appeal. The original cockpit instrument panel was removed and replaced by a black panel on which the experimental positioning task (B) was located to the right of center and a subordinate, pursuit task (D) in midcenter. This panel, approximately 28 inches in front of the subject, was illuminated by two 28-volt white cockpit lights. An electric fan at the front of the cockpit below the panel helped to maintain a comfortable temperature when the cover was closed.

The experimental positioning task (B) consisted of 2 parallel arcs of 7 lights and a control knob. The lower green lights were controlled by the experimenter. The upper red lights could be controlled with the

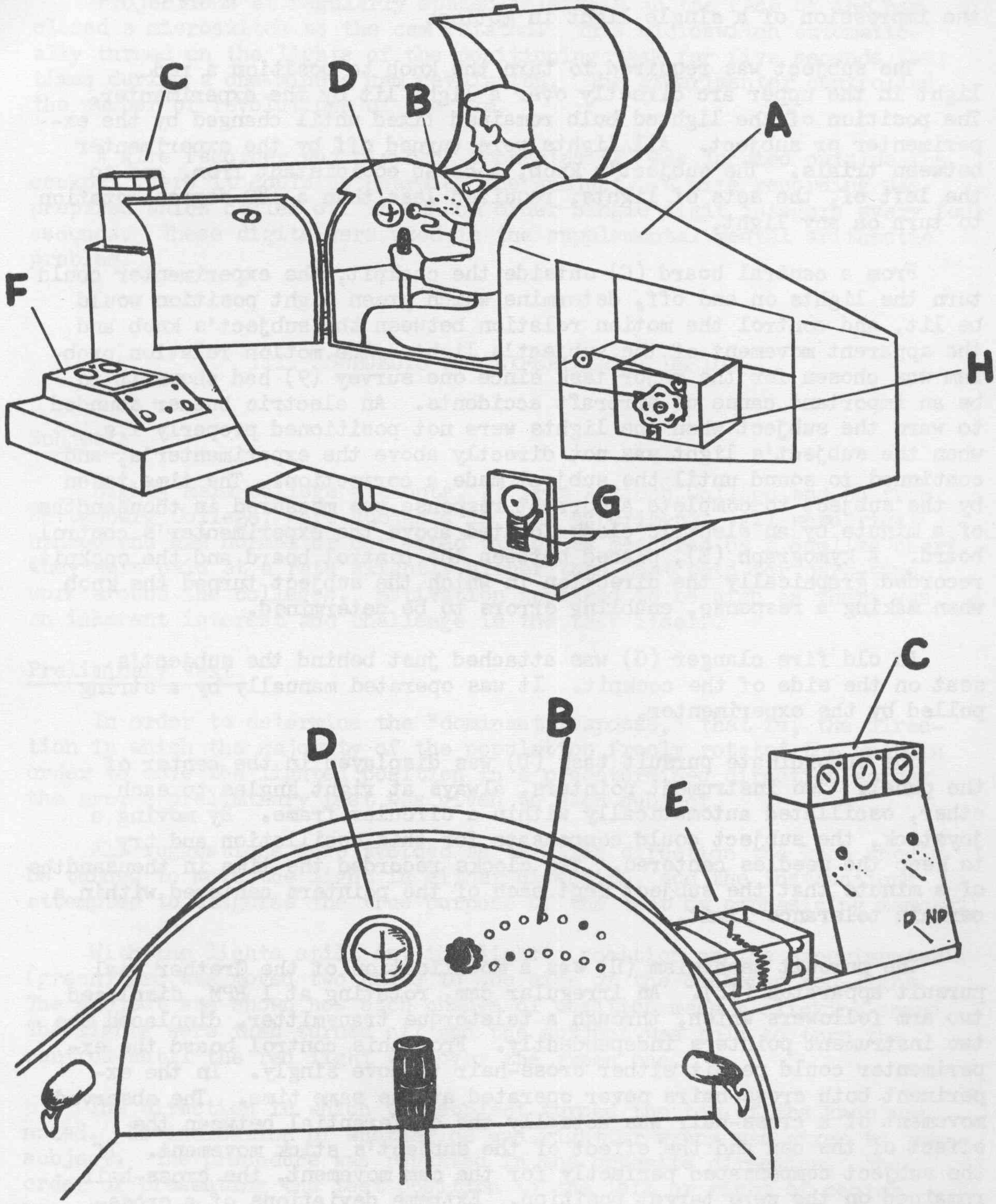

Figure 1. Views of Experimental Apparatus

panel knob by the subject. Only one bulb in each arc could be lit at any time. The display was electrically wired, so that a quick turn of the subject's control knob caused bulbs to light successively, giving the impression of a single light in motion.

The subject was required to turn the knob to position a red light in the upper arc directly over a light lit by the experimenter. The position of the lighted bulb remained fixed until changed by the experimenter or subject. All lights were turned off by the experimenter between trials. The subject's knob, located equidistant from, and to the left of, the sets of lights, required less than a 180 degree rotation to turn on any light.

From a central board (C) outside the cockpit, the experimenter could turn the lights on and off, determine which green light position would be lit, and control the motion relation between the subject's knob and the apparent movement of the subject's light. The motion relation problem was chosen for the major task since one survey (9) had shown it to be an important cause of aircraft accidents. An electric buzzer sounded to warn the subject when the lights were not positioned properly i.e., when the subject's light was not directly above the experimenter's, and continued to sound until the subject made a correction. The time taken by the subject to complete a correct response was measured in thousandths of a minute by an electric clock located above the experimenter's control board. A kymograph (E), placed between the control board and the cockpit, recorded graphically the direction in which the subject turned the knob when making a response, enabling errors to be determined.

An old fire clanger (G) was attached just behind the subject's seat on the side of the cockpit. It was operated manually by a string pulled by the experimenter.

The subordinate pursuit task (D) was displayed in the center of the panel. Two instrument pointers, always at right angles to each other, oscillated automatically within a circular frame. By moving a joystick, the subject could compensate for this oscillation and try to keep the needles centered. Two clocks recorded the time in thousandths of a minute that the subject kept each of the pointers centered within a certain tolerance limit.

The pursuit mechanism (H) was a modification of the Grether dual pursuit apparatus (12). An irregular cam, rotating at 1 RPM, displaced two arm followers which, through a teletorque transmitter, displaced the two instrument pointers independently. From this control board the experimenter could permit either cross-hair to move singly. In the experiment both cross-hairs never operated at the same time. The observed movement of a cross-hair was actually the differential between the effect of the cam and the effect of the subject's stick movement. If the subject compensated perfectly for the cam movement, the cross-hair remained on the zero target position. Extreme deviations of a cross-hair in either direction from the zero point automatically sounded a buzzer.

Projections at regularly spaced intervals on the face of the cam closed a microswitch as the cam rotated. This microswitch automatically turned on the lights of the positioning task for five seconds four times during a one-minute cam revolution. The experimenter controlled the number of revolutions of the cam.

A wire recorder and playback apparatus (F) was located outside the cockpit where it could be heard by the subject. A wire recording was prepared which called off in random order single digit integers every four seconds. These digits were used in the supplemental mental arithmetic problem.

III. SUBJECTS AND EXPERIMENTAL DESIGN

Subjects

Eighty male college students, 26 from Antioch College and 54 from Wittenberg College, were subjects in this experiment. All were right handed and had normal or corrected vision as measured by a Snellen chart. They were paid at a rate slightly higher than that paid for part-time work around the colleges. Motivation appeared to be high as there was an inherent interest and challenge in the task itself.

Preliminary Test

In order to determine the "dominant response," that is, the direction in which the majority of the population freely rotated the knob in order to move the lighted position in a predetermined direction across the arc, a preliminary test was given to each subject.

All suggestions were avoided as to which direction the knob should be turned to move the light in either direction, and the instructions attempted to disguise the true purpose of the test by emphasizing memory.

With the lights still on, the lighted position on the experimenter's (green) arc was moved two bulbs to one side of the centered red light. The subject was shown how each change of position made a clicking sound. The lights were then turned off and the subject was told to turn the control until the red light was over the green one.

The direction in which the subject turned the top of the knob was noted. No indication of whether he was right or wrong was given to the subject. The procedure was repeated in the opposite direction. The order of presenting the test position to the left or right of center was counterbalanced between subjects.

If the two trials failed to agree, no comments were made, but a third trial was given. It was unnecessary to give the third trial except in a very small number of cases where subjects were still unclear about the instructions. Most of the subjects were consistent with themselves from the first to second trial, turning the top of the knob in the direction they wished to move the light.

Design and Operational Definitions

The 80 male subjects were divided into 8 groups of ten subjects each. Each group represented a different experimental condition, as shown in Table I.

TABLE I

EXPERIMENTAL GROUPS OF THE 80 SUBJECTS

	Days of Practice			
	Dominant Task	Nondominant Task		
	1-Day	1-Day	2-Day	3-Day
Degree of Stress				
Mild Stress	10 Ss	10 Ss	10 Ss	10 Ss
Severe Stress	10 Ss	10 Ss	10 Ss	10 Ss

"Dominant" or "nondominant" refers to the motion relation between control and lights which a subject group used throughout the practice and experimental periods. "Dominant," as defined earlier, described the task requiring for its successful operation the motion relation for which the population had shown a response preference during the preliminary trials. Thus, a successful operation of the "dominant" task required that the top of the knob be turned in the same direction that the subject's light had to shift in order to be positioned above the experimenter's light. The "nondominant" task required that the top of the knob be turned in the direction opposite to that in which the subject's light had to shift in order to be brought directly above the experimenter's light.

Previous experimenters have defined or created stress in various ways and have attributed it to numerous causal factors. It was decided that in order to be able to generalize from our research with stress as much as possible, the characteristics representative of the majority of these situations should be used in the present experiment. The present writer believes the following requirements are representative of stress situations described in the psychological literature:

1. The individual is actively engaged in trying to reach a goal, which he does not yet consider inaccessible.

2. Conditions in the environment or limitations within the individual interfere or threaten to interfere with progress toward the goal.

Examples from many areas of psychology are given in the writer's doctoral dissertation (24, pp. 92-94) to illustrate how opinions and methods of psychologists concerned with the problem of stress tend to reflect the above requirements.

In this experiment, motivation was left untouched, while the difficulty of succeeding on the positioning task was increased for the stress period. All subjects were consistently urged to do better, and evidence that their motivation did not decrease is furnished by the general improvement in performance during the practice period. Mild Stress was created by having the subject perform the positioning task while concurrently operating the continuous pursuit task. This second task made it difficult for him to maintain the performance level achieved during practice on the positioning task. Severe Stress was created by having the subject follow the above procedure and also requiring him at the same time to respond orally with the solutions to simple addition problems.

In Table I the number of days each group of subjects practiced before encountering the experimental stress period is indicated. Each day's practice consisted of six problem sets of 16 positioning trials.

IV. PROCEDURE*

The Practice Period

The subject was seated comfortably in the open cockpit. Training on the pursuit task was given immediately following the preliminary test period for one-day subjects, and the first thing on the last practice day of all other subjects. This consisted of eight 30 second trials on the horizontal cross-hair.

Immediately following the above practice for all one-day subjects or following the first day of preliminary tests for all other subject groups, subjects were practiced on the positioning task. The cross-pointers did not operate during this practice period and the cockpit hood was up. The subject was told to hold the stick with his left hand and place his right hand in a resting position over the top of the stick. When the lights went on, he was told to move his hand quickly from the stick and turn the knob to bring the red light over the green light. If the subject was in the dominant group, he was told to turn the top of the knob in the direction he wished the light to move; if he was in

*The precise instructions and secondary details of the procedure can be found in the writer's doctoral dissertation (24, pp. 18-26).

the nondominant group, he was told to turn the bottom of the knob in the direction he wished the light to move. These latter instructions were equivalent to having subjects turn the top of the knob in the direction opposite to that in which they wished the light to move, but were easier to explain and were accepted less critically by the subjects. As long as the lights were not corrected, a buzzer sounded. Subjects were instructed to try first to eliminate any errors in direction, and then to improve their speed.

The experimenter gave each subject four supervised practice trials. If any subject failed to understand the proper manner in which he should turn the knob, it was explained again and an effort was made to see that he did it correctly during the supervisory period. Most of those who had difficulty in understanding the instructions were from the nondominant groups.

Instructions were repeated at the beginning of each practice day for subjects in the two and three-day groups.

Each subject was given six sets of 16 practice trials on each practice day. Thus there were 96 practice trials on the positioning task for the one day group, 192 for the two, and 288 for the three. During the practice periods, the interval between trials varied slightly, allowing the experimenter to write down the response time and errors, and to reset the lights. To avoid developing a temporal response pattern in the subjects, no constant time interval between trials was used. Subjects were not given a ready signal. Between sets of 16 trials, the rest periods were from one to two minutes long. During the rest periods, the experimenter generally discussed the subject's mistakes and encouraged him to do better. Subjects who worked for two and three days returned at the same hour on successive days.

The position at which the experimenter's light appeared was varied from one trial to another. Two sequences of sixteen trials were used alternately. The sequences were so devised that neither of the bulbs at either end of the arc (positions 1 and 7) were ever lit. These two sequences, as presented by the experimenter, were (in terms of light's position from the left of the display): Order A- 2,5,6,3,6,3,2,4,6,4,5,3,2,5,6,4; Order B- 6,4,5,3,2,5,3,4,2,5,6,3,6,2,4. The correct position of the subject's bulb on one trial determined the position where it would light on the succeeding trial. The experimenter, of course, changed his light while the lights were out, forcing the subject to move his to the new position when they came on. For the first trial of each problem set the subject's center bulb (Position 4) was lit as a starting point. Both of the presentation orders required the subject to rotate the knob clockwise and counterclockwise an equal number of times, though not alternately. To position his light correctly, the subject was required to move it one, two, or three positions to either side for 5, 6, and 5 trials respectively.

During the practice period, the experimenter turned on the lights manually and recorded the subject's response time. The subject was told each problem set of 16 trials. Movement errors as seen on the kymograph record were also recorded.

The Experimental Stress Period

Mild Stress. Once the practice period was completed on the final day, the experimental stress period occurred. The vertical pointer of the continuous task was turned on and the subject was shown how to control it by moving the stick to the left and right in the same direction he wished to move the pointer to bring it to the center mark. He was told that the horizontal cross-hair on which he had previously practiced would not operate.

He was then instructed as follows:

> "Continue to use your left hand to operate the stick and keep your right hand on top of it, prepared to operate the lights when they flash on. By keeping the horizontal cross-hair centered, you will be making a safe landing. However, you have to watch out for engine trouble — which is what we will pretend these lights represent — and correct for it, in order not to crash. When the lights and buzzer go on, you must bring the red light quickly over the green light, just as you practiced it. Then bring your hand back to the stick immediately. Remember we will pretend that you are landing a plane by the use of your instruments — the cross pointer — and must keep it centered to do so safely. However, whenever you have engine trouble — when the lights go on — you must correct it quickly to avoid a crash. Are there any questions?"

The hood was placed over the cockpit. The lights were focused on the cross pointer and knob, leaving the arc of bulbs somewhat shaded. The experimenter used light position order B of the practice period for the experimental problem period. Thus, the orders for the last practice trial and the experimental stress period were the same. The lights were turned on and off automatically by the rotating cam of the pursuit apparatus.

During the experimental stress period the subject compensated for the movements of the vertical cross pointer, using his left hand on the stick. The cross pointers oscillated during four one-minute rotations of the cam. The positioning lights came on at relatively equal intervals and remained on for five seconds accompanied by the warning buzzer. This provided enough time for even the poorest subject to correct them. They came on four times per cam revolution, or 16 times during the four-minute stress period. Subjects had to attend to both tasks simultaneously.

Subjects were told that a bell would sound if they failed to respond rapidly enough to the positioning task (thus "crashing"). Actually a fire clanger was rung on the same specified trials for all subjects, who did not suspect it was a false signal. Whenever subjects failed to keep the vertical pointers within rather wide tolerance limits, a loud buzzer would sound. These auditory devices discouraged subjects from ignoring either task for the sake of the other.

Severe Stress. The experimental period for the severe stress group was carried out in the same manner as for the mild stress group, with these additional instructions and conditions:

> "Since you are having engine trouble while making this blind landing, you will also receive instructions from the Tower. They will give you landing instructions in the form of numbers. This is how it will work: numbers will be called to you and you must answer with the sum of the last two numbers that were called out. For example, I would say 3, 5; you would answer 8. I would then say 4; you would say 9, adding the last two numbers I call out, not your own."

The subject was given examples until he understood this new task.. The play-back apparatus was started. On it were the instructions for the subject to "get ready," "begin," and the numbers, all single digit integers, which were called 4 seconds apart. The actual numbers were 2,6,3,1,9,4,5,7,2,3,8,6,5,3,4,2,9,7. This list was repeated. No attempt was made to record errors in addition; when any was noted, the experimenter called to the subject to correct it. When the subject became excessively confused with a pair of numbers, he was told to go to the next set. Both their behavior and their comments left little doubt of the strain the mental arithmetic, plus the other two tasks, imposed on the subjects.

V. RESULTS

The Measures Obtained

During one set of 16 trial positioning problems, the following measures were obtained of each subject's performance on the positioning task:

1. Response time: the average time in .001 of a minute required for the subject to position his light correctly above the experimenter's light.

2. Reversal errors: the number of times in 16 trials that the subject's initial response was to turn his knob so as to move his light in the direction away from the experimenter's.

3. Overshoot errors: the number of times in 16 trials that the subject's initial response was to turn his knob so that his light moved in the correct direction but passed beyond

the experimenter's light.

4. Variability: the standard deviation of the response time during the 16 trials in any one set.

When multiple, complex error movements were made, all responses beginning with movements in the incorrect direction were counted as a single reversal error, irrespective of the movements which followed. Any other type of multiple error was called an overshoot.

A fifth measure was taken during the stress period. The amount of time during which the subject held the vertical cross pointer in the pursuit task within the tolerance limits during the entire stress set was recorded in thousandths of a minute.

Learning Curves

The learning curves for measures of response time, reversal errors, and overshoot errors of subjects working on the dominant task and nondominant task are shown in Figures 2, 3, and 4 respectively. The curve of the nondominant task group represents the mean trend of 60 subjects' scores on the first day, 40 on the second, and 20 on the third. Subgroup scores are well represented by the mean curve.

The time required to position the light correctly decreased in a negatively accelerated manner for practice groups operating both the dominant task and nondominant task. However, the mean performance level of the nondominant task did not reach that of the dominant task until the end of the second practice day. Initial responses were slower on the problem set following the between-days rest interval, though earlier performance levels were reached again by the second problem set of the day.

There appeared to be little or no reduction in the number of reversal errors for the dominant task group. This absence of learning may be due to the fact that the number of reversals was so small, only slightly above zero, from the very beginning. However, the number of reversal errors made during practice on the nondominant task showed a negative deceleration throughout the practice period. It was not until the end of the second day of practice that the number of reversal errors made by the nondominant task group reached a level not significantly different from that of the nondominant task group.

The overshoot errors, plotted to give a learning curve, showed only slight improvement with practice. No differences in the number of overshoots made during practice could be observed between the dominant task and nondominant task groups.

Choice of Groups to Study

Our interests in the differential effects of stress on the dominant task and nondominant task were based on the premise that before stress, all groups would be trained until they were performing at an equivalent

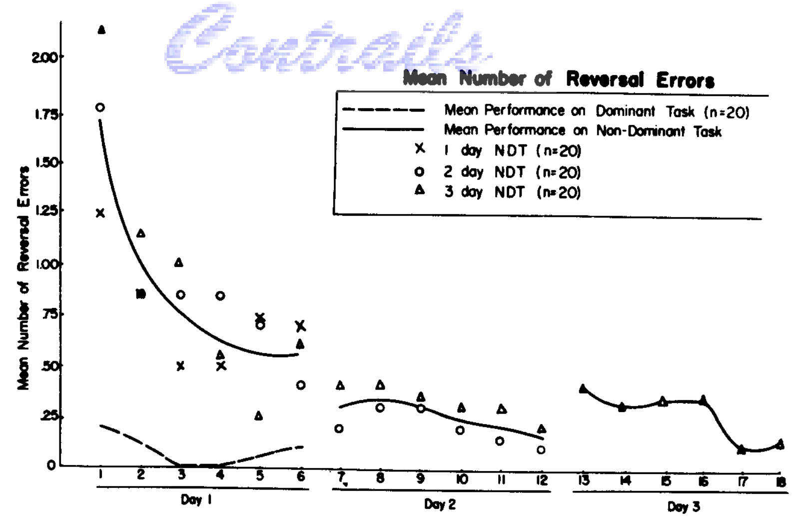

Figure 2. Learning Curve of Mean Number of Reversal Errors

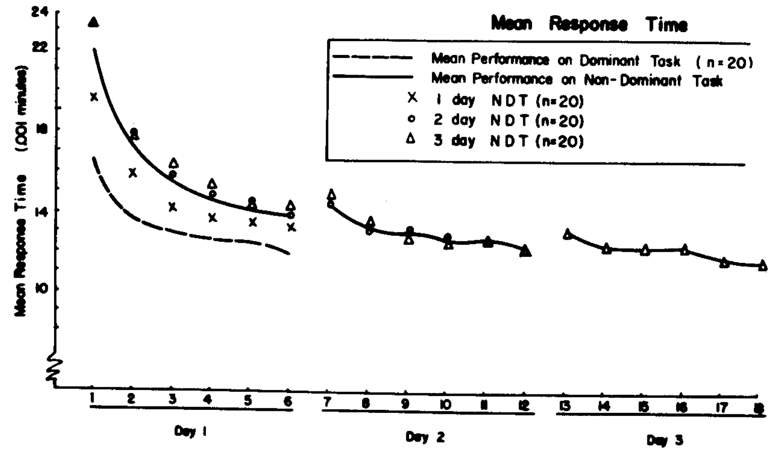

Figure 3. Learning Curve of Mean Response Time

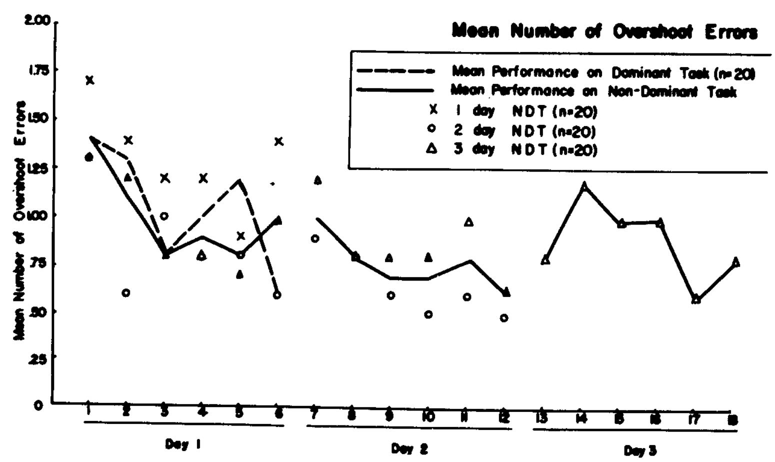

Figure 4. Learning Curve of Overshoot Errors

level. It was first necessary, therefore, to discover if our eight subgroups fulfilled this assumption.

Table II shows the means and sigmas of the performance of each group of 10 subjects on the last practice set for each of the measures of reversal errors, response time, overshoot errors, and variability.

The results of a simple analysis of variance of the 8 groups during the last practice set are shown in Appendix I. Each of the measures was analyzed separately. With the exception of the mean response time, all overall F's are significant.* Since we did not test for the homogeneity of variances in each of these tests -- and there is good reason to assume they would not be homogeneous -- it is not correct to assume that the significant F's imply significant differences between means. The groups' variances may be significantly different or both means and variances may be different. In any case, we can conclude that where the F's were significant the performance between groups differed in some respect. Thus our initial criterion of performance equality on the last practice set before stress was not fulfilled.

An examination of Table II and the Learning Curves in Figures 2, 3, and 4 suggested that for all measures performance was poorest during the last practice set for the nondominant groups with one day of practice.

When the scores of the nondominant task groups with one day of practice were not considered, an analysis of variance of scores on the remaining six cells revealed no significant F-values among performances on the last practice sets for any measure (See Appendix I). In fact, the variance between group mean performance scores was even less than the variance within the groups. The writer believes that this shift in the F-values justified the removal of the one day practice groups on the nondominant task in order to study the effects of stress on previously equated performance of the dominant task and nondominat task. "Six subgroups" throughout the remainder of this paper will refer to the dominant group with one day of practice and the nondominant groups with two and three days of practice under mild and severe stress, with the nondominant groups under one day of practice omitted. Though the mean response time measure on prestress trials showed no significant differences among the eight subgroups, the scores of the nondominant one day group were also removed in order that this set of scores would be consistent with the other measures.

Disruption Scores

A disruption score was obtained for each subject by subtracting the score made on the last set of practice trials from the score made during the experimental stress trials. Thus, the higher the score, the greater the disruption. For the remainder of the paper, unless otherwise indicated, all scores discussed on the positioning task are disruption scores.

* Reference throughout the paper to results as "significant" are based on a 5% or smaller confidence level, unless otherwise stated.

TABLE II

MEANS AND SIGMAS OF PERFORMANCE DURING LAST PRACTICE PERIOD BEFORE STRESS

(N = 10 Subjects in Each Group)

Task		Dominant		Nondominant					
Days of Practice		1		1		2		3	
Degree of Stress		Mild	Severe	Mild	Severe	Mild	Severe	Mild	Severe
Mean Number of Reversal Errors	M	.1	.1	.9	.5	.1	.1	0	.3
	SD	.32	.32	1.29	.71	.32	.32	0	.67
Mean Response Time (.001 Minute)	M	12.2	11.7	13.2	13.2	12.0	12.3	11.7	11.7
	SD	1.39	1.14	2.31	2.47	1.69	1.34	1.30	1.18
Mean Variability of Individual Response Time	M	2.2	2.0	3.0	3.0	1.9	1.9	1.9	2.2
	SD	.18	.38	1.76	1.23	.47	.53	.71	.85
Mean Number of Overshoot Errors	M	.8	.5	1.5	1.1	.7	.3	.7	1.0
	SD	1.26	.50	2.06	.90	.82	.42	.82	1.33

Table III shows the mean disruption score and standard deviation on each of the measures for the six groups of ten subjects each. For each measure, Bartlett's test of homogeneity was applied to the disruption score variances for the six groups. Table IV shows the results of these tests and the steps taken to correct for heterogeneity whenever it occurred. The disruption scores of the response time and reversal errors were transformed, and the means of the transformed measures are given in Table V. Overshoot error disruption score variances were homogeneous to begin with. The variances of the individual response time variability scores were so heterogeneous that after various unsuccessful attempts to transform the data, it was decided to use the Mann and Whitney U test (17) as a test of significance of differences, for it makes no assumptions or restrictions on the variances.

Reversal Error Disruption Scores*

The component variances were analyzed for the transformed reversal errors scores (Appendix II-A). Performance on the dominant task with one day of practice was quite significantly ($p < .001$) better than performance on the nondominant task with two and three days of practice. Performance was also better under mild than under severe stress ($p < .05$). The F value obtained for the interaction variance was significant at the .06 probability level.

In order to determine where the significant differences were between tasks and days of practice, t-tests between paired groups were made, Table VI shows the t-values obtained. The standard error of the mean differences for computing these t's were obtained by using the F-test error variance as the best estimate for the variance in any single column; the assumption of homogeneity of variances justifies this practice. The results showed that the increase in reversal errors was significantly greater for the nondominant tasks than for the dominant task under both degrees of stress. This was true with two or three days of practice on the nondominant task. No significant difference was found between the mean reversal error scores of the two-day and three-day practice periods on the nondominant task.

Response Time Disruption Scores

The analysis of the component mean squares of the transformed disruption scores of response time is given in Appendix II-B. The interaction between tasks and degree of stress was significant below the .05 probability level. The variances between tasks and also between stress levels were tested by the significant interaction variance. The resulting F's were not large enough to be significant. An analysis of the differences between the mean scores of cells was made in order to determine which combinations of the tasks and the stresses were significantly different from each other.

In order to present the 15 comparisons most effectively, a Deltagraph (23) was constructed and is shown in Figure 5. The mean disruption scores of transformed response time are positioned in their rank order along the linear scale. Below and to the right of the scale are the linear distances required between two means in order for the differences to be significant

* Additional analyses of reversal error scores can be found in the writer's doctorial dissertation (24, pp. 52-55)

TABLE III

MEAN DISRUPTION SCORES

(Disruption Score = Score on Stress Trials minus Last Practice Period Score)*

(N = 10)

		Dominant Task		Nondominant Task			
Days of Practice		1		2		3	
Degree of Stress		Mild	Severe	Mild	Severe	Mild	Severe
Mean Number of Reversal Errors	M	.3	1.1	1.0	4.7	3.4	3.4
	SD	.68	1.45	1.33	4.37	2.32	3.63
Mean Response Time (.001 Minute)	M	4.4	11.6	4.7	12.1	7.5	10.5
	SD	1.44	4.29	1.47	4.40	1.97	3.43
Mean Variability of Individual Response Times	M	1.4	5.1	1.8	3.9	2.9	5.0
	SD	1.55	5.15	.62	3.10	1.76	4.29
Mean Number of Overshoot Errors	M	-.1**	.9	.5	.6	-.1**	.6
	SD	1.45	1.53	1.44	.96	1.45	1.26

* The higher the score, the greater the disruption.
** A negative score indicates fewer overshoot errors under stress.

TABLE IV

CHI-SQUARE OF BARTLETT'S TESTS BEFORE AND AFTER TRANSFORMATION OF DISRUPTION SCORES*

Measure	d.f.	Chi-square Before	Transformation	Chi-square After
Mean Reversal Errors	5	35.38**	$\frac{1}{X + 5.0}$	3.87
Mean Response Time	5	21.46**	Square Root	6.66
Mean Variability Time	5	161.90**	(Not done) #	-
Mean Overshoot Errors	5	2.13	(Not needed)##	-

* Based on 6 cells of data, less one day, NDT group

** Significant, P <.01

\# The experimenter was unable to homogenize variances

\## Variances were already homogeneous

TABLE V

MEANS OF TRANSFORMED DISRUPTION SCORES

(N = 10)

	Dominant Task				Nondominant Task	
Days of Practice	1		2		3	
Degree of Stress	Mild	Severe	Mild	Severe	Mild	Severe
Mean Number of Reversal Errors $\left(\frac{1}{X+5}\right)$	.1918	.1726	.1731	.1213	.1271	.1327
Mean Response Time $(\sqrt{X})$	2.008	3.409	2.207	3.476	2.751	3.245

TABLE VI

VALUES OF t's FOR DIFFERENCES BETWEEN MEANS ON THE TRANSFORMED REVERSAL ERROR SCORES*

	Nondominant 2	Nondominant 3
Dominant 1	2.11**	3.15***
Nondominant 2		1.04

* Standard error of mean differences based on F-test error variance = .01659; d.f. = 38

** $p < .05$ *** $p < .01$

at the 1, 5, and 10 per cent confidence levels, respectively. Examination of the Deltagraph yields the following results:

1. It is apparent that in spite of the results of the F test, response time performance on all of the severe stress conditions (represented by S on the Deltagraph) was significantly poorer (higher disruption scores) than on the mild stress conditions (respresented by M on the Deltagraph).

2. No significant differences between any of the groups were found under the severe stress conditions.

3. Though the response time was greater under mild stress for the nondominant task with two and three days of practice than under the dominant task with one day of practice, only the difference between the dominant task with one day of practice and the nondominant task with three days of practice was significant below this .05 probability level. However, when the data from both nondominant groups under mild stress are combined, and the significance of the difference is computed between the mean of these transformed disruption scores and that of the dominant task under mild stress, a t of 2.64 was obtained, which is significant below the .05 level with 28 degrees of freedom (not shown on the Deltagraph). Disruption was greater for the nondominant than for the dominant group under mild stress. When the same data were combined for the severe stress groups, there was still no significant difference (t = -.218) between response time disruption under dominant and nondominant conditions.

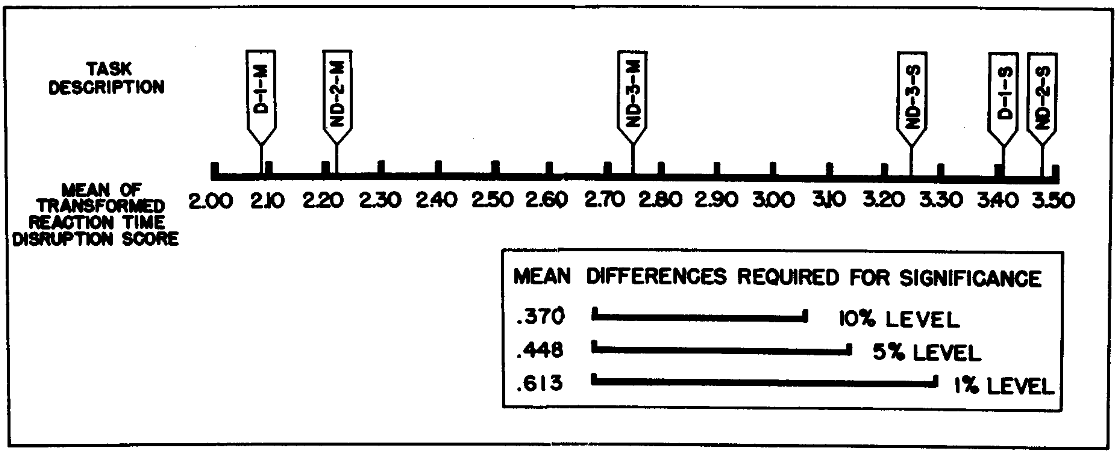

Figure 5. Deltagraphic Representation of Significance of Differences Between Means of Transformed Reaction Time Disruption Scores

Individual Response Time Variability Disruption Scores

The significance of the differences between the means of individual variability in reaction time was computed by using the Mann and Whitney U test. The results of this analysis are given in Table VII. When comparisons were made between the dominant task and the nondominant task (the practice periods of the latter being compared separately and combined), no differences below the .05 level of confidence were found, though the trend under mild stress conditions tended to favor the hypothesis that greater disruption as respresented by greater variability occurred on a nondominant task.

When the U test was used to compare the significance between the mean variability of mild and severe stress conditions for all eight conditions (the nondominant task with one day of practice included), the difference was highly significant ($U = 3.73$; $p = .0002$). Severe stress conditions increase the variability of the individual's response time considerably over mild stress conditions.

Overshoot Error Disruption Scores

Though the over-all F test (Appendix II-C) indicated no significant differences in overshoot disruption scores among the six conditions, groups were combined along with the nondominant, one-day conditions and the significance of the mean differences in overshoot error disruption scores was tested between mild and severe stress. A t of 1.91 with 78 degrees of freedom was found. This value is not quite significant at the .05 level, though the tendency was consistent with the trend found in the other measures, with more overshoots occurring under severe stress (mild stress, .025; severe stress, .600; sigma of the difference, .301).

Effects of Practice on Disruption

It had also been hypothesized that additional practice would have a beneficial effect on the performance of the nondominant task under stress. The question may be asked in two ways: first, what effect does practice have on performance disruption, i.e., on the difference between performance scores on the stress trial and those made during the last preceding practice period? Second, what effect does practice have on performance scores under stress when considered from a base line common to all the groups?

Reference to the means for the nondominant task in Table III permits an examination of the effects of different amounts of practice on stress disruption scores. If any over-all trend is present, and this is doubtful, the tendency is toward more disruption with the increased amount of practice. However, for each of the measures, there was no consistent trend. Disruption scores for nondominant tasks with one day of practice are shown in Table VIII.

When we compare the performance level achieved during the stress periods after different amounts of practice, but from a common performance point, i.e., the scores made on the sixth trial, we find the mean results shown in Table VIII. There is a slight over-all trend showing that with increased practice, errors tend to increase, while reaction times tend to decrease. These tendencies are not consistent and must be subject to further verification.

TABLE VII

SIGNIFICANCE OF DIFFERENCES (U) BETWEEN MEAN INDIVIDUAL VARIABILITY DISRUPTION SCORES*

		Nondominant Task		
		2 day	3 day	2 + 3 day
Dominant Task[1] (Mild Stress)[1]	U	1.08	1.85	1.65
	p**	.28	.06	.10
Dominant Task[1] (Severe Stress)	U	.00	.00	.00
	p	.00	.00	.00
Dominant Task[1] (Combined Stress)	U	.53	1.29	
	p	.59	.20	

* Mann and Whitney U-test for nonparametric measures. A positive U indicates agreement in the hypothesized direction.

** Though the Mann and Whitney U-test is a one-tailed test of significance the given probabilities were doubled in order to make the test a two-tailed one and consistent with the others in this paper.

TABLE VIII

MEANS OF DIFFERENCES BETWEEN THE EXPERIMENTAL TRIAL SCORE AND THE SCORE ON THE 6TH TRIAL FOR THE NON-DOMINANT GROUPS SHOWING PRACTICE EFFECTS*

N = 10

	One Day	Two Days	Three Days
Reversal Errors			
Mild Stress	1.4	1.0	2.9
Severe Stress	3.1	4.1	3.3
Combined Mean	2.2	2.6	3.1
Response Time			
Mild Stress	7.6	3.9	4.8
Severe Stress	10.8	10.2	8.5
Combined Mean	9.2	7.0	6.6

* The higher the score, the poorer the performance on the experimental stress period.

Analysis of Continuous Pursuit Task Scores

Though the compensatory pursuit task, for inducing the mild and a portion of the severe stress, was not changed from group to group, it is desirable to see if this task reflected differences due to the simultaneous performance with the dominant task and nondominant task, under the different degrees of practice and different degrees of stress.

The mean time-on-target scores for the 8 groups and their standard deviations are shown in Table IX. Bartlett's test for homogeneity yielded a chi-square of 13.78, which was not significant below the .05 probability level, permitting us to accept the hypothesis of variance homogeneity. With 7 and 72 degrees of freedom an F of 1.66 does not permit us to reject the null hypothesis for group mean differences on this continuous task at the 5% level of confidence.

However, when all mild stress groups and all severe stress groups were combined, a t of 2.89 with 78 degrees of freedom between the two stress levels indicated that performance was significantly poorer on the continuous task under severe stress conditions.

Relations Between Measures

The rank order correlations between scores on the continuous task, response time, and reversal errors on the positioning task for conditions of mild and severe stress are shown in Table X.

Though each comparison involved only 8 degrees of freedom and required a correspondingly high rho coefficient to be significant, certain trends are apparent. These are:

1. The time to respond on the positioning task under mild stress varies inversely with the time-on-target of the continuous task. Three of the four relationships are significant. Under conditions of severe stress, this negative relationship tends to disappear and there appears to be little relationship between the scores.

2. There appears to be no strong relation between performance on the continuous task and the number of reversal errors.

3. No relation is found under mild stress between response time and reversal errors on the positioning task. Under severe stress, however, these scores tend to be negatively correlated.

4. When response time was one of the measures being compared, the lower correlations seemed to occur on the dominant task.

VI. DISCUSSION

The Differential Effects of Stress

As hypothesized, the greater the stress, the greater the performance

TABLE IX

MEANS AND STANDARD DEVIATIONS OF CONTINUOUS TASK SCORES*

N = 10 Subjects in Each Group

Task		Dominant	Nondominant			
Days of Practice		1	1	2	3	
Mild Stress						**Mean of Stress**
	M	340	341	345	308	333
	SD	25.7	56.7	42.8	76.2	47.33
Severe Stress						
	M	296	290	305	314	301
	SD	69.2	50.5	53.6	33.8	52.03
Combined Mean of Tasks						
	M	318	315	325	311	

* The higher the score, the better the performance.

TABLE X

TABLE OF INTERCORRELATIONS (rho) BETWEEN CONTINUOUS TASK SCORES AND RESPONSE TIME AND REVERSAL ERRORS ON THE POSITIONING TASK

Mild Stress

	Continuous vs. Error	Continuous vs. Error	Time vs. Error
Dominant	-.10	.35	-.09
Nondominant$_1$	-.74	.08	.00
Nondominant$_2$	-.65	.06	-.05
Nondominant$_3$	-.82	.23	.06

Severe Stress

	Continuous vs. Error	Continuous vs. Error	Time vs. Error
Dominant	.03	.24	-.08
Nondominant$_1$	.44	.17	-.37
Nondominant$_2$	-.27	.27	-.18
Nondominant$_3$	.16	-.34	-.74

p of .05 = .632

p of .01 = .765

d.f. = 8

decrement for all measures on both positioning tasks and for scores on the pursuit task. The important question is whether or not stress had a differential effect on the dominant and nondominant tasks. Is there less performance decrement under stress for the dominant than for the nondominant task when both were previously performed at comparable levels? It is believed that, in general, the results support an affirmative answer, though some qualification is needed.

When an error measure was used, the hypothesis was well supported. Both tasks were negatively affected by stress, but the number of errors on the nondominant task increased considerably more than those on the dominant task. Since our initial choice of "dominance" was based only on the direction the knob was rotated (which the reversal error measures), the hypothesis seems substantially supported.

However, our interests lead us to examine other measures of disruption as well. How did the hypothesis fare in these cases? When stress was mild, the nondominant group responded more quickly than the dominant group, but when stress was stronger both groups slowed down equally.

Several explanations can be suggested to show why the severity of stress affected the response time differently than it affected the reversal errors. First, the total time to respond to a task may be divided into four parts: the reaction time to initiate a movement of the hand to the knob, the time required to move from the stick to the knob, the time required to make a judgment which may, of course, overlap the two preceding time measures, and the time required to turn the knob. Thus, since the real difference between the two tasks is in deciding how to turn the knob, any difference occuring in the time required to make this decision is actually only a part of the total recorded time. This may tend to hide the effect and make the time measure a less sensitive one than the reversal error measure. Under severe stress, the reaction time may increase, increasing the total response time for all groups. Thus, the differences between dominant and nondominant tasks as reflected by the time required to decide how to turn the knob may, under severe stress, become even less significant when hidden within the extended response time.

As greater external interferences occur, the subject may feel less inclined to "stop and think" (however momentarily) before responding. Thus, under severe stress he would tend to choose the dominant response more often. This would create larger differences in reversal errors under severe stress but smaller differences in response time between the dominant and nondominant task, since the essential cause of the time difference has been ignored. The change from no relationship to a negative relationship between time and error disruption scores under the two degress of stress tends to support this interpretation.

Specificity of the Dominance Measure

Neither overshoot errors nor individual response time variability provided much support for the hypothesis of differential effects of stress on the dominant and nondominant task, though the nondominant group scores of the latter tended to become more varied than those of the dominant group under mild stress only. However, since the tasks were not chosen as dominant or nondominant on the bases of these measures, there is no reason to expect our hypothesis to be upheld or rejected by them, except as they are related to the reversal error measure of dominance. This suggests the generality that the dominance of a task is specific to the measure being used. It is an all too common occurrence in psychology to choose measures quite arbitrarily, mainly on the basis of convenience. Many psychologists who would hesitate to draw general conclusions on a single subject would not hesitate to do so with a single type of measure. The engineering psychologist, however, who finds problems of speed and accuracy both important, is constantly concerned with the representativeness of the dominance measure. In the present experiment, the time and reversal error curves for dominant and nondominant tasks reflect this difference. If a task has been chosen as dominant in one measure, there is no assurance that it will be dominant on another.

The Effects of Practice on the Nondominant Task

We had hypothesized that increased practice on the nondominant task would decrease the negative effects of stress. This was not borne out by our results. It is interesting to note that although a relatively short period of practice was sufficient to equate performance on a dominant and nondominant task under normal conditions, not even overpractice was enough to maintain that equality under stress.

Several hypotheses may be advanced to account for these results. First, perhaps the amount of practice was too limited to have any effect. Second, subjective observations reported by the subjects suggested that increased practice on the nondominant design may have actually increased the disruptive effects of stress by lowering the level of cautiousness which appeared to be present in earlier stages of learning. This hypothesis would explain the possible trend of a decrease in mean response time and the increase in group reversal errors with practice.

The effect of practice on the nondominant task is a problem of particular practical importance. In this study, the comparisons made were between naive subjects practiced only on one design or the other. This might be analagous to comparing the performance of a new pilot, trained only on a new design with the dominant motion relationship, with the performance of an older pilot who is using the older and much practiced nondominant design. But in the practical situation, were the newer dominant design introduced, the established pilot would also be required to change from the familiar nondominant design to the revised and dominant one. The question which must be answered is -- will the advantages of the dominant design be offset by negative transfer from the originally learned nondominant one? Though this experiment was not designed to study this question, two answers can be suggested. First, contemporary research (15) on transfer of motor skills suggests that, at most, the negative effects would be transitory and brief, if present at all, for positive effects are taking place simultaneously. The very nature of the task which involves the dominant motion-relation allows responses to the dominant design to be consistently reinforced outside of the flying situation. As will be discussed in a later section, this type of dominance is constantly being reinforced from birth.

This fact alone may create a positive transfer effect which more than offsets the negative one. Second, experiments on transfer (4, 18) have found that with increased training on the two tasks, there is a decrease in negative transfer.

The Relationship Between the Main Positioning Task and the Interfering Tasks

Some brief discussion is warranted concerning the secondary continuous pursuit task — the interfering task of the stress situation. Our results showed that it was not differentially affected by the concurrent operation of the dominant or nondominant positioning task.

When the number calling was introduced to create severe stress on the positioning task, it also effected the continuous task in a stressful manner, lowering the time-on-target scores.

The scores made on the continuous task had little relation to the errors made on the positioning task, though they seemed negatively related to the time scores on the nondominant positioning task under mild stress. Under severe stress this relation disappeared. Thus it might appear that the person who did best on the continuous task also showed less time disruption on the positioning task under mild stress. Perhaps the one task kept the subject more alert on the other. That errors are not correlated with the continuous task scores helps support the view that the stress effect is not merely one of pulling the subject away from one task to perform another. Subjects tend to respond independently and concurrently on both.

VII. THEORETICAL CONSIDERATIONS AND HYPOTHESES

How might we explain post facto the results of the present study in terms of current learning theory and known principles of behavior? Below are listed a number of hypotheses which might account for our results.

Contextual Change and Stimulus Generalization

The dominant task in the present experiment requires for its correct response a movement relation between stimulus and control which is being used constantly by the majority of the population in their normal pattern of living. When we wish to place an object on a table perceived in our left visual field, we move our arms to the left. In the dominant response of the instrument control configuration used in the present study, if we wish to move a light to the right, we rotate the top of the knob to the right. This movement relation has been found to be dominant in a number of experiments (22, 26, 27). It has been reinforced in a wide variety of tasks and life situations.

On the other hand, the correct movement relation required to perform successfully the nondominant task has, for all practical purposes, been reinforced only in the experimental situation. Occasionally in life, reinforcement may occur, from an improperly designed radio control, which requires the operator to turn the knob in the direction opposite to that which he wished the pointer to go. But for all practical purposes, the movement relation for the nondominant response was reinforced quite specifically in this experiment.

The introduction of the secondary tasks created a change in environment from that existing in the original practice period. The positioning task was performed in a new context. The early work of Carr (5) on forgetting and the later work of Dulsky (6), and Abernethy (1) showed that recall was reduced when there were changes in the environmental background from that which was present during the original learning. The work on stimulus generalization (24) has also suggested a drop in performance as the new stimuli become more and more removed from the original stimulus condition.

Since change is a part of the original preexperimental training context of the dominant group, introduction of further change should not differentiate the new total stimulus situation for that group as much as it would for the nondominant group trained in the specific situation. Thus, on the basis of greater contextual change and from the principles of stimulus generalization, we would expect to find a greater drop in the performance of the nondominant group than of the dominant group during stress.

The Effect of a Shifting Set

The movement of the control on the continuous task was a left-right one of the same relation to its display as the stimulus-control relation of the dominant response on the positioning task. On the other hand, the motion relation between indicator and control of the nondominant task was the reverse of that of the continuous task. Thus, for the dominant group, no shift in the movement relation set was required by the subject to operate concurrently the continuous task and the positioning task; this was not true for the nondominant group.

Warrick (27) found that when two tasks with dominant and nondominant stimulus-response movement relations were operated concurrently, there was a lower performance level than when even two nondominant tasks were operated. The continual shift of set required for the nondominant group in the present experiment between the dominant motion relation set of the continuous task and the nondominant set of the positioning task may account for the greater drop in this group's performance on the positioning task. Where both sets were of the dominant motion relation, a lesser drop occurred.

Other evidence, however, tends to weaken this hypothesis. For one thing, there was no corresponding drop in the continuous task when the shifting set was required. Furthermore, when the severe stress condition was added, though it was a nondimensional type of task and presumably required a set which would favor neither the dominant nor the nondominant positioning task, the differential increase in reversal errors between the two tasks was even greater than and in the same direction as under mild stress. When the subjects discussed their performance in the experiment, none ever commented on being disturbed by this effect. If the shifting set is the cause of the differential regression during stress, it is believed its effect is small and that we must look elsewhere for more probable hypotheses.

Loss of an Automatous Habit

It might be hypothesized that in order to perform successfully on the nondominant task, subjects must develop a set to respond contrary to the manner to which they have been accustomed. One might postulate that the set is actually one to inhibit the usual response. However, with suitable practice, this inhibitory set tends to be automatized into a total response sequence, and the subject is no longer required to think consciously of it before each response. When the stress condition, a secondary task, is introduced, then errors may result from the breaking up of the automatic pattern and the reawakened awareness of the total situation. Vince has suggested this explanation and adds that this would bring "a state of confusion similar to that experienced in the early stages of learning" (25, p. 16).

The practice period was so arranged as to enable the subject to automatize his responses on the nondominant positioning task. Over and over, the subject heard a buzzer and quickly responsed to the display light which appeared. The interval between trials on the practice period was relatively short. Vince (25) believed this condition facilitated automatization. Thus the following automatic sequence might have been established: buzzer, inhibitory set, sight of stimulus, response. Bahrick, Noble, and Fitts (3) believed that automatization was facilitated when the sequence was bound together in such a way that circular feedback processes from one response tended to elicit the next. In the present study, one of the experimenters observed that subjects tended to be less cautious and did not have to stop and think by the third day of practice on the nondominant task, strongly suggesting that the task had become more automatized. With practice the performance becomes less conscious and more efficient (3, 28).

The introduction of the second task to be operated concurrently with the positioning task tended to break up the sequence. The intervals between trials were longer than before. A buzzer which sounded occasionally during the continuous pursuit performance could be confused with the buzzer in the positioning sequence. Bahrick et al (3) postulated that automatization is believed to stand for a learning process perhaps analagous to classical conditioning. If this were so, the presence of the second buzzer would tend to extinguish any connections between the first positioning buzzer and the subsequent sequence.

The concurrent continuous activity made it difficult for the circular feedback hypothesis to operate in the positioning sequence, reducing the automatous nature of the task, making it necessary for the inhibitory set to be consciously established. This would tend to slow performance and would also increase the probability of errors developing when the inhibitory set was overlooked.

With the dominant task, the situation was different. No special inhibitory set was necessary. Due to the amount of preexperimental practice, the response sequence was so highly automatized that the secondary task had less effect on it. Bahrick et al (3) believed that one consequent condition of automatization was that it results in a better combined performance when combined with a second task.

Relative Amounts of Practice

The dominance in this experiment is one which has been acquired through years of living. Spatial orientation, as the work of Reisen (19) has shown, is not innately developed, but acquired from birth. Thus, the dominant response in this experiment had received a great deal of transfer from the life situation and even the minimum practice in the present experiment was merely overlearning.

Thus, when the nondominant groups were practiced until their performances appeared to reach that of the dominant group, we may assume that, had we more subtle measurements, we might have found that the apparent performance equality was not a fact. This is illustrated by the work of Ebbinghaus (7), who found that successive performance to the same criterion level was not equal when measured by relearning or retention.

The experiments on animal instrumental act regression as reviewed by Sears (20) found that in the two-alternative type of maze, sudden shock at the choice point caused the animal to respond to the alley on which he had received the most practice rather than simply to the earlier learned task. The results in the present experiment coincide with the results of these researchers for we found more subjects reverting to the dominant response during stress than to the nondominant, the former being the more highly practiced, when we consider the practice as being transferred from outside the experimental situation since birth.

How then does the amount of practice on the two tasks react with the same stress situation to make performance which once appeared equal become unequal? The following hypothesis is expressed in Hullian terms. Originally, before the experiment began, the effective reaction potential ($s\bar{E}r$) of the dominant response was greater than that of the nondominant response, as evidenced by the almost universal preference for the former response during the pretest period. Hull (13), in his Postulate XIV Corollary xiii, stated that when there is a competition of incompatible reaction potentials and both are above threshold, then the reaction whose momentary potential is greatest will be evoked.

For the dominant group in this experiment, this relative difference between dominant and nondominant response $s\bar{E}r$'s was left untouched or increased with the extra practice. Presumably the difference would be quite great in favor of the dominant response $s\bar{E}r$, considering the lifetime of reinforcement of the dominant response.

For the nondominant group, however, the incentive (K) and delay of reinforcement (J) variables were modified to favor the nondominant response. This presumably resulted in a drop in the $s\bar{E}r$ curve of the dominant response and rise in the $s\bar{E}r$ curve of the nondominant response. At some point, the $s\bar{E}r$ of the nondominant response became consistently greater than that of the dominant response and the former response tended to occur except for occasional behavioral oscillations.

The equated performance between the dominant and nondominant groups only reflects the relative heights of the $s\bar{E}r$'s on the two responses within each group, indicating the one in each group which was significantly higher than the other. It does not reflect, however, the relative levels of the two responses between groups, and this is where it is believed that the differential results of this experiment are fostered.

Because of the great amount of preexperimental practice on the dominant response and the expected slow drop of its extinction curve, the $s\bar{E}r$ curve of this response should be only slightly below that of the nondominant response in the nondominant group. For the dominant group, however, the long period of extinction and reinforcement should widely separate the $s\bar{E}r$ curves of the nondominant and dominant tasks, placing the latter far above the former.

Thus when the second task is introduced, Hull's Postulate XII, "Afferent Stimulus Interaction," is applicable. From it we could hypothesize the drop in the reaction tendency one would expect when the secondary stress task is introduced after original learning. (At this point, the stimulus generalization hypothesis presented earlier might be developed. However, a slightly different approach will be used.)

If the secondary stress situation created an equal drop in the effective reaction potential for the dominant and the nondominant responses in their respective tasks (and it is unlikely that this would be the case), we would expect that the effective reaction potential of the nondominant response would soon drop equal to or below the level of the dominant response only slightly below the former. Behavioral oscillations (Hull's Postulate XIII) would increase the chances of the appearance of the incorrect response on the nondominant task. But in the case of the dominant group, where the effective reaction potential of the nondominant response is so far below that of the dominant response, even the drop due to the afferent neural interaction should not bring the effective reaction potential of the dominant response to a level where it might be surpassed by the nondominant potential. Thus, we would tend to obtain more errors on the nondominant task under stress than the dominant.

The Present Experiment, Clinical Regression, and Dominance

The work "regression" has been freely used throughout this paper to refer to the performance decrement under stress. Though the term originated with the psychoanalytic school under Freud (11), and has been associated with all of that school's hypothetical constructs, as a descriptive term it has served a much wider use throughout the psychological field. The general idea of some sort of performance decrement occurring when the situation becomes too much for the highly motivated individual to handle is comparable to the Freudian's regression, the clinician's schizoid behavior, the "emotionalist's" disruption, the industrialist's accident proneness, the comparative psychologist's instrumental act regression, and many of the other phenomena in the various fields of psychology. In addition, various engineering psychologists have used the term "regression" descriptively (24, pp. 2-3) and it has served its purpose. A person can show behavior which appears to be "regressive." What occurs is quite clear, and to avoid the usage of a descriptive term because of the "odium sexualis" is merely hiding behind a "semantic curtain."

The concept of dominance, however, as used in the present paper, tends to give a sounder foundation to the concept of regression. One might almost say that the Freudian type regression is a special case of the "Dominance" principle. That is, whereas Freud postulated a regression to an earlier learned habit, it has been stated here that we tend to regress to the dominant habit. The habit may be dominant if it is the earlier learned one, but, as has already been pointed out, this has been found to be a function of the amount of relative practice on the earlier and later habits.

But "dominance" covers an even broader range of conditions. It is not a unitary concept. The present experiment studied only two of several possible types of dominance. The conclusions drawn cannot be applied to the other types until they have been studied independently. There has been a tendency for psychologists concerned with dominance to overlook the broadness of the concept. It is therefore believed worthwhile to list briefly and give examples of several types of dominance which can readily be found in the literature. Such a list should help to clarify the use of the term "dominance" in future studies of this type; several other uses may be suggested.

First, the list of dominances may be used as a beginning for a check list for the systematic analysis of already constructed tasks and equipment without the need for further research. Second, it should encourage the search for additional examples of dominant responses which, it is hypothesized, should be the correct responses for newly designed equipment. Third, it may provide greater insight into crucial uncontrolled variables sometimes overlooked by researchers in psychology.

Other types of dominances probably will be discovered; the descriptions below may easily be modified.

The present study was primarily concerned with what might be called <u>Universally Acquired Dominance</u>. It is characterized by sensori-motor connections which have been reinforced since birth or at a very early age, but which are not the result of specific training. These connections are quite strong and often appear to be innate though they are not. One large subgroup is the dominance of certain spatial-motor relations. This type was studied and discussed in the present experiment. Within a second subgroup of this type are the symbolic, universally acquired dominances. Examples of these are preferences for certain numbers (29), or the greater than chance occurrence of a particular word in response to a stimulus word on word association tests (15).

A second type of dominance might be called <u>Specifically Acquired Dominance</u>. This differs from the first only in the amount of time in which the dominance has had to be developed and the amount of training given. It is exemplified by the task where no precedent exists for giving the correct response to a stimulus prior to specific and formal training on the task. When two incompatible responses are trained to the same stimulus, the one with the most training is the dominant one. Tasks which might be considered in this category are the opening and closing of a switch at the sound of a bell, or the turning on or off of a light in response to a particular color. In the present experiment, giving special training to the originally non-dominant task was actually an attempt to shift the universally acquired dominance by strengthening a specifically acquired one.

A third type of dominance is Neurological Dominance. Here dominance is determined by the particular characteristics of the nervous system which favors one response over another antagonistic response. The flexor and extensor reflexes to noxious stimuli are good examples of this; the former is the dominant reflex (21).

A fourth type is Anatomical Dominance, where the skeleton and the musculature of the individual determine which response will be most likely to occur. Thus, due to the particular construction of our joints and their attached muscles, if given a choice, we tend to run forward rather than backwards. Visual displays in a horizontal plane favor performance over visual displays in the vertical plane; this may be partially due to the position and musculature of the eyes (10).

A fifth and final type of dominance is Sensory Dominance. Here the dominant response has been connected to the dominant stimuli through training, that is, to the stimuli which will be perceived first from a number of alternatives by the greatest number of the population. This differs from Specifically Acquired Dominance only by the fact that it is not practice but the stimulus characteristics which determine the dominance. Two subtypes can be found. The first is intermodal sensory dominance, where there is a tendency to respond faster to the stimulation of one sense than another. Studies comparing reaction times of the different sense organs reveal this type of sensory dominance. The second subtype is intramodal sensory dominance, or stimulus prepotency, as it has been often called in the literature. This is determined when two stimuli provide conflicting cues to the same sense organ; the one which the individual uses is the dominant one. Thus, the studies of color discrimination by white rats were long misinterpreted by a failure to recognize the dominance of brightness over hue as the discriminating cue (2).

The examples could be multiplied many times. The general problem of dominance is not a new one, but it is believed that it represents a different orientation which might be developed to aid in the analysis of tasks and the problems of instrument design which must be met by the engineering psychologists, as well as to aid in clarifying issues encountered by the theoretical experimental psychologist.

Summary

Several hypotheses have been suggested to explain the differential effect of stress on the dominant and nondominant tasks. Each represents explanations from current psychological theory. It is quite obvious that any one explanation does not exclude the others. It is possible that all are operating to some degree, and, in some cases, may not be completely independent from one another, i.e. automatization and the amount of practice.

If one were to test the major hypothesis of the present study, using different type of dominances than were used in this study, one might find that many of the suggested explanatory theories would not be applicable. These theories have been oriented toward the acquired situation, whereas if differential effects of stress were found with physiologically dominant and nondominant behaviors, different explanatory theories may be required.

VIII. CONCLUSIONS

1. The basic hypothesis which the experiment was planned to test was upheld. Stress resulted in more reversal errors for subjects performing on the originally nondominant task than for those performing on the originally dominant one, although both groups had been practiced to an apparently equal performance level previously.

2. Under severe stress, the performance of all measures and tasks showed greater disruption effects than were found under mild stress.

3. Scores on the continuous pursuit task were not differentially affected by its simultaneous operation with a dominant or nondominant positioning task.

4. Though originally equal, under mild stress the time required for a subject to respond on the nondominant task increased more than the time required to respond on the dominant task. No differences were found between response times on the two tasks, however, when the stress was more severe.

5. Under mild stress, there was a nonsignificant tendency for each subject's response time to become more variable on the nondominant task than on the dominant task. This tendency disappeared under severe stress.

6. No differences were found between dominant and nondominant tasks as to the frequency with which overshoot errors occurred under normal or stress conditions.

7. Extra practice on the nondominant task was insufficient in this experiment to decrease the disruptive effects of stress on performance.

8. Poorer performance under stress on the nondominant task than on the dominant one was explained in terms of current psychological theories in the following ways:

   a) by the greater stimulus generalization which occurs while performing in the nondominant task as compared to that occurring in the dominant task.

   b) by a shifting set or attitude required when the nondominant task was performed simultaneously with the continuous pursuit task but not required when the dominant and continuous tasks were performed simultaneously.

c) by the nondominant task being less automatized than the dominant task.

d) by the stronger effective reaction potential of the antagonistic response of the nondominant task than that of the dominant task.

9. The concept of "dominance" was discussed and more precisely defined by indicating several subcategories. These were anatomical, neurological, sensory, universally acquired, and specifically acquired dominances. Classical regression was considered a special case of the hypotheses of regression to the dominant behavior under stress.

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APPENDIX II

ANALYSES OF VARIANCE OF PERFORMANCE OF SIX SUB-GROUPS DURING THE LAST PRACTICE TRIALS

Measure	Source	Sum of Squares	d.f.	Variance	F*
Mean Response Time	Between Groups	3.95	5	.79	-
	Within Groups	98.67	54	1.83	
	Total	102.62	59		
Mean Reversal Errors	Between Groups	.483	5	.097	-
	Within Groups	7.700	54	.142	
	Total	8.183	59		
Mean Variability (Time)	Between Groups	1.00	5	.200	-
	Within Groups	19.83	54	.367	
	Total	20.83	59		
Mean Overshoot Errors	Between Groups	2.93	5	.586	-
	Within Groups	36.40	54	.700	
	Total	39.33	59		

* No F's were indicated because the variances within the groups were all greater than those between groups.

APPENDIX III

ANALYSES OF VARIANCE OF DISRUPTION SCORES FOR SIX OF THE GROUPS*

Source of Variance	Sum of Squares	d.f.	Variance	F	P
A. Reversal Errors (Transformed)					
Between Tasks	.0284	2	.0142	10.29	<.001
Between Stress	.0068	1	.0068	4.93	<.05
Interaction T x S	.0086	2	.0043	3.13	<.06
Error	.0743	54	.0014		
B. Mean Response Time (Transformed)					
Between Tasks	.636	2	.318	—	N.S.
Between Stress	15.852	1	15.852	14.74	N.S.
Interaction T x S	2.146	2	1.073	4.718	<.05
Error	12.278	54	.227		
C. Overshoot Errors					
Between Groups	6.73	5	1.35	—	N.S.
Within Groups	100.00	54	1.85		

* The one day nondominant task groups were omitted from this analysis because they did not reach the criterion of equivalent performances with the dominant groups before stress.