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Physiological Correlates of Optimal Performance

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Semiannual Status Report

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During this six month period, the second half of the second year supported by the grant, further work has been completed in the following areas: data collection, data analysis and the preparation and presentation of scientific papers.

I. Data Collection

A. Additional Testing

In the last semiannual status report it was reported that 21 additional subjects had been added to the experiment in order to insure the availability of sufficient data to satisfy statistical assumptions underlying the analyses. At that time, during the initial phases of the third experimental run, 40 subjects of the original 53 remained in the experiment. At the end of this six month reporting period, 33 subjects, all of the available subjects, had completed the third experimental run. Seven additional subjects were lost to the experiment during this period for a variety of reasons. The testing consisted of all-night sleep deprivation as outlined in the original proposal, followed by the same performance task which the subjects practiced during the first two testings. The purpose of this testing was to examine the relationship of physiological variables to the level of performance under a sleep deprivation condition, using the data from the second testing as a baseline comparison for each subject. An additional purpose was to provide baseline sleep deprivation data for assessing the contribution of sleep deprivation to performance decrement during the fourth experimental run (see below). Preliminary inspection of the data revealed substantial decrement in performance from the second run.

B. Additional Data Collected

Because of the interests of the principal investigator, psychological test data was collected on all of the subjects. This data included the scores for each subject on the Taylor Manifest Anxiety Scale and the Ego Strength Scale from the MMPI and the Zuckerman state anxiety, depression and hostility scores before and after each experimental run. In addition, during the all-night sleep deprivation of the third testing, the following psychological tests were also administered: the Guilford-Zimmerman Aptitude Survey, Parts IV, V, & VI; the Guilford-Zimmerman Temperament Survey; the California Personality Inventory; the Holtzman Inkblot Test, the Ambiguity-Tolerance Scale, the Minnesota Multiphasic Personality Inventory, the Embedded Figures Test; the Rod and Frame Test; the Stein Ego Strength Scale, the Barratt Impulsivity Scale and the Eysenck Personality Index.

The foregoing psychological test data will be examined in relation to the psysiological and performance data for the presence of relationships which may be of predictive value.

In addition to the psychological test data, biochemical determinations - catecholamines, creatinine, urea nitrogen, magnesium and urinary volume-per-hour-were made before and after each performance in the first three experimental testings. These values will also be examined in relation to the psychological, physiological and performance variables.

None of the above psychological and biochemical data was proposed initially and was collected and analyzed without cost to the grantor. Because of the interests of the grantor in such data, however, an additional biochemical parameter will be added to the data collection in the fourth and final experimental testing - blood glucose levels before and after performance.

C. Fourth Experimental Testing

The fourth experimental testing, as originally planned, is a 72-hour vigil in the laboratory with periods of performance, rest and sleep, and with time out for eating and personal hygiene. After pilot work, the schedule of these activities was finalized as shown in Table I.

At this time it is not known whether it will be possible to complete the fourth experimental run because of lack of funding, due to the budgetary reduction in the Apollo Applications Program. However, four subjects who will be leaving the city in the near future and who would otherwise be lost to the experiment even if it is funded later, will be tested during the month of May.

II. Data Analysis

As in previous reports, only a summary of the analyses which hqve been completed will be provided here. Detailed presentation of the results will be incorporated in scientific papers as they are prepared for publication.

A. Sleep Classification

In the last interim report it was noted that a program for the classification of sleep stages had been completed and was being employed to classify the depth of sleep on the subjects with good electroencephalographic data for Runs I and II. In the interval, considerable additional work has been done in this area.

It was noted that the existing literature contained minimal information on the reliability of clinical classification of sleep stages, both within and between raters. Checks on the reliability of such classification in our laboratory and between such classifications and the computer program included in the last report were therefore carried out. The intra-rater reliability did not exceed .80 and between-rater reliabilities were of comparable magnitude. This indicated that up to 36% of the total variance of the clinical classification of EEG stages was error variance. High agreement between any digital classification and clinical classifications could not be expected for this reason. Nevertheless, because Program IV did not approximate the degree of agreement which would be expected even if error variance were discounted, four additional programs have been checked for agreement with clinical classification. The last, Program 8, is shown in Table 2. The degree of agreement between this program and clinically rated stages of sleep for one subject is shown in Table 3. It is readily apparent that the degree of agreement between the digital classification and the "eyeball" continues to leave something to be desired, especially in the classification of stages 1 and 2. (REM sleep is not included as a separate category because period analytic data of the major period, it was found, cannot distinguish between stage 1 and stage 1-REM sleep. The apparent low agreement on "awake" is due to the small number of epochs; other subjects showed agreement of .80 and above.)

The criteria employed in the clanical classification of sleep stages were those in "A Manual of Standardized Terminology, Techniques and Scoring System for Sleep Stages of Human Subjects", edited by Kales and Rechtschaffen. (1) Neither those criteria nor those of Williams and Agnew (2,3), mentioned in the previous interim report, are sufficiently discrete to differentiate between stages 1 and 2 with a high degree of agreement. We will therefore attempt to validate the latest classification of sleep depth by correlating it with other variables such as catecholamine excretion. Further efforts to obtain better agreement between digital and "eyeball" classification seem fruitless in the presence of the substantial error variance in the eyeball classification. If the digital classification correlates better with other variables, then it is more "correct" than clinical classification. Such a classification is perfectly reliable, of course.

B. Skin Conductance, Personality Variables and Performance Variables

In the last semiannual status report, the results of an analysis of covariance on the relationship between basal skin resistance (BSR) and performance was reported. On the basis of this analysis it was concluded that, ". . . it appears therefore that a lower skin resistance (higher activation) is associated with better performance." Correlations of each subject's BSR and galvanic skin responses (GSRs) across all stimulus conditions and across hours revealed a very high degree of consistency. A single value for each of the variables shown in Tables 4 and 5 was computed for each subject, therefore, and the correlations among these variables computed. With this type of analysis there is no relationship between skin conductance (reciprocal of BSR) and the various performance variables. However, the related variable, sum GSR amplitudes per minute, did correlate significantly with reaction time, interrogation rate and number correct. After further practice during Run II, however, this relationship between the physiological variables and the performance variables disappears. In their place a relationship between the psychological variables and the performance variables appears. Values of all the physiological variables were lower during the second testing than during the first. It appears that the level of activation is lower after practice and that personality variables are related to performance only after learning has occurred. These conclusions must be tentative, however, because the latter were not predicted and the number of subjects (21) in these analyses is small.

A principal components factor analysis on the variables shown in Tables 4 and 5 was also computed for both the first and second runs. The results are shown in Table 6. The first factor on the first run, accounting for more than 28% of the total variance, is obviously a performance factor that contains an appreciable loading (.56) from sum GSR amplitude per minute. The second factor is a personality factor with heavy loadings on ego strength and trait anxiety and lower, but appreciable, loadings on state anxiety. The third factor, accounting for 23% of the variance, is obviously a GSR and skin conductance factor, but with a loading of .33 on number correct.

The factor analysis of the second experimental run reveals the performance factor, this time accounting for approximately 27% of the variance, as the first factor, but in this run the number of GSRs per minute rather than the sum of GSRs per minute loads on this factor and a new variable, state anxiety, loads at a .75 level. The second factor on this analysis is obviously comparable to the third factor on the first analysis - i.e., it is a GSR and skin conductance factor and contains no appreciable loadings from any other variable. The third factor in this analysis is comparable to the second factor on the first experimental run except that, in addition to the high loadings on ego strength and trait anxiety, there are smaller but appreciable loadings on all of the performance variables. In summary, the results of the factor analysis reinforce the conclusions made after inspection of the results of the correlational analyses. The two types of analyses are, of course, based on the same data and are therefore subject to the same qualifications.

C. Other Physiological Variables and Performance

Heart rate, finger volume, finger pulse amplitude and respiration data were also collected in these experimental runs. The results of the heart rate analysis on the first experimental run were included in the last semiannual status report. Analysis of heart rate on the second and third experimental runs and of all of the other physiological variables on all three runs is in progress.

III. Preparation and Presentation of Scientific Papers

Two scientific papers which were supported in part by this grant have been prepared during this six month period. The first, dealing directly with data collected in this experiment, was entitled "Personality, Skin Conductance and Performance" and was prepared under the supervision of the principal investigator by a second year medical student, Larry J. Strausbaugh, who presented it as a medical student research project. The second paper, "Ego Strength and Galvanic Skin Responses to Motion Pictures" was authored by Charles Kaiser and the principal investigator. A final version of this paper is being prepared and will be submitted subsequently for publication.

IV. References

1. Kales, Anthony & Rechtschaffen, Allen (Eds.) "A Manual of Standardized Terminology, Techniques and Scoring System for Sleep Stages of Human Subjects". National Institutes of Health Publication No. 204, 1968.

2. Williams, R. L., Agnew, H. W. Jr., & Webb, W. B. "Sleep Patterns in Young Adults: An EEG Study". Electroencephalography and Clinical Neurophysiology, 17:376-381, 1964.

3. Agnew, H. W. Jr., Webb, W. B. & Williams, R. L. "The First Night Effect: An EEG Study of Sleep". Psychophysiology, 2:263-266, 1966.

Table I. Schedule of Activities, Run IV

Day 1

6:30 -	7:30 AM	S arrives. Void (save). Give 200 ccs Tang. Prep.
7:30 -	9:20 AM	Performance. (record). Void (save).
9:20 -	10:20 AM	Rest. Give 200 ccs. fluid. (S may shave, brush teeth, etc.)
10:20 -	12:10	Performance. (do not record). Check electrodes.
12:10 -	1:10 PM	Lunch.
1:10 -	2:10 PM	Check electrodes. Rest-Alert (record). Give 200 ccs water.
2:10 -	4:00 PM	Performance. (record).
4:00 -	5:00 PM	Rest-Alert (do not record). Give 200 ccs. water.
5:00 -	6:00 PM	Supper
6:00 -	7:50 PM	Check electrodes. Performance (do not record).
7:50 -	8:50 PM	Rest-Alert (record). Void (discard).
8:50 -	10:40 PM	Check electrodes. Performance (record). Void (save).
10:40 -	11:00 PM	Prep for sleep. Give 200 ccs. water.
11:00 -	6:30 AM	Sleep (record).

Day 2

Repeat above schedule.

Day 3

Repeat above schedule.

Table 2

Criteria for Sleep Depth Classification
Program 8

Sleep Stage		
W		54–60 sec./min of 8–30 Hz
1		0–53 sec. of 8–30 Hz
	plus	0– 4 sec. of 0–3 Hz
	plus	0–23 sec. of 0–7 Hz
2		0–53 sec. of 8–30 Hz
	plus	0–12 sec. of 0–3 Hz
	plus	24–60 sec. of 0–7 Hz
3		0–53 sec. of 8–30 Hz
	plus	13–30 sec. of 0–3 Hz
4		0–53 sec. of 8–30 Hz
	plus	31–60 sec. of 0–3 Hz

Table 3

Agreement between Program 8 and Clinical Classification of Sleep Stages *

		"Eyeball" Designation					
		0	1	2	3	4	% Correct
	Stage 0	1	3				25
	Stage 1		33	41			45
Computer Designation	Stage 2		13	72	2		83
	Stage 3			10	93	4	87
	Stage 4			2	32	45	57

* Epochs of one minute's duration

Table 4: Correlation Matrix, Run I

	Σ GSR amp/min	# GSRs/ minute	Skin Conductance	Reaction Time	Interrogation Rate	# Correct	Ego Strength	Trait Anxiety	State Anxiety
Σ GSR amplitude/minute	1.0	.76*	-.43*	.53*	-.49*	-.62**	-.28	.26	.04
# GSR's/minute		1.00	-.51*	.26	-.25	-.35	-.23	.10	.23
Skin conductance			1.00	.00	.09	.20	.18	-.16	-.03
Reaction Time				1.00	-.72***	-.69***	-.09	.17	.32
Interrogation Rate					1.00	.47*	-.15	-.19	-.06
# Correct						1.00	.26	.15	.04
Ego Strength							1.00	-.61**	-.24
Trait Anxiety								1.00	.37
State Anxiety									1.00

* $r > .43$; $p < .05$ ** $r > .55$; $p < .01$ *** $r > .66$; $p < .001$

Table 5: Correlation Matrix, Run II

	Σ GSR amp/min	# GSRs/ minute	Skin Conductance	Reaction Time	Interrogation Rate	# Correct	Ego Strength	Trait Anxiety	State Anxiety
Σ GSR amplitude/minute	1.00	.67***	-.41	.07	-.09	.06	-.12	-.15	.24
# GSR's/minute		1.00	-.22	-.28	.16	.24	-.11	.00	.19
Skin conductance			1.00	-.16	.22	.16	.29	-.04	.07
Reaction Time				1.00	-.74***	-.62**	-.44*	.39	-.42
Interrogation Rate					1.00	.30	.43*	-.39	.23
# Correct						1.00	.32	-.49*	.45*
Ego Strength							1.00	-.71***	.06
Trait Anxiety								1.00	-.10
State Anxiety									1.00

* $r > .43$; $p < .05$ ** $r > .55$; $p < .01$ *** $r > .66$; $p < .001$

Table 6: Factor Analyses of Skin

Conductance and Performance Data

Run I

Percentages of Total Variance			
	28.60	20.77	23.20
Rotated Factor Loadings			
Σ GSR amplitude/minute	.56	.12	-.72
# GSRs/minute	.26	.10	-.82
Skin conductance	.07	-.04	.83
Reaction Time	.93	.18	-.01
Interrogation Rate	-.86	.05	.06
# Correct	-.72	-.13	.33
Ego Strength	.09	-.80	.29
Trait Anxiety	.10	.85	-.09
State Anxiety	.17	.66	.09

Run II

Percentages of Total Variance			
	26.71	21.61	22.83
Rotated Factor Loadings			
Σ GSR amplitude/minute	.08	-.91	.01
# GSRs/minute	.41	-.74	-.09
Skin Conductance	.30	.68	.04
Reaction Time	-.82	-.07	-.37
Interrogation Rate	.62	.16	.42
# Correct	.69	-.08	.34
Ego Strength	.17	.20	.87
Trait Anxiety	-.16	.12	-.92
State Anxiety	.75	-.14	-.14