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STUDIES OF PERFORMANCE ASSESSMENT AND
ENHANCEMENT

Ben B. Morgan, Jr., et al

Louisville University

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**Studies of Performance Assessment and Enhancement:
Annual Progress Report
1 September 1970 - 31 May 1972**

By

Ben B. Morgan, Jr. and John D. Repko

June 1972

U. S. Army Behavior and Systems Research Laboratory
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ANNUAL PROGRESS REPORT, 1 SEPTEMBER 1970 - 31 MAY 1972

By

Ben B. Morgan, Jr. and John D. Repko

June 1972

U. S. Army Behavior and Systems Research Laboratory
Office, Chief of Research and Development
Department of the Army
Room 239, The Commonwealth Building
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Performance Research Laboratory
Graduate School
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FOREWORD

This report was prepared by Dr. Ben B. Morgan, Jr. (Associate Research Professor and Interim Director) and Mr. John D. Repko (Assistant Research Professor), Performance Research Laboratory, University of Louisville, Louisville, Kentucky 40208.

The research program under which this work was completed is supported by the Army Research Office under Army THEMIS Contract Number DA HC19-69-C-0009, "Studies of Performance Assessment and Enhancement," Project Number 2T014501B81B, Task Number 2T014501B81B 00, monitored by the U. S. Army Behavior and Systems Research Laboratory, Office, Chief of Research and Development, Department of the Army, Room 239, The Commonwealth Building, 1320 Wilson Boulevard, Arlington, Virginia 22209.

The authors wish to acknowledge the assistance of all the personnel who have contributed to the conduct of the research reported herein. A complete listing of these persons will be found in the section on personnel (pp. 31,32). Also, the authors gratefully acknowledge the guidance and assistance provided by the personnel of the U. S. Army Behavior and Systems Research Laboratory, especially Dr. Aaron Hyman, the contract technical monitor.

* * *

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SUMMARY

This is an annual progress report for the period, 1 September 1970 through 31 May 1972. The reporting period covers 21 months because the contractual year was rephased during FY 70-71 to run 1 June through 31 May instead of 1 September through 31 August, and the reporting period was extended to cover the additional months in the rephased contractual year. Subsequent reports will cover the 12 months from June through May.

This report presents brief summaries of research activities under six major headings: (a) studies of sustained performance, (b) psychophysiological and biomedical correlates, (c) personality, social, and subjective correlates, (d) technical studies and supporting laboratory research, (e) methodological and theoretical formulations, and (f) liaison activities.

Major accomplishments during the reporting period include the completion of data collection in seven long-term investigations of sustained performance and the reporting of results from several of these studies. The completed studies include investigations of the effects of continuous work and sleep loss, time displacement, and noise on sustained performance and four investigations of the behavioral effects of interrupted recovery. Another major accomplishment was the development of an Experimental Control System to provide complete control and operation of the multiple-task performance battery (ECS-MTPB). This system is now ready for full use in future MTPB studies. Other efforts included the publication of numerous reports based on THEMIS-supported research completed during or prior to this reporting period. Plans for next year call for the publication of additional studies completed this period and the continued investigation of sustained performance during periods of continuous work.

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STUDIES OF PERFORMANCE ASSESSMENT AND ENHANCEMENT

The Performance Research Laboratory was officially organized in September 1968 as one of the Institutes for Advanced Studies in the Graduate School of the University of Louisville. The establishment of the Laboratory as a separate department was made possible through the support received in the form of Army THEMIS Contract No. DA HC19-69-C-0009, "Studies of Performance Assessment and Enhancement." It was a step in the direction of creating a center of excellence for research in the important area of efficient and proper utilization of manpower resources. The development of this center has continued during the 21 months covered by this report, primarily through the support of the THEMIS Contract, although one-fourth of the Laboratory faculty and staff are now supported by the University of Louisville.

The over-all mission of the Laboratory represents an expansion of the program of research undertaken previously with other sources of support. This expansion has been previously reflected by a tabular format of all the research being conducted in the Laboratory (see First and Second Annual Progress Reports, Nos. PR-69-13 and PR-70-17, respectively). Only that research directly supported by the present contract will be discussed in detail in the present report; other research will be discussed briefly in order to show its relationship to the total research program. Entries are made only when reportable progress has been achieved.

1. STUDIES OF SUSTAINED PERFORMANCE

A synthetic-work technique for the study of man's work behavior or sustained performance has been developed and used over the past 15 years (cf. Alluisi, 1969). It is based on the measurement of time-shared, multiple-task performance in a synthetic (rather than simulated) work situation under controlled laboratory conditions; it represents an approach that has been used successfully in the assessment of complex operator performance (cf. Chiles, 1967). The synthetic-work situation is presented with the use of a multiple-task performance battery (MTPB) of six tasks that test both individual and small-group (or crew) performance. (For a brief description of the MTPB see section 1.1 of the First Annual Progress Report No. PR-69-13; more complete descriptions are given in Alluisi, 1969; Morgan & Alluisi, in press.)

1.1 Development, Design, and Construction of the MTPB

The Digital Equipment Corporation PDP-12A LINC Experimental Control System (ECS) ordered under the present contract was placed in full operation during this reporting period. The construction of the interfacing components, as well as the linkage of the ECS with the MTPB operator panels were completed during the first half of the period. Major efforts during the past 12 months have been directed toward the development of the software control programs, including the final debugging and revision of those programs. A complete check-out of the

ECS-MTPB was accomplished during SPADE-3 and SPADE-4N (see sections 1.5.1 and 1.6.1), and as a result of this check out, it appears that the system has been successfully developed to a point that will allow it to be employed in all future THEMIS-supported studies of sustained performance. Nevertheless, efforts are being continued in the further development of the software necessary for efficient experimental control and data summarization. During the next contractual year, efforts will be made toward expanding the software capabilities of the ECS to handle supporting laboratory research as well as the MTPB control and data reduction and summarization. In addition, two electromechanical versions of the MTPB continue to be used, as they have in the past (with permission under U. S. Army Contract No. DA-49-193-MD-2567), in the supporting studies and other laboratory research.

A report providing an up-to-date description of the synthetic-work methodology and the tasks of the MTPB was completed during the past year. This manuscript has been accepted for publication in Perceptual and Motor Skills (see section 5.1.15).

1.2 Reliability and Statistical Studies

1.3 Experimental Studies of Endurance and Work-Rest Scheduling

This is one of the principal areas of research being conducted under support of this Army THEMIS Contract. The continuation of this research should permit further advances in our understanding of endurance, "fatigue," work-rest scheduling, recovery patterns, and other temporal effects on sustained performance. It should also provide guidelines for the application of work-rest scheduling and other temporal factors to the enhancement of performance and the efficient utilization of manpower resources.

1.3.1 SPADE-1: Effects of 48 hours of continuous work and sleep loss on sustained performance (Morgan, Brown, Alluisi; Submitted Reports, Item 6).

A report of this study was submitted during the previous contractual year as Interim Technical Report No. ITR-70-16. A report based on this investigation was subsequently presented at the annual meeting of the Psychonomic Society, San Antonio, Texas, November 1970. In addition, a manuscript based on these results has been drafted and is currently undergoing final editing for possible publication in the psychological literature.

1.3.2 SPADE-2: Sustained performance during 36 hours of continuous work and sleep loss (Morgan, Brown, Coates, Alluisi; Submitted Reports, Item 13).

This experiment represents the second in the series of Studies of Performance Assessment and Enhancement (SPADE-2). It was conducted during the periods 9 November to 12 December 1970 (training) and 4 to

16 January 1971 (continuous work). The synthetic-work approach was employed to investigate (a) the decrements in performance produced by 36 hr. of continuous work and sleep loss, and (b) the recovery of performance from these decrements following 12 hr. of rest and recovery. Ten volunteer Navy and Air Force ROTC cadets were hired to participate in the training phase of the study by working 20 hr. per week as undergraduate research assistants. During this 4-week period, each subject was scheduled to spend 12 hr. per week (during three, 4-hr. work sessions) performing the tasks of the MTPB; the remaining 8 hr. per week were spent in working at other tasks normally assigned to undergraduate research assistants in the Laboratory. During the 6-day continuous-work phase of the study, the subjects worked 8 hr. according to a schedule of 4-hr. on-duty, 4-hr. off, 4 on, and 12 off (4-4-4-12) on each of 2 days, then on the next 2 days they worked 36 hr. continuously followed by 12 hr. of rest and recovery, and finally, they worked the 4-4-4-12 schedule on each of 2 additional days.

Performance during the 36 hr. of continuous work was greatly influenced by the circadian rhythm. The first performance decrements occurred after approximately 18 hr. of work, during the early morning hours of the first night; average performance decreased to approximately 92% of baseline performance. During the first half of the 2nd day of continuous work (by the end of the 36 hr.), performance improved to about 97% of baseline. All measures of performance indicated that the recovery of performance was complete (to baseline levels) following the 12-hr. period of rest and recovery. These results essentially replicate those of SPADE-1 (section 1.3.1) in three respects: (a) in both studies the first performance decrements began to occur after 18 hr. of continuous work, (b) the effects of diurnal cycling were evident in both cases, and (c) complete recovery of performance was obtained, even with only 12 hr. of rest and recovery. The results of the two studies differed in that a maximum performance decrement of only 11% was obtained in SPADE-2 as contrasted with a 34% decrement in SPADE-1.

A manuscript based on this study has been submitted to the Behavior and Systems Research Laboratory for publication as a technical report. In addition, a report of the combined SPADE-1 and SPADE-2 results was presented at the annual meeting of the Human Factors Society, New York, New York, October 1971.

1.3.3 BEIR: Behavioral effects of interrupted recovery (Coates, staff).

The research in this area has been supported primarily by U. S. Army Grant No. DA-ARO-D-31-124-71-C109. However, the research is directly related to the THEMIS-supported SPADE series of investigations (see sections 1.3.1 and 1.3.2); it will contribute significantly to our knowledge concerning man's performance during extended periods of continuous work, but also has been designed to provide specific information concerning the time course of recovery from the effects of continuous work and sleep loss.

During the period 31 May through 7 August 1971, data collection was completed in a series of four investigations of the Behavioral Effects of Interrupted Recovery (BEIR-1, -2, -3, and -4). The orientation and training of 10 volunteer Navy and Air Force ROTC cadets took place on 26 May and data collection began on 31 May and continued for the subsequent 10 weeks. Each of the two crews of five subjects worked alternate weeks serving (in a partially counterbalanced order) in each of four continuous-work/recovery conditions; namely 44 hr. continuous-work/4 hr. rest and recovery, 36/4, 36/3, and 36/2.

The results of these studies indicate that during the periods of continuous-work, performance followed a consistent pattern for all four studies: i.e., performance efficiency began to deteriorate after about 18 hr. of continuous work, it reached a maximum decrement after 22-24 hr., improved from that point to about 30-32 hr., and decreased slightly thereafter. Both the pattern and the degree of recovery were related to the length of the continuous-work period as well as the amount of rest and recovery provided. Recovery of performance was incomplete in all cases, although 4 hr. of sleep following 36 hr. of continuous work (BEIR-2) did produce a significant degree of recovery. In fact, approximately 73% recovery was obtained in BEIR-2, whereas only 40% was obtained in BEIR-1, 53% in BEIR-3, and 58% in BEIR-4. In addition, the immediate recovery of the BEIR-3 and -4 performance was found to decrease by several percentage points before climbing rapidly toward complete recovery. This result was undoubtedly produced by the interaction of the circadian rhythm with the recovery functions.

A report of the first of these investigations (BEIR-1) was presented at the annual meeting of the Southern Society for Philosophy and Psychology, St. Louis, Missouri, 30 March - 1 April 1972. Additional efforts have been directed toward the preparation of an interim technical report combining the results obtained from all four of these BEIR studies.

1.4 Experimental Studies of Illness and Organismic Stresses

This has been the major area of research supported by the U. S. Army Medical Research and Development Command under Contract No. DA-49-193-MD-2567, "Behavioral Effects of Infectious Diseases," or the BEID program as it has been called. The goal of this research has been the assessment (measurement and evaluation) of performance changes that take place during the course of man's incapacitation with infectious diseases. The results of eight experimental studies have been reported under this program, and the final report of progress to be submitted under this contract is being prepared at this time.

The results of research conducted under the BEID program have clear implications for the assessment and enhancement of man's performance. Specifically, these results have produced the following conclusions: (a) The average performance efficiency of a crew of men will drop between 25 and 33% during their illness with tularemia and between 18 and 25% during their illness with Phlebotomus fever. (b) During these illnesses, the average drop in performance efficiency is between 6 and 8% per 1°F rise in rectal temperature with tularemia and between 3 and 6% per 1°F

rise with Phlebotomus fever. (c) Individual differences range from essentially no decrement to maximum decrements of approximately 20% (with tularemia) and 14% (with Phlebotomus fever). (d) These individual differences seem to be correlated with the severity of the symptomatology or subjective feelings of the person suffering the disease. (e) The use of symptomatic chemotherapy with field-available drugs (Aspirin and Darvon) is sufficient for the enhancement of performance (or abatement of the otherwise expected performance decrements) during periods of infection with Phlebotomus fever.

The entries listed below represent those studies which have been completed since the last report of progress (PR-70-17). They are included in order to evidence the progress made toward the completion of this line of research.

1.4.6 BEID-6: Effects of illness (Phlebotomus fever) on sustained performance and muscular output (Morgan, Coates, Alluisi).

This study has been completed and a report based on its results has been accepted for publication in Human Factors.

1.4.7 BEID-7: Effects of symptomatic treatment on performance during illness with Phlebotomus fever (Coates, staff).

See section 1.4.8.

1.4.8 BEID-8: Effects on sustained performance of symptomatic treatment without illness: A control study (Coates, staff).

Data collection has been completed and a report combining the results of BEID-7 (section 1.4.7) and BEID-8 is being drafted for publication as an interim technical report.

1.5 Experimental Studies of Rest and Sleep-Wakefulness Cycling

1.5.1 SPADE-3: The effects of a 6-hour time displacement on sustained performance (Brown, Morgan, Coates, Thurmond, Alluisi).

An investigation of the effects of trans-zonal time displacement on sustained performance was conducted during the periods 17-22 December 1971 and 22-27 May 1972. Ten volunteer Navy and Air Force ROTC cadets, who also served in a study of the effects of noise on performance (see section 1.6.1), were required to work for 2, 8-hr. days on Eastern Standard Time. They then experienced the 6-hr. time shift associated with a ground-simulated air plane flight from New York City to Rome, Italy, and worked 4 days on the Rome-based time schedule.

Preliminary analyses of these data indicate that the initial time shift was accomplished by a 10-15% decrement in performance although

this varied as a function of specific tasks. Performance on the time-displaced schedule was characterized by relatively high performance during the first few hours of work with a symptomatic decrease in performance throughout the 8-hr. work day. Full recovery was not achieved during the 4-day post-shift period. The summarization and analyses of these data are complete, and the preparation of an interim technical report has begun. This study which has been designated SPADE-3, was supported in part by the THEMIS contract.

1.6 Experimental Studies of Environmental, Task, and Situational Stresses

1.6.1 SPADE-4N: Behavioral effects of prolonged exposure to continuous and intermittent noise (Repko, Loeb, staff).

During the periods of 3 to 15 January 1972 and 15 to 20 May 1972, sustained performance was assessed in a typical work situation wherein 90 dB continuous and periodic 96 dB intermittent broadband noise were added as environmental or work-situation stresses. The 10 subjects in this experiment (SPADE-4N) were trained to asymptotic levels of performance during the period of 8 November to 9 December 1971; they worked three, 4-hr. shifts per week, on alternate days of the week, during each of the 4 weeks. Subsequent to training, they were required to work 8 hr. per day for 6 successive days according to a 4-4-4-12 work-rest schedule, have 1 day off, then work 6 additional days according to the 4-4-4-12 schedule. During the first 4 days, five subjects worked while being exposed to 90 dB continuous noise and five other subjects were to be exposed to 103 dB intermittent noise during their work sessions. However, during the 1st day of noise exposure it became apparent that the 103 dB intermittent noise was causing much larger TTSs than was predicted on the basis of the available noise-exposure standards. The obtained TTSs were so large, in fact, that even though use of the intermittent noise was discontinued after the 1st day, all but one of the subjects required more than 5 days to recover from the inducted TTS (45-48 dB shifts).

During the first 4 days of the second 6-day work period the intermittent noise was reduced to 96 dB and conditions were reversed for the two groups. This provided data for 10 subjects under continuous noise, but only five subjects who served under the intermittent noise condition. The experiment was completed during the period of 15-20 May 1972 when data were collected for five additional subjects under the condition of periodic 96 dB intermittent noise.

The results of this study indicate that performance was influenced by both the temporal pattern and intensity of the noise. Specifically, it was found that neither noise condition had a deleterious effect on performance. In fact, it appears that performance under certain work-load conditions was enhanced by the presence of the periodic 96 dB intermittent noise (SPADE-4N-I). Furthermore, it was found that under both noise conditions, those work-load conditions which contained the greatest number of stimulus elements produced the best performance.

A report of this research, which also served as a doctoral dissertation for Mr. John Repko, is being prepared for publication in the form of an interim technical report. A presentation of the SPADE-4N results will also be made at the bi-annual meeting of the Acoustical Society of America, Miami, Florida, 28 November to 2 December 1972.

2. PSYCHOPHYSIOLOGICAL AND BIOMEDICAL CORRELATES

As changes in work behavior or sustained performance take place, it is to be expected that concomitant psychophysiological and biomedical correlates can be isolated and identified in "causal" relations where such relations exist. This is especially true of changes that take place as a function of illness and organismic stresses, and one of the specific goals of the BEID research is the correlation of performance changes and reactions, including those induced by direct (curative) and indirect (symptomatic) physical and chemotherapeutic treatments. The isolation, identification, and correlation of associated psychophysiological and biomedical changes will also be sought where changes in sustained performance are measured as functions of endurance and work-rest scheduling, forced rest and sleep-wakefulness cycling, or environmental, task, and situational stresses.

2.1 Development of Indices, Techniques, and Computer Programs

During this report period, new efforts have been directed toward developing psychophysiological and biomedical correlates of sustained performance. It is anticipated that these efforts will further advance our knowledge and understanding of the existing biomedical correlates of sustained performance; progress in this area is evidenced in section 2.2, below.

2.2 Reliability and Statistical Studies

During this reporting period an extensive series of correlational analyses have been computed with the data of BEID-6 (see section 1.4.6). Specifically, 14 MTPB performance measures, 11 strength, endurance, and recovery measures of muscular output, and 22 biomedical measures (including the results from blood, urinary, and dietary analyses) have been intercorrelated for each of the 10 subjects as well as for the average experimental subject and the average control subject. These intercorrelations were computed in an attempt to isolate and identify any of the biomedical correlates of performance that might provide some information concerning the wide range of individual differences in the behavioral effects of illness that typically have been obtained in the BEID-series studies.

These analyses have resulted in the identification of eight new biochemical correlates of sustained performance; five of these were useful in identifying those subjects who were highly reactive (showed large performance decrements) to illness with Phlebotomus fever, and three were found to correlate only with the performance of the control (uninfected) subjects. All of these correlates were related to the urine

and dietary analyses; the blood-analysis data seem to have had little value in predicting a subject's behavioral response to illness. These results were included in a report that has been accepted for publication in Human Factors (see section 1.4.6).

2.3 Experimental Correlates of Sustained Performance

2.3.1 Changes in muscular strength, endurance, and recovery during periods of performance stress (Smith, Morgan, Caldwell, Lyddan).

During the 6 working days of the continuous-work phase of SPADE-2 (see section 1.3.2), muscular output was measured using isometric measurements of muscular strength, endurance, and recovery. The results of this study indicated that the stress imposed by the 36 hr. of sleep loss and continuous work did not influence muscular output detrimentally. A report of this study has been included as an appendix to the SPADE-2 technical report (see section 1.3.2).

2.3.3 Effects of symptomatic treatment upon muscular performance during illness with Phlebotomus fever (Coates, staff).

This study, which was conducted as part of the BEID-7 experiment (see section 1.4.7), investigated the effects of symptomatic treatment on muscular performance during illness with Phlebotomus fever. Muscular performance (strength, endurance, and recovery) was measured once each day, at 1525 hr. for Able crew and 1600 hr. for Baker crew. These data have been analyzed, and will be combined with those of BEID-8 (see section 1.4.8) in a report based on these two studies. This interim technical report is being drafted currently.

2.4 Supporting Laboratory Research

2.4.1 Measurements of muscular strength, endurance, and recovery over fifteen successive days. Journal of Motor Behavior, 1971, 3, 213-223 (Lyddan, Caldwell, Alluisi; Submitted Reports, Item 11).

Muscular output was measured in terms of strength, endurance, impulse, and recovery, with 10 subjects, 4 times per day over 15 successive days. A general index (the mean percentage of baseline performance with all measures) indicated that performance generally improved over the first 5 or 6 days, and remained relatively stable thereafter. The measures of strength were sensitive to within-day effects, whereas endurance and recovery measures were not influenced by such circadian rhythms.

This research was supported in part by this THEMIS contract and in part by the U. S. Army Medical Research and Development Command, Department of the Army, under Contract No. DA-49-193-MD-2567.

2.4.4 Auditory adaptation and its relationship to a model for loudness. Journal of the Acoustical Society of America, 1971, 51, 638-643 (Weiler, Loeb, & Alluisi; Submitted Reports, item 12).

Predictions, inferred from Small's model, of significantly lower auditory adaptation when test-tone intensity exceeds adapting-tone intensity were confirmed. Adaptation effects with test and adapting tone equal in intensity increased between 40 and 60 dB and remained relatively constant between 60 and 80 dB. When adapting-tone intensity exceeded test-tone intensity, previous findings that adaptation does not increase generally were confirmed.

This research was supported in part by the U. S. Army Medical Research and Development Command, Department of the Army, under Contract Nos. DA-49-193-MD-2197 and DA-49-193-MD-2688, and in part by this Army THEMIS contract.

2.4.8 Effects of alcohol and amphetamine on speech (Smith, Hamon).

A preliminary study has been conducted in order to investigate the feasibility of (a) using drugs in the study of sustained performance (either to stress or to enhance performance) and (b) using speech analyses as a research tool in studying the effects of various stresses. Each of 10 students from the University of Louisville School of Medicine served as subjects, in what they thought was an experiment investigating the effects of amphetamine and alcohol on strength and endurance, in each of five counterbalanced conditions--(a) alcohol alone, (b) d-amphetamine alone, (c) a mixture of alcohol and amphetamine, (d) placebo, and (e) no administration. The amount and rate of speech were increased by d-amphetamine and by the mixture, but were unaffected by alcohol and the placebo. Although these results are equivocal, they do suggest that speech analyses might be sensitive to the kinds of stresses studied with the MTPB. A presentation of this study and its results were made at the Psychonomic Society meetings, St. Louis, Missouri, 11-13 November 1971.

2.4.10 Examination of patterns of temporary threshold shift (Loeb, Vanderhei, Repko, Brown).

The purpose of this series of investigations is to determine the pattern of TTS recovery as functions of the intensity of continuous and intermittent noise exposure, different duty cycles of intermittent noise exposure, and the intensity (less than 80 dB) of the background noise in the recovery period. The first phase of this research, which is currently being conducted, will concentrate primarily on continuous noise, although a pilot study on intermittent noise was also completed during the reporting period. In the continuous noise study, 6 subjects are being exposed to 1414-2828 Hz (center frequency 2 KHz) noise, beginning with a 2.5 min. exposure and increasing the duration of each successive exposure by a multiple factor of two until a criterion shift of 40 dB is attained. Subsequent to each exposure, retesting with both 3 KHz and 4 KHz test tones is performed at 2, 4, 8, 16, 32, 64, 128,

256, and 512 min., and at subsequent doubled-length intervals until complete recovery is obtained. Curves of the obtained recovery data will be fitted by a least-squares procedure in order to determine the exposures that produce TTS_2 of 10, 20, 30, and 40 dB; these exposure conditions will then be repeated for verification of the curves.

Subsequent experiments will attempt to identify those durations of exposure of various intermittent-noise conditions (e.g., 1 sec. on and 9 off; 5 on, 5 off; 10 on, 1 off) which produce TTS_2 of 10, 20, 30, and 40 dB. Recovery curves will then be determined for these conditions and compared with those for continuous noise.

2.4.11 Analyses of hearing capacities of ROTC cadets at the University of Louisville (Loeb, Vanderhei, Repko, Brown).

The purpose of this study (and that reported in section 2.4.12) is to identify a group of people which has an appreciable possibility of sustaining permanent hearing loss (PHL) as a result of long-term, environmental (e.g., occupational) exposure, to obtain from these people measurements of TTS and TTS recovery, and eventually to correlate these and other possible indices with any PHL sustained by these individuals at the end of a 2-year period.

The first phase of this research is directed toward identifying a population of subjects that can be employed in the correlational studies. The current efforts in this regard have compared the hearing levels of 1st-year and 4th-year NROTC midshipmen at the University of Louisville and found significant differences in hearing levels for the two groups. Similar testing for 30 non-military subjects is also being conducted in order to obtain control data for the NROTC midshipmen.

2.4.12 The relationship between temporary and permanent hearing loss in humans (Loeb, Vanderhei, Repko).

The purpose and design of this study are essentially identical to that described in section 2.4.11, however, the subject populations are different. Plans are being made for testing the hearing levels of 1st- and 4th-year midshipmen at the U. S. Merchant Marine Academy. The results of this study will be compared with those of section 2.4.11 in order to determine which population of subjects is more likely to experience PHL. That population will then be selected for the more detailed correlational studies of TTS and PHL.

This and the above two studies (sections 2.4.10 and 2.4.11) are being supported principally by U. S. Army Medical Research and Development Command, Contract No. DADA-17-72-C-2039 and conducted with the cooperation of personnel at the U. S. Army Medical Research Laboratory, Fort Knox, Kentucky.

2.5 General Theory Related to Psychophysiological and Biomedical Variables

2.6 Comparative Studies of Psychophysiological and Biomedical Correlates

In order to provide an efficient and comprehensive research program, certain technical laboratory studies are conducted to provide information relevant to the design of the more expensive and more laborious MTPB studies of sustained performance (see section 1). Although animal studies are of only marginal interest to this research program, there are certain problems that can not be easily researched with humans because of the involvement of drugs and other dangerous procedures. Thus, during this reporting period, a series of comparative studies were conducted to provide data relevant to performance as affected by selective sleep loss.

2.6.1 Effects of REM sleep deprivation on rotorod and open-field behavior of the rat (Corum, Thurmond, Repko).

A series of studies were conducted to assess the effects of REM-sleep deprivation on rotorod and open-field behavior in the rat. In the first study, REM sleep was deprived through the use of a sleep-deprivation technique employed by Cohen and Dement (1965) and Joy and Prinz (1969). Preliminary analysis of the data indicate that after 15 days, motor coordination and balance on the rotorod test dropped about 71% from a criterion of 2-min. on the rotorod. On the other hand, behavior assessed in the open-field situation showed significant hyperactivity.

Because REM deprivation was only about 80% complete using this technique, an additional study was conducted utilizing parachlorophenylalanin, which manipulates serotonin levels in the brain, to produce immediate and total REM-sleep deprivation. Data collection has been completed in this phase of the study and analysis of the results is currently being conducted. This research, which is being conducted as Mr. Ronald Corum master's thesis, is supported by the Department of Psychology and, in terms of minimal staff research time, by this Army THEMIS contract.

3. PERSONALITY, SOCIAL, AND SUBJECTIVE CORRELATES

It is reasonable to assume that as measurable changes in work behavior or sustained performance are created by stresses of various sorts (section 1), associated changes will occur in psychological factors such as the personality, social, and subjective reactions of the persons so affected. Also, it may be expected that persons of different psychological make-up will react differently to the presence of such stresses. One of the goals of the Laboratory's research program calls for the measurements of the psychological changes that occur in relation to concomitant changes in the psychophysiological variables (section 2) as well as sustained performance (section 1). An additional goal is the development of testing instruments that will permit the prediction of man's behavioral reactions to stress on the basis of psychological characteristics such as personality, social, and subjective reaction patterns.

Much of the work done in this area in the past has, of course, been directed toward the prediction of performance as affected by the stress of illness under support of the BEID Contract No. DA-49-193-MD-2567. Additional details regarding these phases of the Laboratory's research program have been given elsewhere (Thurmond, Driscoll, & Morgan, 1970). Efforts have been made during the past 21 months, however, to extend these predictions to performance as affected by sleep loss, trans-zonal time displacement, and noise stresses.

3.1 Development of Instruments, Measures, Techniques, and Procedures

3.2 Reliability and Statistical Studies

3.3 Experimental Correlates of Sustained Performance

3.3.5 SPADE-1: Psychological responses to 48 hours of continuous work and sleep loss (Driscoll).

See section 3.3.7.

3.3.7 SPADE-2: Psychological responses to 36 hours of continuous work and sleep loss (Driscoll).

This study and that listed above (section 3.3.5) represent areas of research conducted in conjunction with the long-term studies on the effects of sleep loss and continuous work on performance. As indicated above, the present effort to relate subjective and personality variables to performance during continuous work and sleep loss is part of a larger program of research designed to measure the effects of various stressors on performance. The major thrust of this research falls under three main areas: (a) the description of changes in subjective states as a function of stress; (b) the relationship of changes in performance to changes in subjective states; and (c) the prediction of performance under stress from pre-stress measures of attitudinal and personality variables.

The methodology employed in these studies was essentially identical to the general methodology of the larger program; it involved the administration of a standard battery of tests and check lists to the 10 subjects participating in the SPADE-1 and SPADE-2 studies, respectively. The data of each study have been analyzed and a report of the results appears as an appendix to each of the interim technical reports of these sleep-loss studies. Although significant progress has not been made toward the prediction of performance from personality characteristics, substantial changes in subjective states have been found to occur as a result of the continuous work and sleep loss. In addition, significant relationships between changes in performance and changes in subjective states during continuous work and sleep loss have been identified.

3.3.8 SPADE-3: Psychological responses to sustained performance under conditions of trans-zonal time displacement (Driscoll, Brown).

This study was conducted in conjunction with the long-term study of the effects of trans-zonal time displacement on sustained performance (see section 1.5.1). During the next year these data will be analyzed and a report of the results will appear as an appendix to the interim technical report of SPADE-3.

3.3.9 SPADE-4N: Psychological responses to sustained performance under noisy conditions (Driscoll, Repko).

This study was conducted in conjunction with the long-term studies on the effects of 90 dB continuous and 96 dB intermittent periodic noise on sustained performance (see section 1.6.1). During the next year these data will be analyzed and a report of the results will appear as an appendix to the interim technical report of SPADE-4N.

3.3.10 Psychological responses to continuous work under conditions of sleep loss and interrupted recovery (Driscoll, Coates).

This study represents an effort to assess the associated changes in the personality, social, and subjective reactions of subjects affected by sleep loss and varying amounts of recovery from sleep loss. These data were collected in conjunction with the series of four investigations of the Behavioral Effects of Interrupted Recovery, supported by U. S. Army Grant No. DA-ARO-D-31-124-71-G109. These data have been analyzed and a report of the results will appear as an appendix to the report submitted under that contract.

3.4 Supporting Laboratory Research

3.4.1 Uncertainty (H) estimation. Journal of Experimental Psychology, 1969, 79(3), 565-567 (Driscoll & Sturgeon).

The relationship between uncertainty and estimates of uncertainty was studied. Circular stimuli containing either 2, 4, 8, 16, or 32 colors (each covering a specified segment of the circle) were presented for estimation of their uncertainty, $H = -\sum p(i) \log_2 p(i)$, where $p(i)$ is the proportion of the circle covered by segments of the i th color. For stimuli below 28 bits, mean magnitude estimates of uncertainty increased directly with H and were, where expected, significantly different from probability estimates for the same stimuli. For those stimuli above 28 bits, however, subjects appeared to confuse uncertainty with probability. Males and females gave both similar uncertainty and similar probability estimates. Results demonstrated that within limits, human subjects are capable of estimating H .

This research was supported by grants from the College of Arts and Sciences, University of Louisville and, in terms of staff research time, by this THEMIS contract.

3.4.2 The effects of uncertainty and importance on information exchange in decision-making groups (Bednarsky, Driscoll).

The effects and interactions of uncertainty (H), importance (I), and coordination (initial agreement or disagreement, C) on communication in the dyad were investigated in 32 uncoordinated dyads and 8 coordinated dyads. In prescaling, 80 male students were given two decision problems involving Thematic Apperception Test Cards 14 and 38M. In this scaling session each subject was given a list of four or five themes and required to decide the number of people in a group of 100 who would give each theme. In the dyad, the subjects' task was to reach an agreement as to the most frequent theme given by other students like themselves for the cards from four (or five) alternative themes presented them. For subjects who disagreed initially (uncoordinated dyads), those who reported a highly preferred theme (low-H groups) had significantly longer talk-times than those who saw themselves as being given with a more equal frequency (high-H groups). A content analysis of tape recordings of group discussions showed that low-H groups expressed more opinions and feelings and referred more to personal experience, whereas high-H groups tended to rely on more factual information.

This research, which also served as Mr. Bednarsky's master's thesis, reflects the Laboratory's continuing efforts to understand fully group interaction and coordination which is necessary in the performance of the code-lock task of the MTPB.

3.4.3 Psychophysics of uncertainty: Direct estimates of apparent entropy (Woodward, Driscoll, Loeb).

The goal of this research project is to provide further understanding of the effects on man's performance of different levels of subjective uncertainty in a decision-making situation. One major study has been completed under this project, however, inconclusive results have necessitated the collection of additional data. This study is serving as Mr. Woodward's master's thesis and further data collection and analyses are being conducted at this time.

4. TECHNICAL STUDIES AND SUPPORTING LABORATORY RESEARCH

The research conducted in the subareas that follow serves to enhance the efficiency of the overall program. Each subarea is related to a domain of man's behavioral functioning that is measured (or yet to be measured in certain cases) with the MTPB employed in the studies of sustained performance or work behavior. Wherever an answer to a pertinent question can be obtained with the less-expensive and less-involved procedures of a technical study or laboratory experiment, the study will be conducted and classified in this general section of the research program. Where studies have been completed--published--they are listed with full journal citation. Where studies are still in progress, descriptions are given only for those supported by or directly related to this Army THEMIS contract.

4.1 Vigilance, Watchkeeping, and Attentive Functions

- 4.1.13 Influence of observing strategies and stimulus variables on watchkeeping performance. Ergonomics, 1972, in press (Coates, Loeb, Alluisi).

Experiments were performed to determine whether an observing strategy of gazing straight ahead or scanning the visual field is superior when a subject's task involved reacting rapidly to readily observed onsets or offsets of a colored light. A subsidiary goal of the experiments was to resolve conflicting results of past experiments as to the effects of color, position, and onset or offset of signal light. The experiments clearly indicated that a strategy of gazing ahead is superior for this kind of signal, but results were still equivocal regarding the other effects.

This research, which was previously reported under sections 4.1.5 and 4.1.13 (see PR-70-17), was supported in part by U. S. Army Contract No. DA-49-193-MD-2567.

- 4.1.14 Effects of temporal uncertainty and stimulus-response uncertainty on performance of the probability-monitoring task (Coates, Alluisi, Loeb).

An investigation of the effects of six signal rates (9, 12, 18, 24, 48, & 72 signals/hour) was conducted with the probability-monitoring task. The results of this study indicate that probability-monitoring performance as measured by the percentage of correct detections increases linearly with logarithmic increases in signal rates. A report of the results of this study was presented at the Tenth Annual Meeting of the Psychonomic Society, St. Louis, Missouri, 6-8 November 1969. It was decided to attempt to replicate these findings with the warning-lights monitoring task (see section 4.1.15) prior to submitting the results of both studies for consideration as a regular publication in one of the psychological journals. This study was supported in part by U. S. Army Contract No. DA-49-193-MD-2567.

- 4.1.15 Effects of temporal uncertainty on a simple discrete watchkeeping task: Warning-lights monitoring (Alluisi, Coates, Loeb).

This study was designed to measure the effects of the temporal uncertainty on performance of the MTPB's warning-lights monitoring task. This represents the final in a series of three investigations of the effects of temporal uncertainty, as defined by signal density, on watchkeeping performance; it will complete our catalogue of functional relations between temporal uncertainty and performance on the three watchkeeping tasks employed in the MTPB. Data collection in this study has been delayed because of priorities in other areas (particularly those of section 1). It is anticipated that this research will be completed during the next contractual year on an available-time basis and that it will be published in conjunction with the data of section 4.1.14.

4.1.17 Effects of spatial and signal uncertainty on watchkeeping performance with probability monitoring (Aylworth, Thurmond).

A report of this study was presented at the annual meeting of the Psychonomic Society, St. Louis, Missouri, 11-13 November 1971. Efforts are currently being directed toward the preparation of a report of this study for possible publication in the psychological literature.

4.2 Sensory-Perceptual Functions

4.2.18 Identification of histoforms at different levels of complexity as a function of homogeneity (Repko, Thurmond).

A report of this study was made at the annual meeting of the Psychonomic Society, San Antonio, Texas on 5-7 November 1970 and a manuscript is being prepared for possible publication in the psychological literature.

4.2.20 Effects of figural noise, rotation, and other task variables on the visual perception of form. Interim Technical Report ITR-71-18, 1971 (Thurmond; Submitted Reports, Item 9).

This report summarized the results of four experimental investigations of the perceptual performance obtained with tasks displaying visual information in the form of metric figures--visual forms that are analogs of the amplitude modulated waveforms that characterize the signals of certain sonar and radar presentations; these same forms are used in a target-identification task of the MTPB. Nine of the principal independent variables studied in this research were found to significantly affect performance as measured by response time and by accuracy. Performance was relatively poor under conditions of figural rotation, noise, numerous choice alternatives, decreased discriminability, peripheral rather than central viewing, with use of constrained as opposed to random figures, and with use of histoforms instead of polygons. The consistent presence of a "correct" alternative among the possible choice figures improved performance when a relatively large number of random choice figures were presented. Performance was also improved by the use of constrained choice figures when the correct choice was not always present among a relatively large number of alternatives. Under conditions of peripheral viewing, performance was enhanced by using forms with solid surface texture.

The general conclusions reached regarding ways of optimizing visual displays of complex information were as follows: (a) The display should provide increased cues for discrimination by enhancing the visibility of features that distinguish one pattern from another rather than providing finer figural detail. (b) Increasing the signal-to-noise ratio of the displayed information will benefit the observer in situations where rotations of the display relative to the observer are unavoidable. (c) Analogues of amplitude-modulated waveforms used to represent complex information visually may be more easily identified when they take the form of

patterns that distribute the visual features radially, rather than horizontally, in each shape. (d) Unless practical considerations dictate otherwise, the visually patterned information should be displayed as solid shapes against a uniform background rather than shapes which are outlined in form.

4.3 Memory Functions

4.3.4 Feature encoding and pattern classification with sequentially presented Markov stimuli. Perception & Psychophysics, 1971, 9, 203-207 (Brown, Aylworth; Submitted Reports, Item 8).

The major objective of this experiment was to develop and evaluate a methodology designed to permit more direct assessment of the detailed processes involved in prototype abstraction. Thirty subjects participated in a task having the following characteristics: (1) classifications of Markov-generated stimuli sampled from two different populations, (2) controlled scanning of pattern features, (3) a measure of the degree to which pattern features were correctly identified, and (4) intermittent reproduction of pattern features abstracted from collections of mixed instances. Results showed that a significant number of the subjects learned to classify the stimuli into categories corresponding to generation rules and, at least partially, abstracted the population prototypes from these variable instances. The feature identification data suggested that the subjects who were unsuccessful in classifying the stimuli into the rule-defined categories used an inappropriate strategy for sampling pattern information upon which to base their classifications.

A report of this research was made at the annual meeting of the Southern Society for Philosophy and Psychology, Durham, North Carolina, March 1970, prior to appearing in the psychological literature.

4.3.5 Recognition of prototype deviants under simultaneous and sequential comparison conditions. Perceptual and Motor Skills, 1971, 32, 491-502 (Brown; Submitted Reports, Item 10).

This experiment was conducted to determine the extent to which subjects encode relevant stimulus attributes and abstract conceptual rules in a pattern-recognition task involving complex multidimensional histoforms which are deviants of three different population prototypes. Task-memory requirements were varied in a multiple-alternative discrimination task by presenting stimuli either simultaneously or sequentially for comparison. Results showed that subjects learned the relevant dimensions along which the stimuli varied to the extent that they could only recognize histoforms as having approximately the same magnitudes of deviation from the prototypes. Performance was higher, however, under the simultaneous condition, suggesting that subjects failed to combine learned attributes into conceptual rules to a degree sufficient for a reduction in information processing and storage requirements to occur.

4.3.6 Discrimination of multidimensional stimuli as a function of prototype familiarization and task-memory requirements (Rebbin, Brown).

A report of the results of this experiment was made at the annual meeting of the Psychonomic Society, San Antonio, Texas, November 1970.

4.3.7 Constraint redundancy as a determiner of attribute- and rule-learning aspects of sequential pattern recognition, in press (Corum, Brown).

The purpose of this experiment was to assess the manner in which attribute-learning and rule-formation components of schema learning vary as a function of constraint redundancy magnitude. Twenty-four subjects participated in a pattern recognition task involving 70%, 50%, 40%, or 20% redundant Markov sequences sampled from three different schema families. The subjects were required to work through the 90 sequences in a manner similar to that encountered in a probability learning paradigm. Results showed that decreasing redundancy magnitude reduced the degree to which both attribute- and rule-learning occurred. The supposition that constraint redundancy is a necessary condition for, and one of the main determiners of, the schema learning process was thus confirmed. This report has been accepted for publication in Perceptual and Motor Skills; a presentation of these results was also made at the annual meeting of the Southern Society for Philosophy and Psychology, Athens, Georgia, April 1971.

4.3.8 Recognition of prototype deviants in a pattern classification task involving complex multidimensional stimuli (Brown, Corum).

The purpose of this study was to delineate subjects' capabilities for learning to recognize different levels of stimulus variability in a schema-formation task. Subjects were required to classify, without knowledge of results, 30 sets (six stimuli per set) of complex, multidimensional histoforms which were distortions of three different population prototypes; subjects then provided scaled judgments of stimulus variability following each classification response. Results showed that subjects whose classifications were consistent with the prototype-defined categories also learned to recognize the different magnitudes of prototype distortion, whereas the inconsistent subjects failed to exhibit any degree of variability learning. The supposition that deviant stimuli may be processed and stored in memory as pattern-specific corrections was thus supported, at least with respect to the variability-learning requirement. The results of this study have been submitted for publication in the psychological literature.

4.4 Information Processing and Decision-Making Functions

4.4.6 Effects of relevant and irrelevant information in a digit-cancellation task (Morgan, Corson, Hodge).

As a follow-up to a previous study (section 4.4.3, PR-70-19), performance on a paper-and-pencil digit-cancellation task was investigated as a function of four major parameters; namely, (a) the number of relevant digits (R; digits to be cancelled), (b) the number of irrelevant digits (I; digits to be ignored), (c) instructions (inclusive vs. exclusive), and (d) practice (six pages of 144 digits each). A total of 280 subjects were required to mark certain digits in two booklets, each of which contained three pages of 144 digits selected from the set 0-9. The subjects were divided at random into 28 groups of 10 subjects each, and the subjects in each group were required to cancel a specified number of digits (R=2 through 8) while ignoring certain other digits (I=2 through 8); the 28 performance conditions can be defined by the ratio R/I, where R and I are varied independently from 2 to 8. Five subjects in each group performed under inclusive (e.g., "cancel digits 2 and 4") and five performed under exclusive instructions (e.g., "cancel all digits except 1 and 3"). Results indicated that increases in irrelevant information had a relatively greater detrimental effect on performance than did increases in relevant information. Interactions of the major variables indicated that irrelevant information had a greater effect on performance under exclusive instructions and that improvements in performance with practice was also greater under exclusive instructions. The interpretation of these findings and their theoretical implications were presented at the annual meeting of the Southern Society for Philosophy and Psychology, St. Louis, Missouri, on 30 March-1 April 1972.

4.4.10 Assessment of decision-making functions in a multiple-task performance battery (MTPB) (Rebbin, Morgan, Alluisi).

This study was designed to investigate the parameters of a decision-making (DEMAK) task developed to measure decision-making behavior in a performance setting. The DEMAK task consisted of two components. One of the components was represented by a display used for presenting subjects with "second-hand" (the kind of data on which many administrative-type decisions must be based) information about a problem. The other component in the DEMAK task was represented by a display used to present subjects with a "first-hand" exposure to the decision problem--in this case a pattern discrimination problem containing visual noise. The second-hand (secondary) information which the subjects received represented the judgments of "other subjects" about the pattern discrimination (primary) problem.

The conclusion derived from the data of this study is that when an individual is required to make administrative-type decisions about problems, he should first seek out sources of secondary information which are as reliable as possible. Then, he must determine if it would be advantageous for him to expose himself to the first-level data, realizing that if he does so he apparently runs the real risk of decreasing the overall efficiency of his decision-making behavior.

The results of this study should contribute to the experience required in order to provide for a direct measure of decision-making behavior among the time-shared tasks of the MTPB. A preliminary report of this study was presented at the annual meeting of the SSPP, Durham, North Carolina, March 1970. Efforts will continue during the next contractual year to assess the feasibility of the use of the DEMAK task within the MTPB.

4.5 Group-Performance, Communications, and Procedural Functions

4.6 Special Skills and Perceptual-Motor Functions

4.7 Reasoning, Problem-Solving, and Intellectual Functions

Research has been completed in this area under National Aeronautics and Space Administration (NASA) Research Grant No. NGR 18-002-008, "Performance Measurement of Nonverbal Mediation," with Dr. Alluisi as principal investigator. This research has led to the development of three versions of the code-transformation task (COTRAN). The results of this line of research have been published as NASA Contractor Reports (Alluisi & Coates, 1967, Alluisi & Morgan, 1968; Alluisi, Morgan, & Dempsey, 1970) and in a final report of progress (Morgan & Alluisi, 1971). Certain parts of the results have been published in a psychological journal (Alluisi & Coates, 1969; Alluisi & Morgan, 1971; Coates & Alluisi, 1971; Coates, Alluisi, & Morgan, 1971; Morgan & Alluisi, 1971), and other reports are currently being prepared for publication. It is hoped that further development of this task, and publication of the obtained results, can be continued with support from other sources.

4.7.2 Reliability and correlates of the three-phase code transformation task (3P-COTRAN). Perceptual and Motor Skills, 1971, 32, 971-985 (Coates, Alluisi).

In a further experimental test of a 3P-COTRAN task, 84 subjects solved six blocks of three problems, and later spent 6 hr. in responding to paper-and-pencil tests of intelligence and certain personality characteristics. A factor analysis of 75 measures led to the identification of eight factors, five of which represent 3P-COTRAN performances, one verbal intelligence, and two personality characteristics. Analyses based on nine selected measures indicated differential practice effects, with the problem-solving third phase of the task being more slowly learned. Reliability of the measures and correlates of the task were computed and discussed.

4.7.3 Acquisitions and performance of a problem-solving skill. Perceptual and Motor Skills, 1971, 3, 515-523 (Morgan, Alluisi).

The acquisition of skill in the performance of a 3P-COTRAN task was studied with 20 subjects who solved 27 3P-COTRAN problems during

each of eight successive sessions. Factor analyses led to the identification of five factors that were invariant across the eight sessions and identical to those identified in previous studies (Alluisi & Coates, 1969; Coates & Alluisi, 1971). Analyses of variance of nine selected measures indicated that performance was significantly affected by practice; improvements in speed continued even after accuracy had reached asymptotic levels. Although transformation complexity had no effect on early performances, the three- and four-element transformations were solved more quickly than the five-element in the problem-solving Phase III of later skilled performances.

4.7.4 Effects on sustained performance of time sharing a three-phase code transformation task (3P-COTRAN). Perceptual and Motor Skills, 1971, 33, 639-651.

The 3P-COTRAN task was time shared with five different combinations of tasks selected from a MTPB used in a synthetic-work approach to the study of work behavior or sustained performance (Alluisi, 1969). Twenty subjects previously trained to a high level of skill on the 3P-COTRAN task were divided at random into five groups of four subjects, each of which then time shared the task with a different combination of MTPB tasks. The results were analyzed in terms of both the effects of the time sharing on the 3P-COTRAN performances, and the effects of 3P-COTRAN on the time-shared MTPB performances. Evidence of the adoption of different response strategies to time-shared tasks, especially under conditions of operator over-load, or work-load on performance stress, was found, and the methodological implications of this finding were discussed.

4.7.5 Factor structure of the digital-readout version of the COTRAN task as related to the three-phase version (Morgan, Alluisi).

See section 4.7.6.

4.7.6 Effects of illness with Phlebotomus fever on the performance of two versions of the COTRAN task (Morgan, Coates, Dempsey, Alluisi).

The results of this study have been combined with those of section 4.7.5 in a report that will be submitted for possible publication in a psychological journal. This report has been drafted and is currently being edited for publication.

4.7.7 Acquisition of skilled performance on the digital-readout COTRAN task (Dempsey, Morgan, Alluisi).

This research, which also served as the master's thesis of Mr. Thomas K. Dempsey, has been completed. A manuscript based on the results of this study has been drafted for possible publication in the psychological literature.

4.7.8 Effects of operator work load on performance of the digital-readout COTRAN task (Dempsey, Morgan, Alluisi).

This study has been completed, and its results will be published following the publication of the report referenced in section 4.7.7.

5. METHODOLOGICAL AND THEORETICAL FORMULATIONS

Certain of the methodological and theoretical formulations, which appear here only on publication, were supported by sources other than the present Army THEMIS Contract No. DA HC19-69-C-0009. The titles of all the work done in this area during the current reporting period are included here to provide an overview of the Laboratory's total research program.

5.1 Literature Reviews, Models, and General Theory

- 5.1.8 Alluisi, E. A. Pilot performance: Research on the assessment of complex human performance. In Patton, R. M., Tanner, T. A. Jr., & Swets, J. A. (Eds.), Applications of research on human decision making. Washington, D. C.: NASA Report, 1970, No. SP-209, 13-20.
- 5.1.9 Alluisi, E. A. Information and uncertainty: The metrics of communications. In K. B. DeGreene (Ed.), Systems psychology. New York: McGraw-Hill, 1970, 171-206.
- 5.1.10 Morgan, B. B. Jr. Use of the synthetic-work technique in the assessment of sustained performance. In "Standardization of tasks and measures for human factors research." USA HEL Technical Memorandum, 1970, No. 19-70, 33-48.
- 5.1.11 Alluisi, E. A. Performance research and predictability. In Hennessy, J. R. (Ed.), The prediction and understanding of human behavior. U. S. Army Advanced Materiel Concepts Agency Report, 1971, No. AMCA.
- 5.1.12 Coates, G. D., Alluisi, E. A., & Morgan, B. B. Jr. Trends in problem-solving research: Twelve recently described tasks. Perceptual and Motor Skills, 1971, 33, 495-505.
- 5.1.13 Loeb, M. Factors influencing absolute threshold. In, 1970 Reviews of scientific literature, Committee on Hearing and Equilibrium, B. R. Alford (Chm.). Published by American Academy of Ophthalmology and Otolaryngology; Rochester, Minn., 1971, 66-69.

5.1.14 Morgan, B. B. Jr., & Alluisi, E. A. Applicability of research on sustained performance, endurance, and work-rest scheduling to the development of concepts and doctrines of continuous operations. In "Military requirements for research on continuous operations." USA HEL Technical Memorandum, 1972, No. 12-72, 89-113.

5.1.15 Morgan, B. B. Jr., & Alluisi, E. A. Synthetic work: A methodology for the assessment of human performance.

The purpose of this paper is to provide a complete and up-to-date description of the synthetic-work approach to performance assessment. This manuscript has been accepted for publication in Perceptual and Motor Skills.

5.1.16 The effects of sleep loss and continuous work on time-sharing aspects of sustained performance (Brown, Zwaga, Morgan).

This study assessed the extent to which the time-sharing strategies of operators in a synthetic work situation vary as a function of 48 hr. of sleep loss and continuous work. The data for this study was provided by the SPADE-1 experiment (see section 1.3.1) which required subjects to concurrently perform up to five different MTPB tasks.

Preliminary analyses indicate that the greatest proportion of overall performance decrements accompanying sleep loss is attributable to subjects adopting time-sharing strategies which reduce effective work load. Thus, rather than performing all tasks in a degraded manner, fatigued subjects selectively ignore certain tasks while continuing to perform efficiently on others. As one would expect, however, the exact time-sharing strategies which are adopted by a given operator appear to vary as a function of the specific combination of tasks to be time shared. A report of these data will be made at the annual meeting of the Psychonomic Society, St. Louis, Missouri, November 1972.

5.1.17 Effects of various stresses on overall performance under different levels of multiple-task performance loads (Brown Repko, Alluisi).

Data collected in the BEID and SPADE series of studies are being resummarized according to work-load variability. The individual-performance data collected in BEID-2 and SPADE-4N on the three MTPB watchkeeping tasks (viz., warning-lights, blinking-lights, and probability monitoring) have already been resummarized according to work-load variability. That is to say, the data have been summarized according to the five conditions of concomitant work as follows: (1) arithmetic computations and monitoring, (2) arithmetic computations, code-lock solving, and monitoring, (3) code-lock solving, and monitoring, and (5) target identification and monitoring.

A preliminary examination of the data indicated that additional data should be included to provide for greater stability in the effects suggested. Consequently, the monitoring data of BEID-3, -4, -5, -6, and -7, and SPADE-1, -2, and -3 have also been scheduled for analysis according to these work-load conditions. The overall strategy of these efforts will be to eventually submit for publication a comprehensive report involving all of these findings.

5.2 Statistical and Data-Analysis Techniques

6. LIAISON ACTIVITIES

6.1 U. S. Army

During the period of 8-9 December 1970, Dr. E. A. Alluisi attended and participated in an invitational work-study session on "Prediction and Understanding of Human Behavior" at the U. S. Army Advanced Materiel Concepts Agency, Alexandria, Virginia. During the period of 4-5 January 1971, Drs. E. A. Alluisi, J. W. Brown, and G. D. Coates visited the U. S. Army Medical Research Institute of Infectious Diseases, Fort Detrick, Maryland, for the purpose of presenting a preliminary report of the BEID-7 results and to discuss the possibility of conducting additional research in the future. Dr. Alluisi remained in the Washington area through 7 January 1971, during which he visited the Behavior and Systems Research Laboratory and the Science and Technology Division of the Institute for Defense Analysis, Arlington, Virginia. Lt. Col. Jimmy L. Hatfield, MSC, U. S. Army Medical R & D Command, Washington, D. C., visited the Laboratory on 17-18 February 1971 and discussed the research program of the Laboratory.

Drs. E. A. Alluisi, B. R. Brown, G. D. Coates, J. Driscoll, and B. B. Morgan, Jr. visited the U. S. Army Behavior and Systems Research Laboratory, Arlington, Virginia on 30 March 1971, for the purposes of presenting a briefing and progress report concerning the research of the Performance Research Laboratory. On 19 April 1971, Dr. E. Ralph Dusek of the Behavioral Sciences Division, U. S. Army Research Institute of Environmental Medicine, Natick, Massachusetts (now Director, U. S. Army Motivation and Training Laboratory, Department of the Army, Arlington, Virginia), visited the Laboratory and was briefed concerning the Laboratory research program. During the period 24 May - 4 June 1971, Dr. Alluisi was on active duty (LTC, MSC-USAR) for training in his mobilization designation as Assistant Chief, Biomedical Stress Research Division, Medical Directorate, U. S. Army Medical Research and Development Command, Office of The Surgeon General, Department of the Army, Washington, D. C. On 1 June 1971, he also visited the U. S. Army Behavior and Systems Research Laboratory, Arlington, Virginia, and briefed the BESRL staff on the human-performance research being conducted by the Performance Research Laboratory.

LTC. Jimmy Hatfield, U. S. Army Medical R & D Command, Washington, D. C. paid a return visit to the Laboratory on 26-27 January 1972, in order to discuss further the Laboratory research program. During the period of 22 May - 2 June 1972, Dr. Alluisi was again on active duty for training in his mobilization designation as Assistant Chief, Biomedical Stress Research Division, Medical Directorate, U. S. Army Medical Research and Development Command, Office of The Surgeon General, Department of the Army, Washington, D. C.

6.2 Other Governmental Agencies and Laboratories

During the period of 14-17 September 1970, Dr. Alluisi attended an invitational symposium on "Industrial Safety Performance Measurement" sponsored by the National Safety Council, Illinois Institute of Technology, Chicago, Illinois. On 1 October 1970, Dr. Leon Katchmar of the Human Engineering Laboratories, Aberdeen Proving Ground, Maryland, visited the Laboratory and was briefed on the Laboratory research program. Dr. Dean W. Chiles, Chief, Performance Research, FAA CAMI, Oklahoma City, Oklahoma, visited the Laboratory on 25 January 1971. He briefed the Laboratory personnel concerning his recent research findings and was up-dated concerning the Laboratory research. On 11 February, Dr. D. E. Beischer, Naval Aerospace Medical Institute, Pensacola, Florida, visited the Laboratory and briefed the staff on his work concerning the effects of microwave and electromagnetic fields on human performance.

During the period 27-29 June 1971, Dr. Alluisi attended the 25th Anniversary Conference of National Mental Health Act, Washington, D. C. On 26-27 September, Dr. Morgan attended the second meeting of The Technical Cooperation Program Panel U-2 on "Human Performance and Military Capability," held at the Naval Medical Research Institute, Bethesda, Maryland, and during the period 28-29 September, he participated in a THEMIS sponsored conference on "Military Requirements for Continuous Operations Research," held at Texas Tech University, Lubbock, Texas. Dr. Alexander Cohen of the National Institute for Occupational Safety and Health, Cincinnati, Ohio, visited the Laboratory on 16 November to discuss the performance aspects of worker health and safety. Dr. Leon Katchmar of the Human Engineering Laboratories, Aberdeen Proving Ground, Maryland, paid a return visit to the Laboratory on 15 December 1971, for the purpose of discussing the Laboratory research program. Dr. R. Frank Musten of the Personnel Applied Research Unit, Canadian Forces, Toronto, Ontario, visited the Laboratory on 3-4 February 1972, in order to discuss the possibility of using a battery of performance tasks for the selection of pilots and other personnel for the Canadian Air Force.

6.3 Nongovernmental Institutions, Laboratories, and Conferences

On 18 September 1970, Dr. Joel S. Warm visited the Laboratory in order to discuss research that he had been conducting in cooperation with Dr. Alluisi. During the period 13-16 October 1970, Dr. Alluisi attended the 14th annual meeting of the Human Factors Society, San Francisco, California, where he was co-recipient of the 1970 Jerome H.

Ely Award for his contribution to the 1968 Human Factors article entitled "Work Schedules and Performance During Confinement." During the period 20-22 October 1970, Dr. Morgan attended the 16th Annual Army Human Factors Conference, El Paso, Texas, as the Laboratory representative to that meeting. During the period 5-7 November 1970, Drs. B. R. Brown, M. Loeb, B. B. Morgan, Jr., and J. D. Repko attended the annual meetings of the Psychonomic Society, San Antonio, Texas, to present papers based on research conducted in the Laboratory. Dr. M. R. Baron, formerly of Kent State University, Kent, Ohio, and presently acting Dean, College of Arts and Sciences, University of Louisville, visited the Laboratory on 13 November 1970.

Dr. Alluisi attended a meeting of Southern Graduate Schools, Atlanta, Georgia, on 1 December 1970, and the Council of Graduate School, Miami, Florida, on 2-3 December 1970. On 15 January 1971, Dr. Phillip K. Berger, University of Kentucky, Lexington, Kentucky, visited the Laboratory and was briefed on its research program. On 12 February 1971, Dr. E. B. Turner, Educational Relations, General Electric Company visited the Laboratory. During the period of 8-10 April 1971, Drs. Alluisi, Coates, Loeb, Morgan, and Aylworth attended the 63rd Annual Meeting of the Southern Society for Philosophy and Psychology, for the purposes of presenting papers based on research conducted at the Laboratory. Dr. Edward H. Loveland, Chairman, School of Psychology, Georgia Institute of Technology, visited the Laboratory on 6 May 1971. On 20-25 June 1971, Dr. Alluisi served as a participant in the Mid-Southern Conference on International Higher Education, sponsored by Fisk and Vanderbilt Universities, Nashville, Tennessee, in cooperation with the Committee on the International Exchange of Persons. On 21 June 1971, Mr. Marion Dudek, Warsaw, Poland, visited the Laboratory as a guest of the Dean of the Graduate School, University of Louisville. Dr. Jan Berkhout of the Space Biology Laboratory, UCLA Medical Center, Los Angeles, California, visited the Laboratory on 16 August 1971, and was briefed concerning our multiple-task performance battery and its use in sustained-performance research.

During the period 3-4 September 1971, Drs. Alluisi, Brown, Caldwell, Coates, and Driscoll attended the 79th Annual Meeting of the American Psychological Association, Washington, D. C. Following the APA Convention, Dr. Alluisi travelled to Bellagio, Italy, where he participated in a NATO Advanced Study Institute on "Human Factors/Ergonomics: Research Methods." In route to Bellagio, he made brief visits to the Army Personnel Research Establishment, Farnborough, England, and the Medical Research Council, Applied Research Unit, Cambridge, England; he returned to the Laboratory on 8 October 1971. During the period 19-21 October 1971, Dr. Morgan attended the 15th Annual Meeting of the Human Factors Society where he presented a paper based on the results of SPADE-1 and SPADE-2. During the period 9-11 November 1971, Mr. Lyddan attended the First Annual Conference on "The Use of On-Line Computers in Psychology," St. Louis, Missouri. Drs. Loeb, Smith, and Aylworth attended the 11th Annual Meeting of the Psychonomic Society, St. Louis, Missouri, during the period 11-12 November 1971, where they presented papers based on research conducted within the Laboratory.

During the period 6 January through 19 February 1972, Dr. Harm J. G. Zwaga of the Laboratory for Experimental Psychology, State University, Utrecht, Netherlands, worked with the Laboratory consulting on problems associated with studies of performance assessment and enhancement. Dr. M. M. Ayoub, Department of Industrial Engineering, Texas Tech University, Lubbock, Texas, visited the Laboratory on 7 February for the purpose of discussing research of mutual interest to himself and members of the Performance Research Laboratory. On 14 February, Dr. W. Slukin, NSF Senior Foreign Scientist Fellow for University of Leicester, England, visited the Laboratory and was briefed concerning the research program.

During the period of 30 March - 1 April 1972, Drs. Alluisi, Loeb, and Thurmond, and Mr. Corson attended the 64th Annual Meeting of the Southern Society for Philosophy and Psychology and presented papers based on laboratory-supported research or participated in various symposia; Dr. Mary A. Baker also presented a paper based on research that had been supported in part by the THEMIS contract. Mr. James Sheridan, Project Chief, Human Resources Laboratory, American Telephone and Telegraph, New York, New York, visited the Laboratory on 21 April 1972 and was briefed concerning the operation of our multiple-task performance battery. During the period 26-27 June 1972, Dr. Morgan attended a Seminar in Grantsmanship Management sponsored by University Resources, Inc., New York, New York. Dr. Coates and Messrs. Lyddan and Rothrock attended a local meeting of the Association of Computing Machinery held in Louisville during June 1972. The members of the Association also visited the Laboratory and were briefed concerning the Laboratory research projects related to the ECS-MTPB.

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Morgan, B. B. Jr., & Alluisi, E. A. Synthetic work: A methodology for the assessment of human performance. Perceptual and Motor Skills, 1972, in press.

Thurmond, J. B., Driscoll, J. M., & Morgan, B. B. Jr. Behavioral effects of infectious diseases: Sixth annual progress report, 1 March 1969 - 28 February 1970. University of Louisville Performance Research Laboratory Report, 1970, No. PR-70-15.

PERSONNEL

The following persons were employed on this contract during the period 1 September 1970 through 31 May 1972. (This list does not include students who have served only as subjects in experiments.)

<u>Name</u>	<u>Title or Duty</u>	<u>Proportion of Time</u>	<u>From</u>	<u>To</u>
Alluisi, E. A., Ph.D.	Director and Research Professor	1/3	1Sep70	31Dec70
		1/5	1Jan71	31May71
		1/2	1Jun71	30Jun71
		2/5	1Jul71	31Dec71
Loeb, M., Ph.D.	Professor of Psychology	1/6	1Sep70	31May72
Smith, R. P., Ph.D.	Professor of Psychology	1/3	1Jun71	30Jun71
		3/4	1Jul71	31Jul71
		1/8	1Aug71	31May72
Thurmond, J. B., Ph.D.	Assoc. Res. Prof. (and Assoc. Professor of Psychology)	1/5	1Sep70	31May71
		1/8	1Jul71	31May72
Driscoll, J. M., Ph.D.	Associate Professor of Psychology	1/3	1Sep70	30Jun71
		2/5	1Jul71	31Jul71
		1/8	1Aug71	31May72
Coates, G. D., Ph.D.	Associate Research Professor	2/5	1Sep70	30Sep70
		1/2	1Oct70	31May71
		1/5	1Jun71	1Feb72
Morgan, B. B. Jr., Ph.D.	Interim Director and Associate Research Professor	1/2	1Sep70	31May71
		1/4	1Jun71	30Jun71
		3/5	1Jul71	31May72
Brown, B. R., Ph.D.	Asst. Res. Professor	1/2	1Sep70	31May72
Rebbin, T. J., Ph.D.	Asst. Res. Professor	1/2	1Sep70	4Nov70
Aylworth, C. E., M.A.	Grad. Res. Assistant	2/3	1Sep70	31May71
		1/3	1Jun71	31Aug71
Byassee, Mary	Research Assistant	1/3	7Aug71	31Dec71
		1/5	1Jan72	31May72
Corson, D. L.	Grad. Res. Assistant	1/2	30Aug71	31May72
Holland, Susan	Secretary	1/2	1Sep70	31May71
		1/4	1Jun71	30Jun71
		3/5	1Jul71	1Feb72
Hope, Janice	Editor/Typist	2/3	1Sep70	31Dec71
		1/2	1Jan72	31May72
Lyddan, J. M., M.A.	Research Assistant	3/4	1Sep70	31Nov70
		2/3	1Dec70	31May71
		1/3	1Jun71	30Jun71
		3/5	1Jul71	31May72
Martin, Sara	Secretary	1/4	7Feb72	31May72
Morrison, Betty	Research Assistant	2/3	1Sep70	31May71
		1/3	1Jun71	30Jun71
		3/4	1Jul71	31Aug71

<u>Name</u>	<u>Title or Duty</u>	<u>Proportion of Time</u>	<u>From</u>	<u>To</u>
Reilly, Lyn	Secretary/Bookkeeper	1/3	19Jul71	31May72
Repko, J. D., M.A.	Grad. Res. Assistant	2/3	1Sep70	30Jun71
		3/4	1Jul71	31May72
Rothrock, K. E.	Electronics Supervisor	1/2	1Sep70	31May71
		1/4	1Jun71	30Jun71
		1/2	1Jul71	1Feb72
Yoder, D. J.	Grad. Res. Assistant	2/3	1Sep70	31May71
		1/3	1Jun71	30Jun71
		3/4	1Jul71	31Aug71

The following personnel were paid on an hourly basis as part-time employees during at least part of the contract year: G. Abel, Beverly Bass, R. Bornschein, R. Burke, Mary Ellen Byassee, R. Corum, R. Demaree, M. Farnon, J. Higginbotham, T. Jursek, M. Moore, D. Raper, P. Rosenblum, Rita Scheick, Andrea Smith, R. Upton, V. Vivekaphirat, and P. Wieger.

SUBMITTED REPORTS

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1. Loeb, M., & Alluisi, E. A. Influence of display, task, and organismic variables on indices of monitoring behavior. Acta Psychologica, 1970, 33, 343-366.
2. Alluisi, E. A. Research in performance assessment and enhancement. University of Louisville Performance Research Laboratory Report, August 1969, ITR-69-12.
3. Alluisi, E. A., & Coates, G. D. Studies of performance assessment and enhancement: Annual progress report, 1 September 1968--31 August 1969. University of Louisville Performance Research Laboratory Report, September 1969, No. PR-69-13.
4. Warm, J. S., Loeb, M., & Alluisi, E. A. Variations in watchkeeping performance as a function of the rate and duration of visual signals. Perception and Psychophysics, 1970, 7, 97-99.
5. Brown, B. R., & Rebbin, T. J. Simultaneous vs sequential discriminations of Markov-generated stimuli. Perception and Psychophysics, 1970, 8, 353-357.
6. Morgan, B. B., Jr., Brown, B. R., & Alluisi, E. A. Effects of 48 hours of continuous work and sleep loss on sustained performance. University of Louisville Performance Research Laboratory Report, September 1970, No. ITR-70-16.
7. Coates, G. D., & Alluisi, E. A. Studies of performance assessment and enhancement: Annual progress report, 1 September 1969--31 August 1970. University of Louisville Performance Research Laboratory Report, September, 1970, No. PR-70-17.

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8. Brown, B. R., & Aylworth, C. E. Feature encoding and pattern classification with sequentially presented Markov stimuli. Perception and Psychophysics, 1970, 9, 203-207.
9. Thurmond, J. B. Effects of figural noise, rotation, and other task variables on the visual perception of form. University of Louisville Performance Research Laboratory Report, February 1971, No. ITR-71-18.
10. Brown, B. R. Recognition of prototype deviants under simultaneous and sequential comparison conditions. Perceptual and Motor Skills, 1971, 32, 491-502.

11. Lyddan, J. M., Caldwell, L. S., & Alluisi, E. A. Measurements of muscular strength, endurance, and recovery over fifteen successive days. Journal of Motor Behavior, 1971, 3, 213-223.
12. Weiler, E. M., Loeb, M., & Alluisi, E. A. Auditory adaptation and its relationship to a model for loudness. Journal of the Acoustical Society of America, 1972, 51, 638-643.
13. Morgan, B. B. Jr., Brown, B. R., Coates, G. D., & Alluisi, E. A. Sustained performance during 36 hours of continuous work and sleep loss. U. S. Army Behavior and Systems Research Laboratory Technical Research Report, in press.
14. Morgan, B. B. Jr., & Repko, J. D. Studies of performance assessment and enhancement: Annual progress report, 1 September 1970--31 May 1972. University of Louisville Performance Research Laboratory Report, June 1972, No. PR-72-22.

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15. Alluisi, E. A. Research in performance assessment and enhancement. Paper presented at the 15th Annual Army Human Factors Research and Development Conference, Fort Ord, November 1969. Also, University of Louisville Performance Research Laboratory Report, August 1969, No. PR-69-12.
16. Morgan, B. B. Jr., & Hodge, M. H. Effects of irrelevant information and instructions in a digit-cancellation task. Paper presented at Psychonomic Society, St. Louis, November 1969.
17. Morgan, B. B. Jr. Use of the synthetic-work technique in the assessment of sustained performance. Paper presented at conference on standardization of tasks and measures for human factors research, Center of Biotechnology, Fatigue, and Human Performance, Texas Tech University, March 1970. Also, U. S. Army Human Engineering Laboratory Technical Memorandum, 1970, No. 19-20, pp. 33-48.
18. Alluisi, E. A. Influence of work-rest scheduling and sleep loss on sustained performance. Paper presented at NATO Symposium on "Effects of diurnal rhythm and loss of sleep on human efficiency," Strasbourg, France, July 1970.
19. Morgan, B. B. Jr., & Alluisi, E. A. Sustained performance during forty-eight hours of continuous work. Paper presented at Psychonomic Society, San Antonio, November 1970.
20. Repko, J. D., & Thurmond, J. B. Form perception as a function of histogram complexity and problem homogeneity. Paper presented at Psychonomic Society, San Antonio, November 1970.

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25. Morgan, B. B. Jr., & Alluisi, E. A. Synthetic-work methodology in the assessment of performance. Paper presented at the second meeting of The Technical Cooperation Program, Sub-Group U, Panel U-2 on "Human Performance and Military Capability," at the Naval Medical Research Institute, Bethesda, September 1971.
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29. Aylworth, C. E., & Thurmond, J. B. Effects of signal intensity on alerted visual monitoring. Paper presented at Psychonomic Society, St. Louis, November 1971.
30. Hamon, A., & Smith, R. P. Effects of alcohol and d-amphetamine upon speech. Paper presented at Psychonomic Society, St. Louis, November 1971.

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32. Thurmond, J. B., Coates, G. D., Morgan, B. B. Jr., & Brown, B. R. Human performance during extended periods of continuous work--II. Paper presented at Southern Society for Philosophy and Psychology, St. Louis, March 1972.