1. This document has been approved for public release and sale; its distribution is unlimited.

KANSAS STATE UNIVERSITY

MANHATTAN, KANSAS

Project Themis

Performance and Life Support in Altered Environments

USAFOSR Contract F44620-68-C-0020

Interim Report

September 1, 1967 through July 1, 1968

by

Ralph G. Nevins
Project Manager

Institute for Environmental Research
Kansas State University
Manhattan, Kansas 66502

August 1, 1968

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

Project Themis

Performance and Life Support in Altered Environments

USAFOSR Contract F44620-68-C-0020

Interim Report

September 1, 1967 through July 1, 1968

Introduction

The Project Themis program at Kansas State University entitled Performance and Life Support in Altered Environments was initiated September 18, 1967 under USAFOSR Contract F44620-68-C-0020. The program includes coordinated studies of (1) the use of localized ventilation to maintain the subjects' ability to perform in stressful environments, (2) the distribution of air in confined spaces, (3) human performance in altered environments, (4) physiological and behavioral rhythmicity in altered environments, (5) the effectiveness of a water-cooled headdress for heat stress environments, (6) the effects of the environment on micro-flora growth and survival in various footwear materials, (7) comparative psychophysiology in environmental extremes using animals, and (8) systems analysis and optimization studies.

After initial organization meetings of the Kansas State University Project Themis team, held during the period 18 September 1967 and 15 December 1967, a formal project review was held on 16 January 1968. Progress reports and research plans were presented by each principal investigator. Discussion of each project by the entire team provided an opportunity for coordination and suggestions regarding the work. These presentations were included in the Renewal Proposal submitted 18 January 1968. In addition to those directly involved with the Themis Project, the review was attended by interested staff and graduate students from across the University with a total attendance of over 25.

A Second Project Themis Review was held 26 May 1968. Guests from off-campus included:

Dr. Glen Finch, AFOSR (Project Technical Monitor)

Dr. Harvey E. Savely, AFOSR

Dr. Charles E. Fuller, AFOSR

Dr. Arthur J. Emery, Jr., Army Research Office, OCRD

Mr. Frank Harris, Cessna Aircraft Co., Wichita.

Total attendance was 27. Students participated in the presentations and discussion indicating interest and personal involvement in the various projects. It should be noted here that delays in delivery of equipment prevented several of the investigators from achieving first year goals. However considerable effort was expended during the second half of the year and specifically during the summer months (1968) to put the project on schedule.

A progress report for each area of study was prepared by the major investigator. In some cases, plans for specific goals to be accomplished during July and August are also given. Collaboration between the members of the Project Themis team has been encouraged and has resulted in a number of suggestions for improvement of the individual studies. Cross discipline communication has been excellent. Project Themis has strengthened the environmental program at Kansas State University with the result that a multidiscipline staff exists which has experience and facilities for broad spectrum research in this important area. Few laboratories in the world can provide such a group.

PROJECT REPORTS

Thermal and Physiological Effects of Localized Ventilation
Dr. P. E. McNall

Planning and design were completed and construction begun on a test fixture to be used for subjective testing of the effects of localized air jet cooling. A rough sketch is shown in Fig. 1. It involves a single seat work station, with solid front and back panels and open sides. The air circuit is then a jet or jets from the front over the subjects face, chest, etc. (all adjustable for velocity, direction and area covered) with a return air grill on the panel behind the subject. (This system can also be reversed.) The return air is then treated by cooling, dehumidifying, etc. in the remote conditioning section. This allows the test station to be placed in an environmental chamber under a wide range of ambient conditions, whereas the jets thermal condition can be controlled independently from the environment. In addition to the subjective tests, it is planned to use a visual task which is known to be rather sensitive to thermal stress, such as the detection angle of a light in the visual periphery of the subject. The subject will be given a task, such as arithmetic problems, and asked to press a button when he detects a light

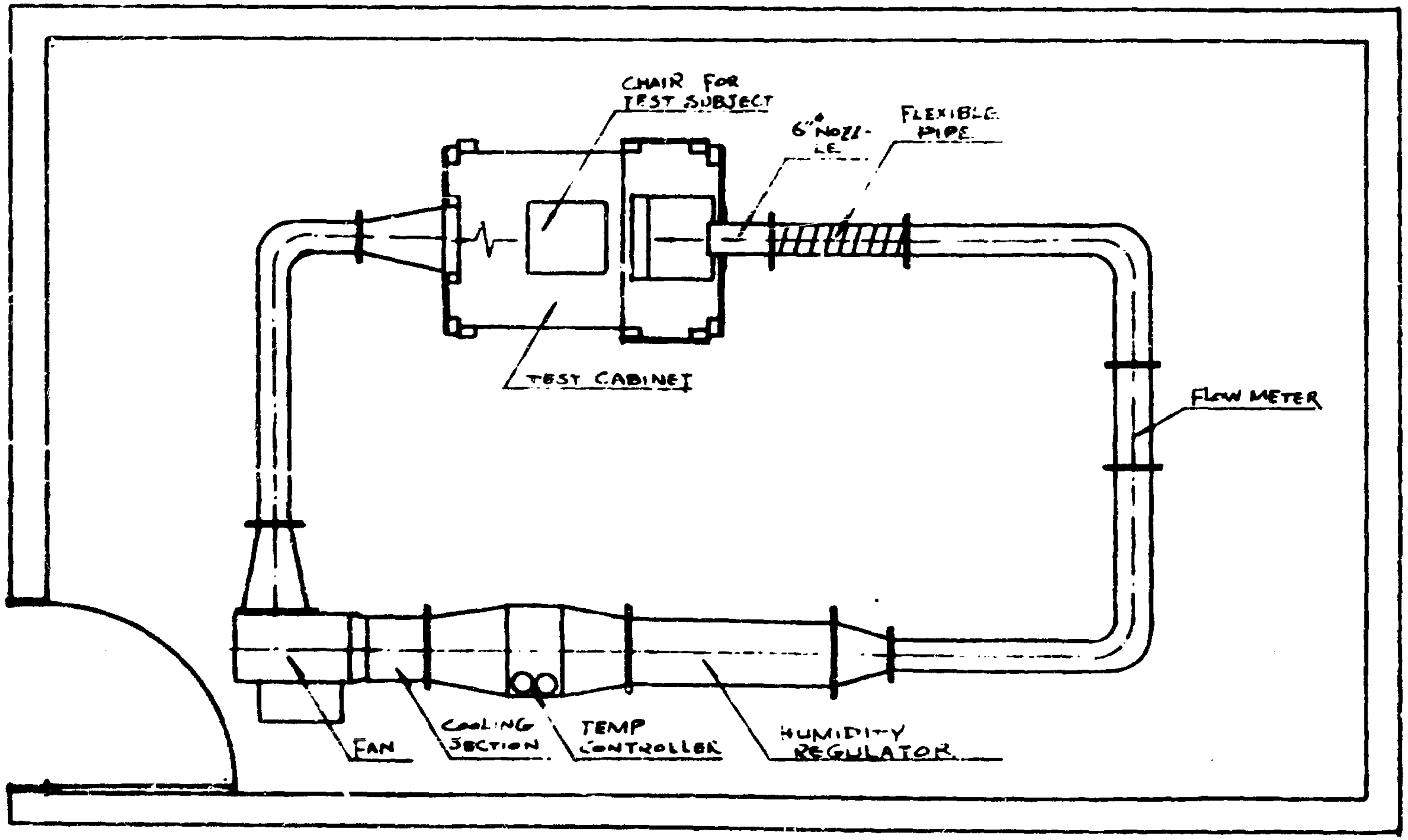


FIG. 1

Test cabinet and apparatus for localized ventilation experiments.

moving into his field of view. Correlation of his performance on this type of task, and his subjective reaction to thermal effects and comfort should give useful design information. Physiological data such as rectal and skin temperatures, sweat rate, heart rate, metabolic rate, etc. will be measured.

In order to be able to predict results, heat loss equations have been under development for the case of heat stress. Fangers[1] comfort equation has been modified for this purpose, since it is felt to be the most extensive and accurate equation known at present. The general heat balance equation is:

$$M - D - S_w - R_w - R_d = R + C$$

where

M = metabolic rate

D = skin diffusion evaporation loss

S_w = sweat secretion evaporation loss

R_w = respiratory evaporation loss

R_d = dry respiratory heat loss

R = body radiation loss

C = body convection loss

The proposed modifications to extend the equation with the heat stress area are:

I. $$\frac{S_w'}{A_{Du}} = 20.8 \sqrt{v}\,(1.92\, t_s - 25.3 - p_a) \quad \text{Kcal/m}^2\text{hr}$$

---

[1] "Calculation of Thermal Comfort: Introduction of a Basic Comfort Equation" ASHRAE Transactions, 1967.

where

v = air velocity

t_s = mean skin temperature

P_a = partial pressure of water vapor in the air

S_w' = maximum evaporation possible from the wet surface

let

$S_w = S_w'$ in the limiting case, for conditions of high thermal stress

$$\frac{S_w}{A_{Du}} = 258\ t_s - 9301 + 3.5\ \left(\frac{M}{A_{Du}} - 50\right) \qquad \text{Kcal/m}^2\text{hr.}$$

A_{Du} = Dubois body area

For conditions above the comfort zone, but not high thermal stress as an approximation,

$$\frac{S_w}{A_{Du}} = 19\ t_s - 645 + \left(\frac{M}{A_{Du}} - 50\right) \qquad \text{Kcal/m}^2\text{hr.}$$

Fig. 2 shows this plotted for three activity levels, M = 50, 130, 190 Kcal/m^{2}hr and further shows the break in the trend of S_w, denoted as the "critical line." This break occurs where the skin surface becomes significantly wetted with perspiration.

II. Since the skin diffusion becomes less in absolute value as the wetted area (and S_w) increase, for most practical cases of stress it could be neglected, however, the term can be modified as follows, by including a "wetted area" term

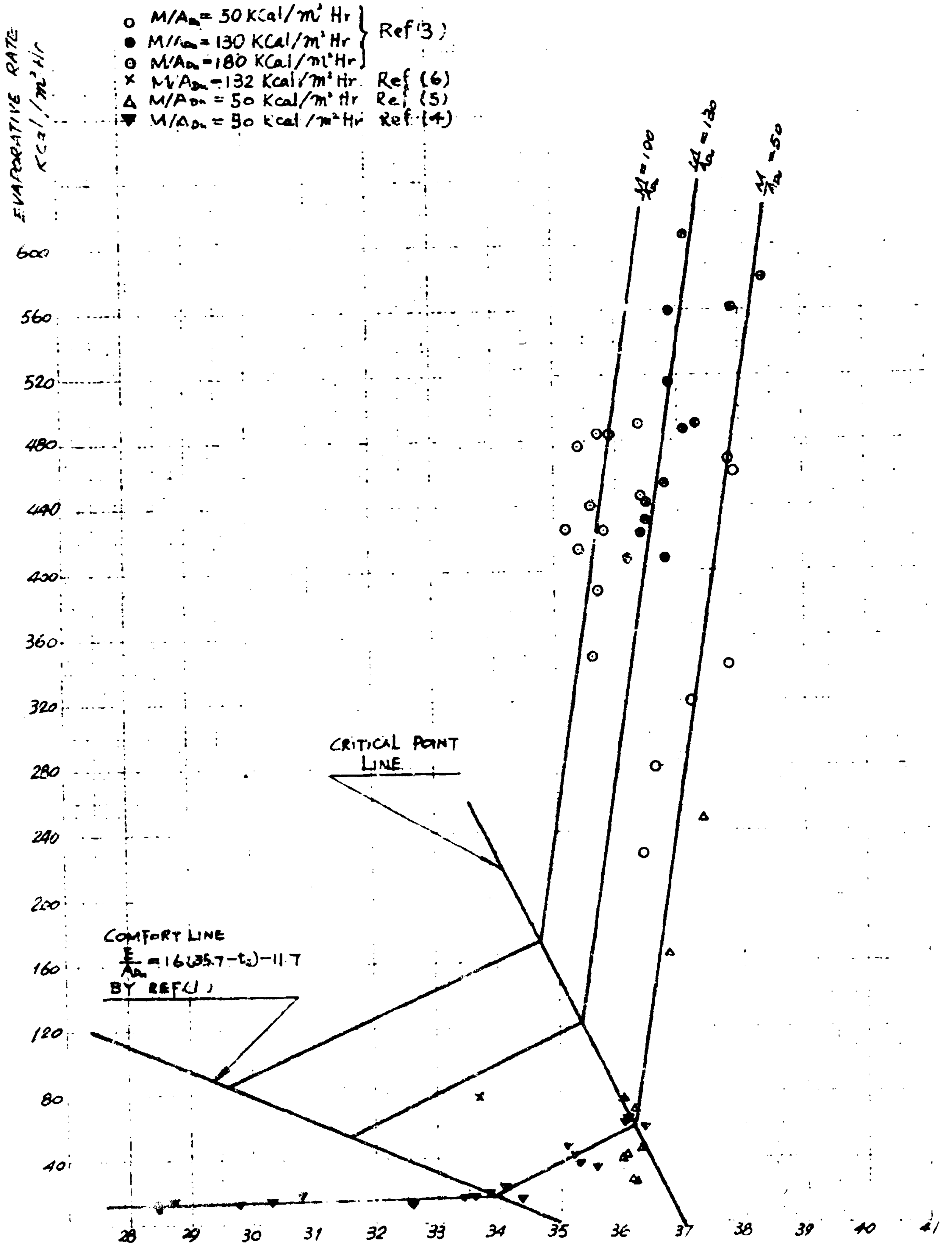


Fig. 2. Evaporative rate as a function of skin temperature.

$$D = 0.35\ A_{Du}\ (1 - WA)[43 - 0.061 \frac{M}{A_{Du}} - p_a] \quad \text{Kcal/hr}$$

where WA = percent of skin area wetted by perspiration

III. The latent respiration term, R_w, remains unchanged.

$$R_w = 0.0023\ M\ (44-Pa) \quad \text{kcal/hr}$$

The dry respiration is unchanged also, $R_d = 0.0014\ M\ (34-t_a)$ kcal/hr.

IV. The insulating value of the clothing must be modified for two reasons. First, it is likely to be wetted, and hence of lower insulation. Second, any high velocity jets of air which penetrate under the clothing, either through openings or through a porous fabric, also lowers the insulation value.

$$K = A_{Du} \frac{t_s - t_{cl}}{0.18\ I_{cl}} \text{ (kcal/hr)}$$

when

K = total sensible heat loss through the clothing

t_{cl} = outer surface temperature of the clothing

I_{cl} = insulation value of the clothing in clo units.

For permeable clothing, $I_{cl} = I_{cl}'\ (f(v))$ where I_{cl}' = clo value in "still air." This function of velocity is yet to be determined, but recent tests on the "copper manikin" at 200 ft/min velocity show as much as a 30% reduction on dry clothing (undershirts and shirt, long sleeved shirt and light slacks). Values for wetted clothing have been reported by Lee and Henschel[2] to be about 40% of the dry clothing values. These

[2] "Evaluation of Thermal Environment in Shelters" TR-8, US Public Health Service, Division of Occupational Health.

ratios, while not very well established, will probably give adequate results for prediction purposes.

V. The heat loss by radiation is unchanged.

$$R = A_{eff}\ \varepsilon\sigma\ [T_{cl}^{4} - T_{mrt}^{4}] \qquad \text{Kcal/hr}$$

where A_{eff} = body area corrected for body attitude and clothing

ε = emissivity of the skin and clothing (0.96)

σ = Stephan-Boltzmann constant

T_{mrt} = mean radiant temperature, absolute

VI. The heat loss by convection is also unchanged

$$h = 2.05\ (t_{cl} - t_a)^{0.25} \quad \text{when } 2.05\ (t_{cl} - t_a)^{0.25} > 10.4\sqrt{v}$$

$$h = 10.4\sqrt{v} \quad \text{when } 10.4\sqrt{v} > 2.05\ (t_{cl} - t_a)^{0.25}$$

where

h = film coefficient for convection (kcal/m^2hrC)

t_a = air temperature (C)

v = air velocity (m/sec)

This shows the cross-over from free to forced convection, the higher value controlling.

Then

$$C = hA_{Du}\ f_{cl}\ (t_{cl} - t_a)\ \text{kcal/hr}$$

when

f_{cl} = correction factor for clothing area, (about 1.1 for a light clothing ensemble.)

This modified equation is now ready for use to predict, for any set of conditions, the effectiveness on heat loss of changes in the four independent thermal variables:

t_a (air temperature)

t_{mrt} (mean radiant temperature)

v (air velocity)

P_a (partial pressure of water vapor in the air)

Computer solutions will be programed to define zones which show the relative effectiveness of each of these variables. At this stage, the prediction equation assumes the same boundary conditions at all points on the subject and cannot yet handle localized cooling, but analysis has begun on general terms which will be empirically modified by the test data for future use in the prediction program.

The first step in the optimization study to be covered in detail in Dr. Fan's presentation, was to consider the minimum energy expenditure system to provide a given environment from the thermal stress standpoint. For this purpose, the following equations have been derived and will be ready for use after applying practical hardware designs, where these are necessary (such as to determine pressure drop, for example).

VII. Cooling Air

In order to cool air with no removal of moisture, the energy rate or power required is

$$P = Q_p c_p (t_1 - t_2) \text{ Kcal/hr}$$

where

Q = air flow rate

ρ = air density

c_p = air specific heat of constant pressure

t_1 = initial temperature

t_2 = final temperature

The energy required to move air for cooling is neglected, since the velocity would be expected to be low, or fixed by other considerations.

VIII. Cooling panels (lower t_{mrt})

A cooled panel will gain heat by radiation from other surfaces it "sees" and also it will gain heat by convection from the air in contact with it. In addition, there will be some "back loss" from the panel to the exterior of the enclosure. Therefore, the power requirement to change t_{mrt} is dependent upon the system chosen. Basic equations are given below, neglecting "back loss" which can be made small by insulstion.

$$P_{(radiation)} = \sigma A\epsilon \, (T_p^{\,4} - T_e^{\,4})$$

where

A = area of the cooled panel

T_p = absolute temperature of the panel

T_e = absolute temperature of the balance of the surfaces

But, for small temperature differences, (less than 50 F or so) the loss is approximately linear with temperature difference, so

$$P_{(radiation)} = K'\sigma A\epsilon(t_p - t_e)$$

where

K' = a constant

and

t_p and t_e need not be in absolute units

$$P_{(convection)} = hA\ (t_p - t_a)$$

where

h = convection film coefficient and is a function of air velocity

t_a = air temperature.

Often in practical enclosures, $t_a = t_e$ for practical purposes, also the surface temperature of the person may equal t_a. When this is the case, and the air velocity is known, the total power for radiation adjustment is:

$$P = K''\ A\ (t_p - t_a)$$

where

K'' = a system constant

Then $t_{mrt} = f(t_p, t_e)$ according to the shape factor of the person to the surfaces at each temperature. These shape factors can be estimated for known geometries and subject location and body attitude.

IX. Drying Air

In the case where air is to be dried only (by chemical means for example) the following equation applies:

$$P = Q\ \rho\ (w_1 - w_2)\ hfg$$

where

w_1 = initial humidity ratio

w_2 = final humidity ratio

hfg = latent heat of vaporization of water at the air temperature.

For practical purposes, hfg is a constant, varying only a few percent as the temperature changes from 80 to 120 F.

X. Moving Air

Where the air is to be moved without heating or cooling (for example, ventilating with outside air) the following equations apply

$$P = f K''' v^3$$

where

f = friction factor for the system

K''' = system constant

The friction factor reduces with increasing velocity, but generally does not vary more than 30% or so in practical cases. K''' depends upon the system design, flow paths, areas, etc.

<u>Additional References:</u>

3. Brebner. "The Relation Between the Coefficients for Heat Exchange by Convection and by Evaporation in Man" J. Physiol., vol. 141, p. 64-168.

4. Robinson, et al. "Physiologically Equivalent Conditions of Air Temperature and Humidity" American J. of Physiol., vol. 143, p. 21-32.

5. Winslow, et al. American J. of Physiology, vol. 124, (1938).

6. Brebner, et al. "The Effect of Atmospheric Humidity on the Skin Temperature and Sweat Rates of Resting Men At Two Ambient Temperatures" Journal of Physiology, vol. 144, p. 299-305.

7. Fahnestock, et al. "Comfort and Physiological Responses to work in an Environment of 75 F and 45% Relative Humidity" ASHRAE Transactions, Vol. 69, 1963.

<u>Human Performance Changes in Altered Environments</u>
Dr. R. E. Christ

<u>Basic Assumptions and Objectives</u>

A. Tasks most sensitive to the effects of altered (and stressful) environmental conditions, both in terms of immediate and more enduring effects, are skilled tasks requiring temporal-spatial organization of continuous adjustive responses and monitoring tasks requiring prolonged attention and visual search.

B. While most studies in this general area have investigated the effects of single and isolated stressors on performance, it is this investigator's belief that in "real life" one stressor is usually accompanied by one or more other sources of stress. Hence, the objective of most of the studies already conducted or planned for the near future is to examine the combined effects of (a) task stressors and environmental stressors and (b) two environmental stressors.

C. The bulk of prior research in this general area has dealt with gross outcome or system measures of performance. Such performance measures, used alone, do not yield descriptions of the manner in which response organization or strategy is altered by environmental extremes or environmental change; nor are they productive of inferences about the effects of environmental factors on information-processing and other psychological processes, such as attention, timing, and pattern perception. Fine-grained analyses developed in connection with our research allow us to describe rather precisely the nature of changes in response organization which occur under conditions of stress.

Progress Since Initiation of the Program

A. Acquisition of Equipment

Immediately after final budget approval for the project was received, orders for the apparatus, equipment, and supplies necessary for the proposed research were initiated. While some apparatus was available to begin pilot studies almost immediately, a considerable amount of time has been used in acquiring new and unforseen equipment needs and in assembling the specific apparatus which was needed. Now, however, all major items of equipment are on hand and in operation.

B. Recruitment of Supporting Personnel

A graduate research assistant from the Department of Electrical Engineering and a full-time research assistant-clerk were hired as supporting personnel for this project. The GRA from engineering had the responsibility of assembling the equipment needed for this research project as well as the continuing duty of modifying the equipment to meet the various demands of the studies being conducted. He furthermore had the added responsibility for devising an automatic computerized program for handling the fine-grained analytical scoring of the temporal-spatial patterning of movements as recorded on the analog recording system. At present the full-time clerk on the payroll devotes almost all of her time tediously hand-scoring oscillographic recordings to obtain these analytical indices of performance. This clerk also has been used to assist in the scheduling of subjects and in the tabulation, analysis, and graphing of data. In addition to these two individuals, three other graduate students in the Department of Psychology, two holding NIH Traineeships and one holding a departmental research assistantship, came into this project to assist in the planning, design, and execution of specific experiments.

C. Major Studies Completed or in Progress

After several small pilot studies, the data for two major experiments have been collected and are in the preliminary stage of being analyzed. Two additional major experiments are at the point where data collection is about to begin. All of these studies have been designed to assist in the determination of tasks and task variables which may prove sensitive to the effects of environmental stress.

General description of apparatus and performance measures. -- The apparatus employed for most of these studies is a slight modification of the KSU Versatile Electronic Tracking Apparatus (VETA) described elsewhere in detail. The VETA system enables either of two types of stimulus inputs (step-or ramp-function) to be presented in either of two different display modes (pursuit or compensatory). Stimulus programs are punched on paper tape, read out by a commercial tape reader, and converted to analog voltages by a D/A converter and a flip-flop circuit. For the pursuit tracking task the analog voltages are displayed on a CRT as a 1/2 inch long vertical hairline. By moving a lateral arm control, pivoted at the elbow, a subject controls a similar vertical line--the cursor. The cursor is displayed below the target on the CRT and overlaps it by 1/8 inch. For the compensatory tracking task the algebraic difference between the target and cursor voltages is displayed as a 1/2 inch long vertical line on the CRT and a null (or zero error) hairline is displayed in a fixed position in the center of the CRT scopeface.

Scoring is accomplished by an operational amplifier manifold which obtains the algebraic and absolute differences between the target and cursor (momentary error), and integrates it over the trial (integrated absolute error). Input, output, and momentary error are simultaneously recorded, as desired, on magnetic tape and/or on oscillographic paper, while integrated absolute error is recorded by the experimenter on each trial from a voltmeter. Several indices of temporal-spatial accuracy are obtained from oscillographic records for selected trials.

Since these latter, time varying indices of performance are so essential to the objectives of this project a concerted effort has been made to devise an analog-digital computer method for scoring continuous performance records. Dale Bentrup, the GRA from the Department of Electrical Engineering, has devised and written some programs for a hybrid (A/D) computer and for the IBM 360/50 digital computer. He has also conducted some analytical data analysis using these computer programs. (A summary of his Master's thesis, which is concerned with this computer scoring of continuous performance records, is attached to this report.) The preliminary results of this scoring procedure suggest that not only is such an automatic scoring procedure possible but that it is highly desirable. The considerably more rapid scoring made possible by computerized data analysis will have a three-fold effect: (a) it will free project personnel so that more time can be devoted to more creative endeavors; (b) it will allow for more extensive analytical scoring than the present restrictive sampling of trials now provides; and (c) it will allow for the rapid detection of ineffective or irrelevant task parameters and hence make for more successful (i.e., fruitful) experimentation in the long run.

Experiment 1. - It is known that one immediate effect of sudden exposure to high intensity sound is an emotional or startle response. During this startle reaction it would appear that certain portions of the ongoing sequence of task stimulation would be completely missed or at least misperceived by the subject. This study was designed to investigate the effects of these missing stimuli in an overlearned pursuit tracking task.

The stimulus input for this task consisted of a fixed sequence of eight irregular but predictable steps (or positions) of constant duration (0.8 sec.) repeated eight times per trial. Only the starting point in the sequence was varied in order to evaluate the effect of starting point on the organization and transfer (to a new starting point) of responses. Two experimental groups of 24 subjects each were employed; one tracking the basic sequence of inputs (seq. A) and the other tracking a sequence (seq. B) which started in the fifth position of seq. A. In addition, a control group of 16 subjects were run on a random sequence of the same eight positions. After 25 trials on day one and 10 trials on day two, one-third of the subjects from each experimental group were transferred to the other starting point without any warning, one-third, with warning, and the remaining one-third continued as before. The subjects in the control group were transferred to the fixed sequence; one-half to each of the two starting points. At the end of the first day's session and again after 15 transfer trials on day two, all subjects were asked to describe with an objective paper and pencil test (PPT) the stimulus pattern they were tracking.

Preliminary analyses of the tracking data of this experiment show that: (a) the performance of all groups stabilized at the end of day one and remained at the same level on the first ten trials of day two; (b) the constant starting point group remained stable throughout day two; (c) the groups which transferred to a new starting point showed an initial increase in tracking error produced by a decrease in the percentage of anticipatory movements and an increase in the frequency and the magnitude of spatial errors; (d) the increase in tracking error following transfer of starting points was only temporary, the performance of these groups returning to pre-transfer levels after about four trials, and (e) the control groups showed an immediate but gradual improvement in tracking proficiency so that by the end of day two their performance was in line with that of the experimental groups. Finally, preliminary analyses of the PPT scores indicate that subjects tended to perceive slightly different patterns in terms of the starting points of the pattern they reported tracking and that their perceptions of the patterns often changed considerably after transferring to a new starting point. In fact, several subjects claimed during post-experiment interrogation that they perceived no similarity between the pre- and post-transfer patterns. Analyses of these data are continuing at present. Specifically, to evaluate the relationship between perceiving a new pattern and tracking of this new perceived pattern, temporal-spatial indices of performance are being determined separately for each of the eight target positions for each of the eight replications of a sequence within a trial.

Experiment 2. - It has been shown that both bodily arousal and psychological distraction are a function of the loudness of ambient noise levels. Furthermore, the overall subjective loudness of ambient noise has been shown to be a direct function of the percentage time noise is on. Finally, intermittent noise has been shown to be more distracting than either continuous noise or no noise conditions and to be less subject to the effects of receptor adaptation. This experiment was designed to explore the effects of intermittent noise on a dual tracking and monitoring task.

The stimulus input for this task consisted of a regularly alternating ramp function which resulted in the target sweeping horizontally back and forth across the center 6 2/3 cm. of the CRT scope face at a constant velocity of either 1 2/3 cm./sec. or 3 1/3 cm./sec. At irregular intervals of 30, 60, or 90 sec. the target would pause for 1/2 sec. before continuing. Careful programming of the target course over time produced pauses which occurred equally often in the center of the scope and at points midway between the center and the end points of the target course. Subjects were instructed to track the movements of the target and, in addition, to press a button mounted on the hand grip of the lateral arm control whenever they perceived a pause in the movement of the target.

Subjects tracked for six - 4 min. 15 sec. trials each day for four consecutive days. During the first trial and the first 2 min. 15 sec. of the second trial no experimental noise was presented to the subjects but from that moment on one of four possible intermittent noise conditions were introduced via a speaker mounted in the tracking booth. The four levels of on-off ratios were defined in terms of the percentage of on-time in a five sec. duty cycle. Zero, 30, 70, and 100% noise-on-time were used as experimental conditions. Twenty six subjects were randomly assigned, 16 to one group which was presented with the slower target speed and 10 to a group which was presented with the faster target speed. Within each group all subjects were run through a latin square arrangement of four successive daily experimental sessions and the four on-off ratios.

The data from this experiment are in the very early stages of analysis but already several conclusions seem warranted: (a) tracking error for the faster target condition was greater than for the slower condition but response latencies to the pauses were much shorter for the faster ramp condition; (b) the tracking aspect of this task was obviously not sensitive to noise as none of the on-off ratios led to any differences between performance curves for either group; and (c) while response latencies for the group with the faster target speed did not differ as a result of any experimental variable, the latencies of the group with the slower target speed varied as a function of on-off ratio, pause position, and interpause interval. These data require much more inspection and analysis but it would seem that tasks which demand more attention, either in terms of the overall difficulty of the tracking aspects of the task or in terms of the temporal-spatial aspects of pauses which require separate responses, are differentially affected by the intermittency of noise. Tentative plans are presently underway for following-up the results and implications of this study during the next contract year.

Experiment 3. - As stated earlier, the sudden onset of high intensity noise is known to produce an emotional response with many accompanying internal physiological effects. These internal effects of noise could be extremely detrimental to performance in highly developed skills since various internal cues, serving largely as feedback, are critical for the maintenance of the temporal-spatial organization of responses. The bulk of studies concerned with these internal cues have manipulated various dynamic characteristics of the control mechanism while holding all other task variables constant with the assumption that increased response-amplitude or force requirements would augment the usefulness of the cues.

This study was designed to hold the control characteristics and all response cues derived from the control constant while the visual characteristics of the target input were manipulated. The experiment, which is just beginning, will employ 128 subjects randomly assigned to one of four groups of 32 subjects each. Two groups will be trained to track an irregular but predictable ranp function input but one group will train with a pursuit display and the other will train with a compensatory display. The remaining two groups will be trained to track an irregular but predictable step function input but, as above, one using a pursuit, the other a compensatory display. After four days of training (and considerable overlearning, considering that the inputs are relatively simple) one-fourth of the subjects in each group will be transferred, eight subjects each, to each of the four possible target by tracking mode combinations. This experiment should serve to determine the relative importance of visual and response-produced cues to the development and maintenance of performance skills.

Experiment 4. - Most studies investigating the effects of noise on performance have compared noise and no noise conditions and, in the noise conditions, the noise comes either from one location in space or is a free field or binaurally balanced noise source. However, there is much evidence that it is not only the presence or absence of noise per se that affects performance but rather a change in the on-going noise condition. Furthermore, in a military or industrial environment the noise source is quite often neither static in location or source nor is it binaurally balanced and, hence, from a source "in the middle of the head." Finally, it must be recognized that except for extreme forms of noise, it is often the psychological or subjective effects of noise and not the physical characteristics of the noise that are related to levels of performance.

This experiment, or rather this series of experiments, is designed to investigate the psychological (subjective) effects of moving or dynamic sources of white noise presented either from one speaker at a time or from two or more speakers at the same time. The goal of these initial studies is to determine whether or not there are any consistent relation-sequences and the subjective impressions experienced by the listener. Rather than using actually moving sound sources, the listener is surrounded by eight loudspeakers which can be independently or jointly activated in a predetermined order.

The initial study, already run but not yet analyzed, investigated the effects of sound movement speed, sound intensity, and head movements on the perceptions of the listeners. Studies planned for the remainder of this contract year will explore the effects of dynamic "phantom" sound sources produced by (a) the front-back confusion usually found in open-field, fixed-head sound localization studies, (b) the simultaneous onset of two or more sound sources, and (c) the delaying of the onset of one of two overlapping sound sources leading to the "precedence effect" wherein the source of the second sound source is not localized at all. Subsequent studies in this general area will be concerned not only with dynamic sound localization judgments but also with the effects that these changing sources of noise have upon performance in skilled tasks and in monitoring tasks.

COMMUNICATION THEORY APPLIED TO THE SCORING OF THE HUMAN TRACKER

by

DALE RICHARD BENTRUP

B. S., Kansas State University, 1966

AN ABSTRACT OF A THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Electrical Engineering

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1968

ABSTRACT

The limitations of the human when operating as part of a control system are becoming more apparent every day. This has prompted considerable research in the area of human behavior in control systems. Research in this area is being performed by the Psychology Department at Kansas State University by presenting a tracking task to numerous subjects. The main deficiency in the present tracking system is in the equipment which scores the subjects. Therefore this research was performed to obtain better scoring methods.

In the past the only index of performance obtained from the tracking system was the integrated error score (IES). To obtain more information on a subject the response of the subject was recorded and other indices of performance were measured. These measurements were made by hand which is time consuming and in many cases called for the scorer to make a judgement on the relative scores obtained. To obtain a better scoring procedure these indices were redefined so they could be measured by a computer. Then a computer program was written to obtain these redefined indices. Also a few indices that had not been obtained before were measured by the computer.

The indices obtained by the computer gave valuable information on the human tracker. Some of these indices were lead-lag, overshoot-undershoot, average error, RMS error and time on target. One index of performance which was of special interest was the RMS error. This index indicates the performance of a tracker close to a target change. This index was of special interest because the RMS error could be implemented

into the present tracking system. The other indices measured by the computer gave information concerning the cause of a certain IES or RMS error, but the equipment required to obtain these indices could not readily be built into the tracking system.

To obtain more information on scoring methods for the human tracker the tools used in communication theory were applied to an assumed mathematical model of the human being. The model was a second order system with a time shift placed at the input to simulate a lead or a lag in the response. The application of the tools of communication theory showed that the cross correlation of the target signal with the error signal gave a weighted average of the error about a target change. Another function considered was the ensemble average of the absolute value of the error close to target change, but equipment to obtain the cross correlation of two signals is easier to obtain.

The conclusions obtained from this research are that the equipment required to obtain the RMS error and the cross correlation of the target signal with the error signal should be implemented into the present tracking system. The equipment required is readily available and should not be too difficult to install.

Physiologic Rhythmicity in Altered Environments

Dr. E. L. Beach

Apparently most, if not all, physiologic functions are rhythmic and these cyclic periods of light and darkness have influenced the physiological state of mammals since their origin in geologic time. Although man has used artificial light to lengthen his light periods, his rhythmic activity does not appear to be different from other day active animals. In an effort to elucidate information regarding physiologic rhythmicity in altered environments, various animal experiments are in progress or are proposed for the future.

I. PROGRESS TO DATE:

A. Most of the effort to date has been in the area of procuring an environmental chamber and related equipment to accomplish the initial objectives of this study.

1. Environmental Chamber:

This chamber is described in detail in the Renewal Proposal, dated 18 January 1968. Although its delivery date was delayed about 5 weeks, it is presently in operation and preliminary experiments have been initiated.

2. Related Equipment:

The primate chairs and the automated feeding equipment (described in Renewal Proposal) have been delivered but presently are not in use pending the delivery of the physiological telemetering equipment (probably about 15 July 1968). At that time, the non-human primates (rhesus monkeys) will be instrumented for the recording, remotely, of deep body temperature, heart rate, respiratory frequency and food consumption rhythms. It is expected that utilization of this equipment will allow for the collection of data without coming into physical contact with the experimental animals during the period of the trials in which base-line values are obtained under suitable lighting schedules (e.g., 12 hours light followed by 12 hours of darkness).

B. The animal experimentation to date has been concerned with the identification of appropriate physiological parameters to be used as examples of circadian rhythmic activity (e. g., plasma sodium, potassium, 17 hydroxyketosteroids, glucose, plasma proteins, leucocyte counts, etc.) and the selection of suitable animals to be used in the planned experiments. At present, this includes several different pilot studies being conducted concurrently:

1. Spontaneous Activity cycles:

Male rats (Sprague-Dawley) are being used in these spontaneous activity rhythm studies. The animals are in activity wheels in an environmental chamber at 45-50% relative humidity. The experimental temperature and light are cycled, automatically, according to the following schedule:

	Temperature		Light	
	Trial A	Trial B	Trial A	Trial B
Solar Day	27 C (81 F)	27 C	12 hrs. light (6am-6pm)	12 hrs. light
Solar Night	16 C (61 F)	16 C	12 hrs. dark (6pm-6am)	12 hrs. light

Activity levels are recorded automatically, remotely, at each 2-hour interval on a cumulative print-out recorder. Feeding and watering animals and cleaning of cages are accomplished at random intervals. The chamber is not sound-proofed but noise is random and approximately similar during the twenty-four hour interval.

The results of Trial A are summarized in Fig. 3. It is apparent from these findings that the peak activity is at or near midnight and that minimal activity is at or near noon. Trial B is in progress and these data are not available for analysis. However, it is anticipated that since rats are night active animals their peak activities will correspond to dark intervals if both temperature and light are cycled (as in Trial A) and will occur in cool periods if light schedule is held constant (as in Trial B). These data are similar to those previously reported by Browman (1943).

2. Restrained and Free Roaming Animals:

Previous work has shown that leucocyte counts (Pauly and Sheving, 1965) and plasma 17-OHCS (Migeon, et al., 1956) exhibit a daily rhythm. It also has been shown that differential leucocyte counts (Besch, et al., 1967; Burton, et al., 1967) and 17-OHCS levels (Selye, 1950; Blivaiss, et al., 1965) may be indicative of an acute stress including that imposed by chronic restraint. Since the present study will utilize restrained animals (e. g., non-human primates, etc.) information relative

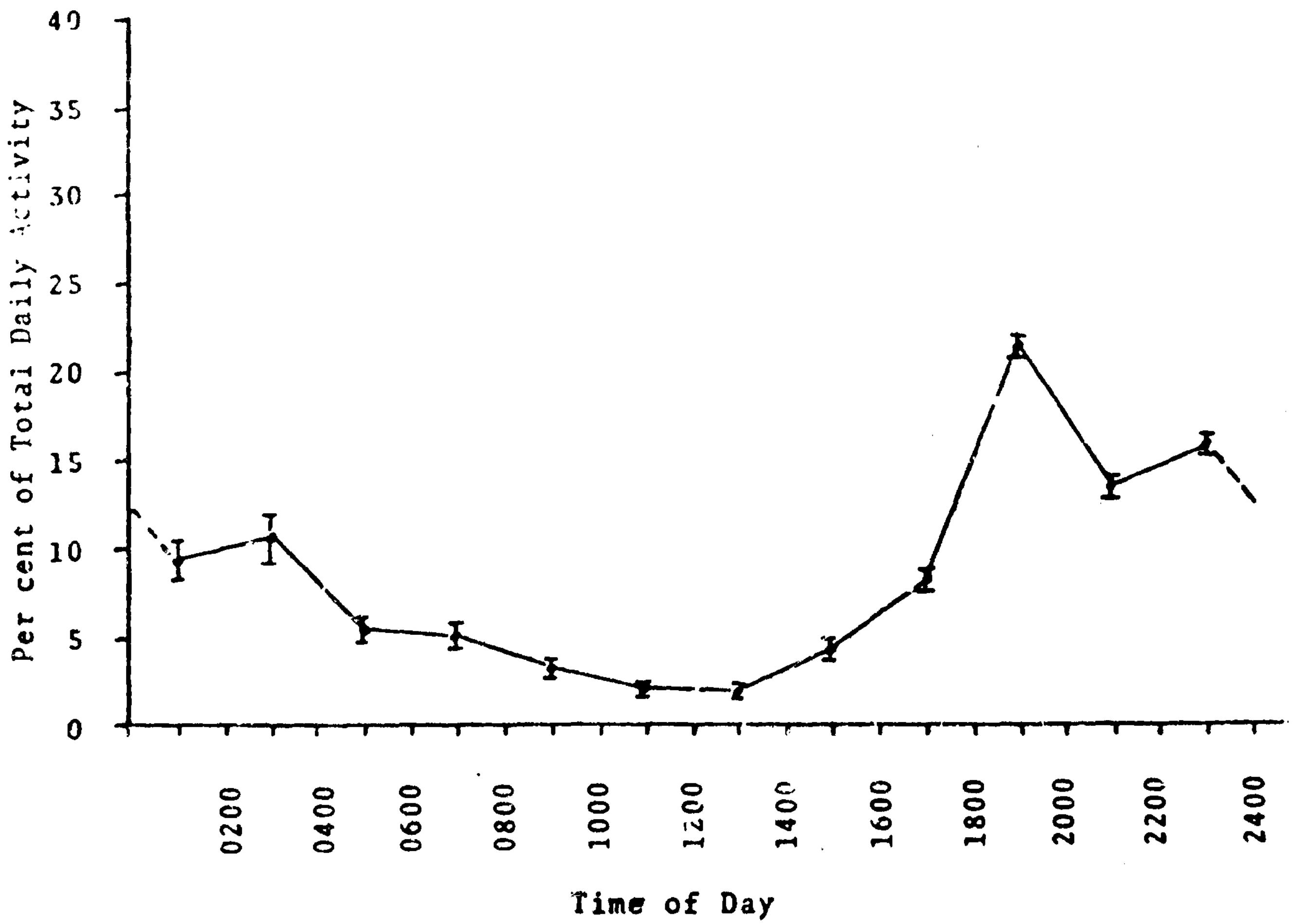


Figure 3. Typical curve of mean percent spontaneous activity (and standard error limits) for 19 consecutive days in a male albino rat.

to the restrained and free-roaming condition of the animal is necessary for subsequent analysis of any rhythm data involving restrained animals.

Male sheep (Range variety) were chosen as the animal for these trials due to their relatively large source of easily accessible venous blood and their "mild temperament". Generally, daily blood glucose levels in ruminants are not as variable as in non-ruminants but little information is available as to the rhythmicity of this measurement. Thus, it appeared that sheep would be appropriate for the simultaneous study of animal restraint and physiological rhythms.

The results of Table 1 appear to indicate that no consistent rhythmic effect is seen in plasma sodium or potassium levels. Although not reported in this table, packed cell volumes (hematocrits) and plasma protein also showed no consistent cyclic patterns. Whether plasma glucose does display rhythmic fluctuations is not readily apparent from these data and accumulation and analysis of more results are necessary before any generalization may be made.

The leucocyte (neutrophils and lymphocytes) counts in Table 1 appear to indicate that there is a relative lymphopenia and neutrophilia in the restrained compared to the control animal. This seems to be consistent with previous results obtained by Besch, et al., (1967) and Burton, et al., (1967) in which a relative lymphopenia appeared to be a valid criterion

Table 1. Comparison of free-roaming and restrained animals. (Restraint period is for first 24 hours in the animal stanchion).

Time of Day	FREE ROAMING Plasma Glucose (mg %)	Plasma Sodium (mEq/l)	Plasma Potassium (mEq/l)	Neutrophils (%)	Lymphocytes (%)	RESTRAINED Plasma Glucose (mg%)	Plasma Sodium (mEq/l)	Plasma Potassium (mEq/l)	Neutrophils (%)	Lymphocytes (%)
0400	84.9	143.5	4.8	10.0	87.5	86.9	145.5	4.5	20.0	77.0
0800	86.6	143.2	4.8	12.5	84.5	80.7	141.6	4.3	34.5	64.5
1200	86.7	143.2	4.8	12.0	85.5	81.0	149.1	4.3	31.5	66.5
1600	83.6	144.7	4.5	18.5	78.0	84.0	149.9	4.2	40.5	56.5
2000	78.2	145.1	4.1	24.0	72.0	82.8	154.3	4.1	41.0	54.0
2400	84.6	141.9	4.4	19.5	77.0	82.5	150.8	4.4	32.0	65.0

of acute stress.

II. FUTURE PLANS:

During the summer, 1968, the experiments now in progress will be continued. Additionally, studies concerned with the dissociation of rhythms will be initiated utilizing rhesus monkeys. After the animals have become physiologically adjusted to a 12 hr. light: 12 hr. dark cycle, these periods will be reduced in length and the effects on physiological parameters (spontaneous activity, etc.) measured.

REFERENCES

Besch, E. L., Smith, A. H., Burton, R. R., and Sluka, S. J., Aerospace Medicine 38: 1130 (1967).

Blivaiss, B. B., Litta-Modignani, R. and Priede, I. in Hormonal Steroids, Biochemistry, Pharmacology and Therapeutics. Proc. First International Congr. on Hormonal Steroids, Academic Press, New York (1967).

Browman, L. G. J. Exper. Zool. 43:477 (1943).

Burton, R. R., Sluka, S. J., Besch, E. L. and Smith, A. H., Aerospace Medicine 38: 1240 (1967).

Migeon, C. J., Tyler, F. H., Mahoney, J. P., Florentin, A. A., Castle, H., Bliss, E. L. and Samuels, L. T., Clin. Endocrinol. and Metabolism. 16:622 (1956).

Pauly, J. E. and Sheving, L. E. Anat. Rec. 153: 349 (1965).

Selye, H. The Physiology and Pathology of Exposure to Stress. Montreal, Canada, Acta, Inc., Medical Publishers, (1950).

Biological Rhythms
Dr. F. H. Rohles

1. Social Entrainment of Feeding Rhythms in Monkeys

Study I. It is generally agreed that there are two types of factors which entrain biological rhythms. The first of these involves physio-chemical factors and includes such variables as light-dark cycles and temperature. The second is the psycho-social factor and the purpose of the present study was to investigate this factor as it relates to feeding rhythms. Two monkeys were trained on a bar pressing task which they could perform anytime they desired food. (Twenty-five bar presses for one 0.15 gm. pellet of food.) In isolation under uniform temperature conditions and constant illumination each animal developed its own feeding rhythm. Following 75 days in isolation the animals were placed together and mutual entrainment took place with both of their feeding periods occurring at the same time. After 30 days in this condition they were again isolated. This resulted in a complete disruption of the previously established rhythms.

Study II. Study I was replicated with similar results. In addition four-hour urine samples were collected and it was found that when the animals were placed together both exhibited a statistically reliable increase in their output of 17 hydroxicorticosteroids, which in turn, dropped significantly when they again returned to the isolation condition. The results of these studies were presented at the Second International Congress of Primatology. (see below)

Study III. Extension of this study will place one of the monkeys on a 0.30 gm. pellet while the other animal will continue to work for the 0.15 gm. pellet. If social entrainment takes place, then either one animal will lose weight (eating at the same time but receiving half the reward) or double the number of times he presses the lever.

2. Symposium.

Funds for this project were utilized to organize and present the following symposium at the Second International Congress of Primatology, Atlanta, Georgia, July 2, 1968.

SYMPOSIUM: CIRCADIAN RHYTHMS IN NON-HUMAN PRIMATES

Chairman: Frederick H. Rohles, Jr, Institute for Environmental Research, Kansas State University, Manhattan, Kansas.

ILLUMINATION INTENSITY AND A BEHAVIORAL CIRCADIAN RHYTHM, D. N. Farrer and J. W. Ternes, Holloman Air Force Base, Alamogordo, N.M.

CENTRAL NERVOUS, CARDIOVASCULAR AND METABOLIC DATA OF A MACACA NEMISTRINA DURING A 30-DAY EXPERIMENT, T. Hoshizaki, W. R. Adey, J. P. Meehan, D. O. Walter, J. I. Burkout, and E. Campean, University of California, Los Angeles, Cal.

SOCIAL ENTRAINMENT OF BIORHYTHMS IN RHESUS MONKEYS, F. H. Rohles, and G. Osbaldiston, Kansas State University, Manhattan, Kansas

CIRCADIAN VARIATIONS OF PHYSIOLOGICAL VARIABLES IN ISOLATED AND NON-ISOLATED MACACA NEMISTRINA, R. E. Smith, University of California and D. K. Wekstein, University of Kentucky.

CIRCADIAN RHYTHMS OF SUSCEPTIBILITY TO EMOTIONAL CONDITIONING IN RHESUS MONKEYS, C. F. Stroebel, Institute of Living Hospital, Hartford, Connecticut.

CIRCADIAN PERIODICITY AND BIGEMINOUS PATTERNING OF THREE CONSUMMATORY BEHAVIORS, J. S. Thach, Naval Aerospace Medical Center, Pensacola, Florida.

PHASE RELATIONSHIPS BETWEEN CIRCADIAN RHYTHMS AND PHOTOPERIODISM (CEBUS ALBIFRONS) C. M. Winget, NASA, Ames Research Center, D. F. Rahlman, University of California, Berkeley and N. Pace, University of California, Berkeley.

DISCUSSANT:

F. Halberg, University of Minnesota

3. Performance on a perceptual motor task following a shift in the Light-Dark cycle.

A monkey was trained on an instrumental skill sequence (18 three-stimulus oddity problems arranged in a fixed order with reinforcement being delivered upon successful completion of all 18 problems) and placed in isolation under constant temperature conditions with 12 hours light and 12 hours of darkness. Performance on the task could be accomplished anytime the animal desired food. After 28 days, light cycle was shifted by 12 hours. This simulated the light cycle one would experience while flying "with the sun" in a westerly direction half way around the world. After 28 days in this condition the dark cycle will be shifted by 12 hours; this will return light-dark phase to its original condition and will simulate the light cycle experienced when flying "against the sun" in an easterly direction half-way around the world. Time of performance and accuracy will be investigated before and after the two shifts.

A subsequent study will examine performance during a 45 minute light- 45 minute dark-period which simulates the light-dark phases during orbital flight.

A Cooling Hood for Hot-Humid Environments
Dr. S. A. Konz

There are some heat environments in which it is not economic to cool the environment. When a man enters these environments, he absorbs heat. In these cases, either heat is stored in the body causing an increase in temperature or the heat is removed from the body by radiation, convection, evaporation of sweat or conduction. This paper describes cooling man with conduction; specifically, cool water in tubes of a hood on the head.

Previous experience (Morales, 1967; Morales and Konz, 1968) had established that a man expending energy at the rate of 6 kcalories per minute (1500 BTU/hour) could be cooled with the hood. Water at 50 F (10 C) circulating at the rate of 0.3 gallons (1.1 liter) per minute was used. The two subjects were tested both at 76 F (24.4 C) and at 100 F (37.8 C); humidity was 70% in both conditions.

Although there was considerable variability, the results can be summarized as follows: Head temperature is kept considerably lower and skin and rectal temperatures are kept lower; cardiac cost is reduced; sweating is at approximately 40% of the rate without the hood, and permitted exposure time to heat stress is longer.

The experiment reported above had demonstrated the concept; this paper reports five more experiments which further explored the parameters of localized cooling on the head.

Experiment One used mental work (addition problems) at temperatures of 99, 103, 107, and 112 F (37.2, 39.5, 41.7 and 44.5 C). Experiment Two had mental work (number recall) at 107 F (41.7 C). Experiment Three had

Measurements. In all experiments except Four, ten temperatures were recorded every five minutes: rectal, four skin, and five head. Sweat rate was also recorded for Experiments One, Two, Three, and Five. Heart rate was recorded through three surface electrodes and was counted on the EKG for all five experiments. An index of productivity was also recorded in each experiment.

EXPERIMENT ONE

Results. The hood kept the temperature on the head approximately 7 F lower than when no hood was worn. Rectal temperature was about 0.3 F lower and skin temperature was from 0.5 to 1.0 F lower with the hood. Sweat averaged 4.0 grams/minute/sq. meter of body area without the hood and 2.0 with the hood. The kcalories removed by evaporation of sweat were approximately 4.5 kcalories per minute when no hood was worn and 2.2 with the hood. Heart rate increased 2 beats per minute less with the hood at 99 F, 8 beats less at 103, 15 beats less at 107 and 6 beats less for a short exposure at 112 F. The variability of the heart rate increased in the heat but a tentative conclusion would be (1) that heart rate variability is influenced by heat stress but not by low levels of heat stress and (2) it is a "noisy" signal with considerable fluctuation. With the hood they added about 4% more numbers than without the hood.

Discussion. The hood worked and no adverse affects were detected. In order to gain further experience, the same two subjects did a different type of mental work in Experiment Two.

EXPERIMENT TWO

Results. The hood kept head temperatures from 3 to 15 F lower than when physical work (walking on a treadmill) at a temperature of 100 F (37.8 C). Experiment Four used addition problems and walking on a treadmill at 38 and 78 F. The hood was not tested but the variability of the heart rate (a proposed index of "mental load") was observed. In Experiment Five, eight subjects tested an improved model of the hood at 100 F (37.8 C) for 120 minutes while doing a creative task (anagrams). The humidity was 70% and air flow less than 50 feet per minute in all five experiments and ambient noise varied from 61 to 68 db.

Hood. For the first three experiments, the "cooling power" of the hood was increased by reducing the temperature of the cooling water from 51 F to 41 F (5 C) and increasing the flow rate from 1.1 to 1.7 liters per minute. The water temperature difference between the inlet and outlet of the hood was 5.2 F (3 C) or approximately 5.1 kcalories of heat were removed per minute. We estimate that approximately 80% of the heat was removed from the man and 20% from the environment so the cooling power was approximately 4 kcalories per minute or 960 BTU per hour.

Experiment Four did not use a hood but in Experiment Five an improved model hood (although still quite crude) was constructed. It has a closer fit to the head and should lose less heat to the environment. Using cooling water at 40 F and a flow rate of 1 liter per minute, the temperature drop of the water was 6F (3.3C). Thus 3.3 x 80% or 2.6 kcalories of heat per minute were removed from the man.

Subjects. American male undergraduates were used throughout. The same two were used in the first three experiments. There were ten subjects in Experiment Four and eight in Experiment Five.

no hood was worn depending on length of exposure. Rectal and skin temperature were the same or slightly (0.2 F) lower with the hood than without it. Sweating with the hood was at approximately 60% of the rate of without the hood; the heat removal rate by sweat was about 1.2 kcalories less with the hood. Heart rate rose 9 beats per minute less when the hood was worn. The variability of heart rate fluctuated considerably with no apparent pattern. In the neutral condition they remembered 10.5 digits per trial. In the heat they remembered 12.8 digits per trial with the hood and 10.4 without the hood. Evidently learning how to do the task continued with the hood but not without the hood.

<u>Discussion</u>. Again no adverse affects were noted when the hood was worn for up to 80 minutes of exposure. Experiment Three investigated the effect of physical work--walking on a treadmill at 3 mph.

EXPERIMENT THREE

<u>Results</u>. Exposure times varied from 75 to 115 minutes at 100 F. Temperature on the head was 4 to 8 F lower when the hood was worn and rectal and skin temperature was about 0.7 F lower when the hood was worn. Sweat averaged 3.0 grams per minute per square meter of body surface area with the hood and 5.1 without the hood; the respective heat removal rates for evaporation are 3.4 and 5.8 kcalories per minute. Heart rate increased 5 to 10 beats per minute less with the hood The standard deviation of the heart rate in the heat was quite consistent at 0.01 second while walking and went up to a consistent 0.02 while sitting. It seems that physical work affects the variability strongly and consistently.

Discussion. The variability of the heart rate continued to intrigue us so Experiment Four was prepared solely to investigate the variation of heart rate under six conditions.

EXPERIMENT FOUR

Results. Ten undergraduates each spent 30 minutes in each of the conditions. The hood was not used. The average for the ten subjects is given in Table 1.

Table 1. Heart Rates in Experiment Four.

Condition	Beats/min	Seconds between beats		Coefficient of Variation
		Mean	Std. Dev.	
Sit 76 F	78	.765	.059	7.7%
Add 76 F	76	.791	.062	7.8%
Sit 98 F	81	.745	.057	7.6%
Add 98 F	93	.647	.042	6.5%
Walk 76 F	108	.555	.019	3.4%
Sit 76 F	79	.761	.056	7.3%

Discussion. The variability of the heart rate does not seem to be changed much by low levels of mental load such as adding. It does seem to be affected by cumulative exposure to heat and by physical work. Thus it seems to be an index of stress but, at the present state of knowledge, no more useful than other indices.

Meanwhile an improved model hood (although still crude) had been designed. The lack of ill effects in previous experiments led to a schedule of 120 minutes exposure at 100 F while the eight subjects did a creative mental task, anagrams.

EXPERIMENT FIVE

Results. Rectal temperature rose approximately 0.1F less with the hood, skin temperature rose 1.7 F less, and head temperature rose 2.8 F less. Sweat averaged 1.35 grams/minute/sq. meter of body area with the hood versus 2.72 without the hood; the respective heat removal rates for evaporation are 1.5 and 3.1 kcalories per minute. Heart rate increased 6 beats per minute less with the hood. The standard deviation has not yet been calculated. While in the heat they composed 8% less words while wearing the hood and 14% less when not wearing the hood.

Discussion. The pattern of the experiments seems clear. The hood works and there seems to be no adverse physiological effects. The next phase will concentrate on improvement of the hood itself. We will try to minimize heat loss to the environment, get better contact of the water tubes with the head, and investigate various heat removal rates. We plan to use the Institute's copper man in this latter phase. Thus by September 1st, we should be ready to start work on humans with a better model hood.

REFERENCES

Morales, V., The Physiological Effect of a Water Cooled Headdress in a Heat Stress Environment, M.S. Thesis, Kansas State University, 1967.

Morales, V. and Konz, S., The Physiological Effect of a Water-Cooled Hood in a Heat Stress Environment, paper presented at summer meeting of ASHRAE, Lake Placid, New York, 1968. ASHRAE Preprint 2091.

Effects of Environment on Microbial Flora in Clothing

Dr. E. H. Coles and Dr. J. A. Warden

Part I

Learning operating procedures and devising and perfecting techniques for aerosolization and recovery of bacteria from fabric have been our major accomplishments.

Some difficulties we have had include delayed arrival of some equipment and the adaptation of said equipment for our purposes. Our material; woven according to Air Force specifications, hasn't yet been obtained. This hasn't been a factor in our preliminary work, but will detain the study if not received soon.

The following is a summary of our research to date.

Check of Material for Original Flora Before Inoculation

We agitated inch square pieces of washed material (that hadn't been inoculated) in 100 cc sterile tryptic soy broth in Waring Blendors for two minutes at high speed. The solution was plated on tryptic soy agar.

Recovery of bacteria was negligible. We found little flora on the material prior to inoculation with bacteria.

Since suspensions are plated on specific agar when bacteria is inoculated, little contamination occurs to interfere with counts of inoculated bacteria.

The above were just trial runs and will, of course, have to be repeated using the specific sock materials.

Technique for Aerosal Exposure of Material to Bacteria

Ten by ten inch squares of material, with inch square samples of the same material cut out and sewn back in for testing, are suspended in the Chromatocab airtight chamber.

The material is suspended from a rotating hanger which turns slowly while the material is being inoculated by means of a bacterial suspension in a nebulizer chamber.

The nebulizer is allowed to run for 20 minutes. By the end of this time a dense fog has been produced in the chamber.

We have found that premoistening the material with sterile, distilled water before inoculation with bacteria, in the same manner as bacterial inoculation, enhances our recovery of the bacteria.

We have been attempting to achieve an even distribution of bacteria on the cloth and have achieved fair results to date.

Technique of Assay of Bacterial Population

We have determined through preliminary work that a better recovery of seeded microorganisms is obtained by the use of Waring Blendors than by manual shaking.

Inch square samples of the inoculated material are agitated in the blendor in 100 cc of tryptic soy broth for 2 minutes on high speed.

Diluations are plated from this on appropriate agar.

Environmental Chamber

We set up the environmental chamber (recently arrived) and were able to maintain a constant humidity and temperature.

We have been unable to use the chamber in actual testing as yet, because we had planned to use gaseous sterilization and after receiving the chamber determined this was impossible because of the manner in which it recirculates the air.

We are planning to use micropore filters to cover the exterior exhausts and to sterilize the interior of the chamber with para-formaldehyde. Efficiency of this procedure is being determined at the present time, and results to date indicate that this method is quite effective.

Recovery of microorganisms will be attempted from inoculated material incubated at constant temperatures and humidities for specific periods of time.

Standardizing Cultures

We have used a method of obtaining a standard number of viable bacteria as related to optical density.

E. coli was grown at 37°C. with constant agitation to obtain a growth curve. Samples were removed at intervals and plated and absorbances were read on a Gilford spectrophotometer.

The optical density was plotted on semi-log paper against viable count to obtain a reference for inoculating the material.

This was done to get a degree of correlation between our inoculums.

Washing Inoculated Material

We are in the process of washing and drying inoculated samples in conjunction with the Department of Clothing and Textiles. Preliminary work is being done to determine survival of bacteria in washing machine and dryer.

A 10 inch by 10 inch piece of material was inoculated with *E. coli* by procedures described previously. This material was washed along with 4 lbs. of filler (towels) using Tide detergent and chlorine bleach. Swabs of the washer tub were made before and after washing. Samples were taken from rinse and wash water and plated.

No recovery of bacteria resulted from the above testing of samples from the washer. We attempted to recover bacteria from an inch square sample of material and results were negative. We concluded that the detergent and bleach were sufficient to remove and destroy the viable E. coli.

More tests are being run to determine efficiency of washer removal of microorganisms. The main objective here is to avoid contamination of equipment.

Note: Initial inoculum 73×10^8

Recovery from sample before laundering 57×10^3/sq. in.

Recovery from sample after laundering--no organisms recovered.

To Be Accomplished in Near Future

As soon as we perfect inoculating procedures and are able to prevent contamination of washer and dryer, we will be ready to start actual testing of the sock material. (Preliminary testing has been done on cotton fabric and small samples of socks.)

Plan for July and August

The following will be begun and/or completed in July and August.

1. Obtain maximum efficiency of aerosol chamber, both in numbers of samples inoculated at one time and in recovery of bacteria inoculated.
2. Begin use of environmental chamber to incubate inoculated fabric samples

at constant temperatures and relative humidities.

3. Check washing machine and dryer more extensively for contamination after processing of inoculated fabric samples. Investigate the possible use of sterile swatches to check rinse and wash water; possible use of launderometer to recover bacteria from above mentioned swatches.
4. Develop and perfect techniques of mold inoculation and recovery.
5. Check further the naturally occurring microflora of fabrics used in tests.

Part II

The first eight months of investigation have been spent in acquiring equipment and supplies and in developing procedures and techniques for determining the effect of environment on microbial flora on clothing. This preliminary work has revealed no major problems which should affect the carrying out of the study as soon as the fabric, knitted to the government specifications,is delivered sometime in July.

Laundry Procedures

Since it is assumed that Air Force socks are laundered an average of one hundred times in two years, the fabric swatches will be seeded with micro flora and laundered one hundred times. Samples will be drawn for textile analysis with zero, one, five, 10, 20, 30, 40, 50, 60, 70, 80, 90, and 100 washings. Washing and drying procedures are being established. (One problem is to be sure that the micro-organisms do not escape from the dryer into the room.)

Washing procedures are planned to simulate those used in home laundering.

Commercial laundries were found to wash few socks and washing temperatures were little or no higher than those used for home laundering. Hot water washing temperatures for home use usually range downward from 140°F to 120°F depending on the use of hot water just prior to doing the family laundry and the distance the hot water must travel from its source to the washer.

Commercial laundries use temperatures of 120°F to 160°F. None of the commercial laundries used temperatures of over 140°F for colored fabrics or known fiber blends of combinations. Men's socks in this study would be included in the fiber blend category.

In one of four commercial laundries, where interviews were conducted, a bactericide to prevent mildew was used. The other companies used a bleach for whitening purposes, but not as a bactericide. A different detergent was used by each company.

Managers of the major supermarkets in Manhattan and the manager of the PX at Ft. Riley were interviewed as to the type of detergent purchased by local consumers and the type, if any, bactericidal purchased. In every supermarket, "Tide", a high sudzing synthetic detergent with whitening agents was purchased in the largest quantity and by the largest number of consumers. Although each store carried several products which could be used as a bactericide, only Clorox, (sodium hypochlorite 5.25%), was purchased by large numbers of consumers.

Final drying time and temperatures will be established with the test fabric.

Textile Analysis

Analysis of physical tests are made to give an indication of fabric end-use performance. All tests will be made according to A.S.T.M. standard procedures. The CRE (Constant Rate of Extension) instrument will be used for bursting strength tests. Resistance to abrasion will be measured by the Schiefer Abrasion Testing Machine and Stoll Instrument. In addition, the Schiefer uses an inflated diaphragm method to determine resistance. Weight and thickness determinations will be made.

Because of the vast number of swatches needed for physical testing, it is planned to use only one detergent and one disinfectant at present. Commercial laundries are more likely to use a low sudzing synthetic detergent than home consumers. The ph of the wash cycle is about the same for both. Thus, little difference in results should occur. When soap is used the ph is different, but few consumers use soap because of the hard water scum which may cause graying of the clothes and clogging of the machine.

Tests will be made to determine any fiber damage which may occur because of chemicals used in laundering.

After these analysis, if it is felt necessary, photomicrographs of fiber cross sections will be studied to compare the effects of abrasion and degree of damage after different numbers of launderings.

Plan for July and August

Work in June consisted of further development of techniques for research. Fabric having similar physical characteristics to that of military nylon and cotton ribbed, stretch type of stocking has been purchased. Ten washings and dryings will be done with the following washing conditions:

1. No detergent

2. Synthetic detergent

3. Detergent plus the 1/2 the amount of bactericidal agent recommended by the manufacturer

Swatches will be drawn after zero, five and ten launderings and physical tests made to determine if damage, if any, is due to the action of the different type of laundry condition.

This analysis will require some work in July.

Fabric for the project should be available for use in July. Final procedure will be perfected including levels of abrasions and ball bursting strength. (Ball burst equipment for the CRE instrument has had to be modified, because of the high degree of stretch of the sock fabrics.)

Comparative Psychophysiology
Dr. Frederick H. Rohles, Jr.

1. The Effect of High Thermal Stress Exposure Rate on Human Performance

There have been a number of studies which have investigated man's performance under various levels of temperature and humidity. Most of these studies have used the same range of temperatures, but for different fixed exposure durations. This means that these studies have utilized different exposure rates. In view of this, any data comparison between these studies may not be valid. Therefore, the present investigation asks this question: will the effects on human performance of rapidly developed heat storage be equivalent to the effects on human performance when heat storage is developed more slowly over a longer period of time? Different rates for the development of a fixed amount of heat storage (2°F over basal rectal temperature) were established by imposing two heat loads, 100°F and 120°F Dry Bulb (DB) at 80% Relative Humidity (RH), upon sitting, resting, semi-clothed male subjects. A separate group of eight subjects was employed for each heat load, but for both groups the load was administered to one subject at a time. A control heat load (80°F DB, 80% RH) was administered to a third group of subjects who were also tested one at a time. No heat storage occurred in the latter group of subjects.

Immediately following heat exposure, each subject was shown a vertical panel containing four one-inch lights. A single pair of illuminated lights, one green and one red, appeared in any one of the four positions which make up the four sides of a square. A small blue light and a small yellow light were placed at the center of this square. The subject was also shown a horizontal panel which contained four spring-loaded toggle-switches, each being located at a different vertex of a 45 degree-rotated square. Pressing the correct switch resulted in the illumination of the blue light below the word "right"; pressing an incorrect switch resulted in the illumination of the yellow light below the word "wrong". The subject was instructed to learn the principle that resulted in the illumination of the blue light. The experimenter recorded 1) the subject's response time for every trial and 2) the number of trials to criterion for each subject.

An analysis of variance performed on the mean response times for the first thirteen trials on the psychomotor task resulted in an overall significant difference between the three ambient temperature groups. Comparisons of the treatment means yielded a significant difference between the control group (80°F) and the 120°F group; and between the control group and the 100°F group; but there was no significant difference between the 100°F and 120°F groups. An analysis of variance performed separately on the trials to criterion data, and on the mean response times for all trials to criterion did not yield a significant difference between the three ambient temperature groups. A trend analysis performed on the error data showed no significant differences between temperature groups, nor was the temperature by trials interaction significant. However, performance over trials for all groups was significant. The difference in mean time (in minutes) for subjects to attain a 2°F heat storage over their BRT was significant (Student's "t"); as was the difference in rise time (in minutes) needed to reach 1°F over BRT and 2°F over BRT (Sandler's "A"). Finally, the change in the subjects' rectal temperature (°F) during behavioral testing was significantly different for the two heat storage groups (Student's "t").

It was concluded that the significantly faster response times for the two heat storage groups resulted from the presence of the heat storage and not from differences in the rate of heat storage. It was also suggested that the unexpected lack of a heat storage effect on the trials to criterion measure could have resulted from the low difficulty level of the psychomotor task.

2. <u>Wind as a Reinforcing Stimulus</u>.

Based on earlier research in which winds of different velocities served as adversive stimuli in an operant conditioning procedure, an extension of these studies was proposed in which not only the velocity of the wind was varied but the temperatures of the wind and the temperatures of the surrounding environment were also studied. A device to study these variables was constructed and installed in a 3 x 12 walk-in refrigerated room. Two Cebus monkeys were procured for subjects and initial training has begun.

THE EFFECTS OF TEMPERATURE AND CROWDING ON AGGRESSION

In the summer of 1966 an investigation was conducted at the Institute for Environmental Research whose purpose was to determine if crowding influenced the rate at which body temperature increased under conditions of high thermal stress. Four crowding conditions were studied (6, 9, 16 and 32 ft^2 per subject) at eight thermal conditions ranging from 86.8 to 94.5 ET and the length of time for the body temperature to increase 2°F above a resting level served as the dependent measure of stress. While no concrete evidence was found that demonstrated a faster rise in body temperature under increased crowding densities, an interesting observation was made which served as the stimulus for subsequent research. In the study cited, subjects were recruited from the Kansas Employment Bureau and consisted of high school drop-outs, juvenile delinquents, parolees and un-employed students. When 48 of these individuals (6 ft^2/subject) were placed in the ASHRAE chamber at 93.5 ET there was a rash of arguments, "needling", fights and several "bloody-noses". Thus, on the basis of these observations, a hypothesis was formulated which stated that if a group of individuals who are prone to exhibit aggressive behavior - that is for whom arguing, fighting and behavior of the type witnessed is considered "normal" - are crowded into a small area and the temperature is increased, the result will be lowering of the threshold of the stimuli responsible for triggering the aggressive behavior. This event coincided with the Watts riots in Los Angeles which provided further support for the hypothesis. In other words, if a militant group of individuals is packed into ghetto conditions during the "long hot summer", tempers get short and fighting will result. A rather inconclusive test of this hypothesis was made when graduate students (probably non-aggressive) were placed at the same temperature under crowded conditions and the aggressive behavior was not observed. Likewise, the same group used in the original study was tested at lower temperatures and the fighting and arguing appeared to be less. At any rate, sufficient evidence was gleaned so that a formal test of the hypothesis was undertaken. This will be described below and is presently under study.

PURPOSE

The purpose of this study is to determine the relationship between temperature and crowding on aggressive behavior.

SUBJECTS

The subjects will be 16 male C57BL mice of the Jackson Laboratory strain (Bar Harbor, Maine). This is a genetically-pure strain that has been identified by the staff of the Jackson Laboratories as being highly aggressive.

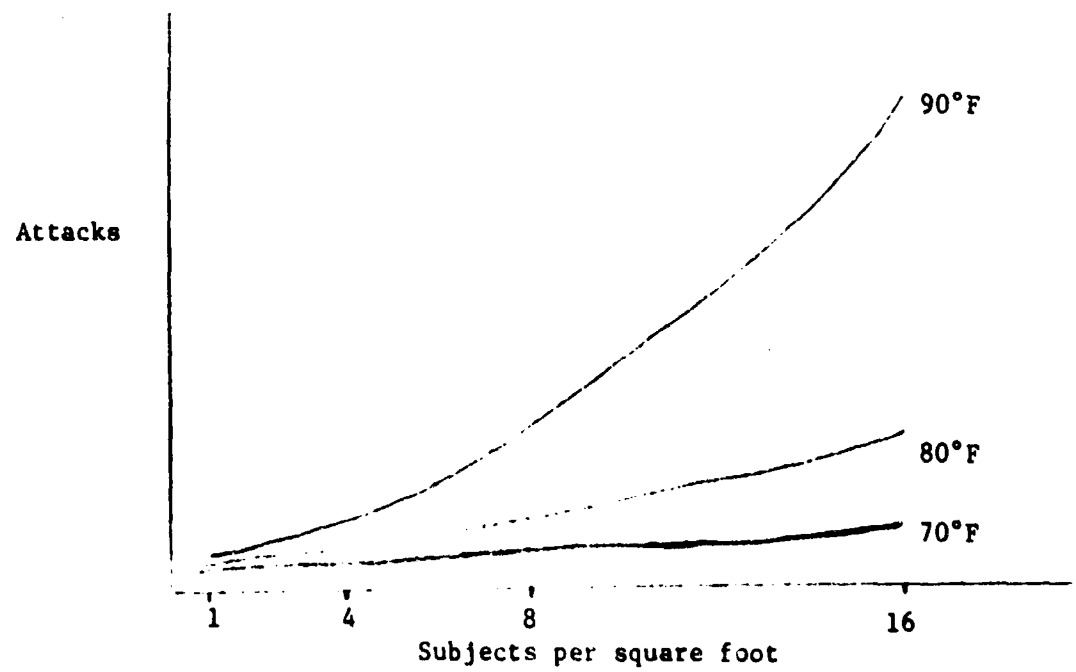
ENVIRONMENTAL CONDITIONS

Three thermal conditions will be studied 70, 80, and 90°F (50%RH) under the following four packing densities: 1, 4, 8 and 16 subjects per sq. ft. All tests will be conducted in the KSU-ASHRAE chamber.

PROCEDURE

The subjects will be housed individually in the KSU-ASHRAE chamber for 18 hours at the temperature under study. They will then be placed in the test unit for six hours. The test unit consists of a 4' x 4' 1/2 inch plywood base and four interchangeable side sections; side sections are 2' high and measure 4 x 4 ft (16 ft^2), 2.8 x 2.8 ft^2 (8 ft^2) 2 x 2 ft (4 ft^2) and 1 x 1 ft (1 ft^2), respectively. A water bottle is mounted in the center of the base. Subjects will be fed and watered ad lib but will be deprived of food for 12 hours before being placed in the test unit. Aggression will be measured in terms of attacks (bites) and will be recorded by means of a time-lapse camera mounted above the test unit. Photographs of the subjects in two packing densities are shown in Fig. 4.

Hypothetical results based on the acceptance of the hypothesis is presented below:



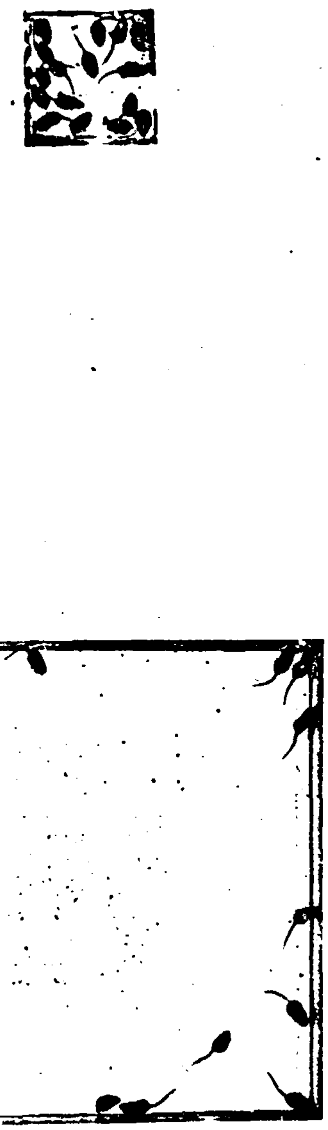


Fig. 4. Photographs of 16 mice in two packing densities.

IMPLICATIONS

If the hypothesis is valid subsequent research will be done with different strains of mice and different combinations of aggressive and non-aggressive animals under various packing and thermal conditions. The two environmental variables of temperature and crowding are obvious but the third factor of the genetically aggressive strain is of equal importance to the testing of the hypothesis.

Systems Design and Optimization Group

Dr. L. T. Fan and Dr. E. S. Lee

This group is working on the identification, analysis, and optimization of life support systems and subsystems investigated by other groups and also is working on the related subjects. It is hoped that the investigation by this group will eventually lead to development of optimal designs for a variety of life support systems and subsystems.

For each system and subsystem that will be considered, the procedure will involve the establishment of system equations or mathematical models based on theoretical and experimental data; the analysis and simulation of the model; the optimization of the operation, control, reliability, and sensitivity of the system based on the model; and, if possible, experimental verification of the proposed optimal solution.

Since the initiation of the project on September 1, 1967, five papers have been written on the method of identification and analysis of life support and related systems (see Appendix). The work can be divided roughly into three categories: (1) the modeling and identification of the system, (2) analysis and simulation of the system, and (3) optimization of the system. Publications (2) through (5) listed in the publication list in the appendix can be classified as the first category and publication no. (1) is concerned with the simulation and analysis of the life support system. Publication no. (3) discussed some optimization problems. The optimization of a life support system based on the thermal comfort equation is being conducted and some of the preliminary results are discussed in the following.

(a) Modeling and Identification

The study in modeling and identification can be classified as especially suited for life support systems, (2) the application of these and existing techniques for the modeling of life support systems. In publications nos. (4) and (5), two newly developed techniques, namely quasilinearization and invariant imbedding, are applied to the identification or estimation of parameters. It is shown that these techniques are useful tools for establishing differential equation models. These techniques will be used to establish life support models in future studies.

A proper air distribution is essential in air heating, ventilating, and air-conditioning systems. Even though a system delivers the required quality and quantity of conditioned air to a confined space such as a room or an underground shelter, unsatisfactory conditions result if the air is poorly distributed and improperly circulated. The mechanism of air flow and distribution in a confined space is very complicated. Although, theoretically speaking, the Naivier-Stokes equation can be used to represent air flow and distribution in such a system, it is extremely difficult, if not impossible, to solve it exactly. Thus, engineers are often compelled to seek approximate solutions based on simplified assumptions.

In publication no. (2), the concept of age distribution is used to study the air distribution in a confined space. This concept has been used successfully in the study of chemical reactors. S[illegible]l flow models based on this concept are proposed. The use of these models in design, data correlation, control, and scale-up problems are discussed. Experimental procedures for verifying the proposed models and predicting the various parameters in the models are also discussed.

The use of the concept of age distribution in the study of mixing and flow in a confined space is especially useful for systems such as an underground shelter, a space craft, and a submarine, where the purity of air is important. Knowing the age distribution of the contaminated air, the optimum way to purify this air for undesirable components may be determined. Furthermore, the impulse response study discussed in this paper should be a useful tool for studying the dynamic behavior of air in a confined space.

(b) Analysis and Simulation

A basic problem in the study of life support systems is to establish conditions under which human beings feel thermally comfortable. In publication no. (1) the feasibility region of the comfort equation of Fanger is studied by simulation. One of the purposes of this study is to illustrate how the systems techniques can be used to analyze complex models. Another purpose is to study characteristics of this equation so that it can be used as one of the constraints for the optimization studies of life support systems.

Fanger's comfort equation was obtained by the use of heat balance based on the assumption that the sensation of thermal comfort is closely related to the mean skin temperature and sweat secretion. This thermal comfort equation can be represented by

$$\frac{M}{A_{Du}}(1-\eta) - 0.35\left[43 - 0.061\frac{M}{A_{Du}}(1-\eta) - P_a\right]$$

$$- 0.42\left[\frac{M}{A_{Du}}(1-\eta) - 50\right] - 0.023\frac{M}{A_{Du}}(44 - P_a)$$

$$- 0.0014\frac{M}{A_{Du}}(34 - t_a) = \frac{35.7 - 0.032\, M/A_{Du}\,(1-\eta) - t_{c\ell}}{0.18\, I_{c\ell}}$$

$$= 4.8 \times 10^{-8} f_{c\ell} f_{eff}\left[(t_{c\ell} + 273)^4 - (t_{mrt} + 273)^4\right] + f_{c\ell} h_c (t_{c\ell} - t_a)$$

where

P_a = partial pressure of water vapor in ambient air

t_a = air temperature

t_{cl} = outer temperature of clothed body

I_{cl} = dimensionless total heat transfer resistance from skin to the outer surface of the clothed body

f_{cl} = the ratio of the surface area of the clothed body to the nude body

f_{eff} = the ratio of the effective radiation area of the clothed body to the surface area of the clothed body

t_{mrt} = the mean radiant temperature

h_c = convective heat transfer coefficient, kcal/m^2hr C.

The products, $A_{Du}\ f_{cl}\ f_{eff}$ and $A_{Du}\ f_{cl}$, represent the effective heat transfer area of the clothed body for radiation and convection, respectively. For free and forced convections, the values of h_c have been found to be

$$h_c = 2.05\ (t_{cl} - t_a)^{0.25} \tag{2}$$

and

$$h_c = 10.4\ v^{1/2} \tag{3}$$

respectively, where

v = relative air velocity <2.6 m/sec.

For a motionless person, the relative air velocity is equal to the actual air velocity. The mean radiant temperature, in relation to a given person placed at a given point with a given body position and a given clothing, is defined as that uniform temperature of a black enclosure which would give the same heat loss by radiation from the person as in the actual enclosure under study.

Equation (1) actually contains two separate equations. The left hand side of Equation (1) can be solved for the outer surface temperature of the clothed body, t_c, giving rise to the following relation.

$$t_c = g\left(\frac{M}{A_{Du}}\eta,\ I_{c\ell},\ P_a,\ t_a\right) \qquad (4)$$

where g is a fairly complex expression. Setting the left hand side of Equation (1) equal to the right hand side gives

$$\begin{aligned}\frac{M}{A_{Du}}(1-\eta) &- 0.35\left[43 - 0.061\frac{M}{A_{Du}}(1-\eta) - P_a\right] \\ &- 0.42\left[\frac{M}{A_{Du}}(1-\eta) - 50\right] - 0.023\frac{M}{A_{Du}}(44 - P_a) \\ &- 0.0014\frac{M}{A_{Du}}(34 - t_a) = 4.8 \times 10^{-8} f_{c\ell} f_{eff}\left[(t_{c\ell} + 273)^4\right. \\ &\left. - (t_{mrt} + 273)^4\right] + f_{c\ell} h_c (t_{c\ell} - t_a). \qquad (5)\end{aligned}$$

Equation (5) is the basic equation. The feasible region of this equation is discussed in publication no. (1) listed in the Appendix

(c) Optimization

Based on Equation (5), an optimization study is being carried out. Equation (5) can be considered as an equality constraint which must be satisfied in order to attain comfort conditions. Many of the variables in Equation (5) can be considered as control variables. However, in most practical situations in life support systems, only the thermal environmental variables, P_a, t_a, t_{mrt}, and v can be controlled. Note that the variable $t_{c\ell}$ can be eliminated from Equation (5) by using Equation (4). The variable v comes into Equation (5) under forced convection condition through the convective heat transfer coefficient, h_c. The other variables, namely, M/A_{Du}, η, $I_{c\ell}$, $f_{c\ell}$, and f_{eff}, can be considered as parameters with various sets of values. The values of these parameters under different activity levels and under different clothing ensembles are tabulated in the literature.

Among the four control variables proposed, t_{mrt} cannot be controlled easily in most practical situations. Thus, during the early stages of the investigations, only three variables, P_a, t_a, and v, will be considered as control or decision variables.

At least three different optimization problems can be defined according to the objective of the optimization study. For a given set of parameter values, find the values of P_a, t_a, and v so that

(a) the total weight (or space) of the equipment for providing P_a, t_a, and v, which attain comfort conditions, is minimized.

(b) the cost or energy of providing P_a, t_a, and v which attain comfort conditions is minimized.

(c) the probability of equipment failure is minimized.

In addition to the equality constraint, Equation (5), the range of the control variables must also be restricted. For example, the value of v must be between 0.1 and 2.6 m/sec. These feasible ranges of the control variables are tabulated in publication no. (1).

The minimization of total energy required to attain comfort condition in a life support system within an enclosed spaced is being conducted. From the simulation study reported in publication no. (1) the comfort zone is defined. This comfort zone together with velocity and relative humidity are used in the optimization of the energy in the system. The simplex pattern search technique is used to search for the optimum combination of room temperature, partial pressure of water vapor and the room air velocity so that the minimum amount of energy due to the incoming air needed to be removed from the room to attain the comfort condition.

For all three outside conditions of 50° C, 40°C and 30°C with 100% relative humidity the optimum room air velocity is .1 meter per second which was the lower constraint; while the optimum temperature and partial pressure of water vapor is between the range of 28.83°C to 26.46°C; and between 29.87 mm Hg and 20.68 mm Hg from sedentary activity of 52 Kcal per $(m^2)(hr)$ to high activity of 132 Kcal. per $(m^2)(hr)$. For the same activity at different outside conditions the optimum temperature and partial pressure of water vapor vary very slightly because of the lower velocity and the upper relative humidity constraints which do not permit further search.

Dynamic Optimization

The dynamic behavior of a life support system, especially in a space craft, is a very important factor, which must be considered in its design and operation. For example, if there is a sudden disturbance (step input) in the environmental temperature, what is the quickest (optimum) way to return this temperature back to the normal comfort temperature under the restrictions of the available equipment. Any variables other than temperature such as humidity, pressure, and undesirable chemical species in the enclosure can also be studied in essentially the same way.

This dynamic optimization problem is much more difficult to solve than the steady state optimization problem. The recently developed techniques as well as any improved techniques that may be developed will be used for this optimization study. Invariant imbedding appears to be a useful tool to overcome some of the computational difficulties.

Appendix

Publication List of the Systems Design and Optimization Group

1. Lee, E. S., L. T. Fan, C. L. Hwang, and M. A. Shaikh, "Simulation and Feasibility Study of a Thermal Comfort Equation," Report No. 3, Institute for Systems Design and Optimization, Kansas State University, Manhattan, Kansas (1968), also to appear in ASHRAE Journal.

2. Chen, M. S. K., L. T. Fan, C. L. Hwang, and E. S. Lee, "Air Flow Models in a Confined Space -- A Study in Age Distribution," Report No. 5, Institute for Systems Design and Optimization, Kansas State University, Manhattan, Kansas (1968).

3. Lee, E. S., "Invariant Imbedding -- A Versatile Computational Concept," to appear in Ind. Eng. Chem., Aug., 1968.

4. Lee, E. S., "Estimation of Parameters in Differential Equations From Experimental Data," Report no. 1, Institute for Systems Design and Optimization, Kansas State University, Manhattan, Kansas (1968).

5. Lee, E. S., "The Estimation of Variable Parameters in Differential Equations by Quasilinearization," Report No. 2, Institute for Systems Design and Optimization, Kansas State University, Manhattan, Kansas (1968), also presented at A.I.Ch.E. 63rd National Meeting, Feb., 1968, St. Louis, Mo.

Air Distribution in Confined Spaces
Dr. Ralph G. Nevins

Contact with various aircraft manufacturers was established to provide the range of parameters to be investigated. Boeing Aircraft (Seattle and Wichita) has provided photographs and unclassified data regarding cockpit air distribution including location of outlets, size and quantity of air flow. Cessna Aircraft (Wichita) has provided similar data and has supplied a cabin mock-up (Cessna 320) for the proposed experiments. Vought Aeronautics has provided information relative to the Logistic Shelter Air Transportable (LSAT) program. This latter program is a good example of a high heat load - confined space. Ventilation rates are specified and arrangements for heating and/or cooling must be adapted to two-2'x2' panels indicating a minimal air distribution system.

Model studies have been initiated to formulate general principles for distribution systems. Motion pictures of smoke introduced into the models will provide qualitative data. This procedure was developed previously at Kansas State (see reference 1).

Instrumentation will be delivered in August for full scale mock-up studies. Air velocities and temperatures will be obtained in confined spaces utilizing various air distributing systems.

Report No. 5 of the Optimization group headed by Dr. L. T. Fan, is a study related to this project (see Dr. Fan's report). This formulation of an air flow model will be tested experimentally and used to determine the effectiveness of a system in ventilating a confined space.

REFERENCES

1. Comfortable, Uniform Environment, R. G. Nevins, ASHRAE Journal, July, 1961.

2. Advanced Laminar Flow Techniques and Model Studies, M. Meckler, Trans. ASHRAE, Vol. 72, Part I, 1966.

3. Room Air Distribution with an Air Distributing Ceiling, R. G. Nevins and E. D. Ward, Trans. ASHRAE, Vol. 74, Part I, 1968.

Summary of Accomplishments, September 18, 1967 through June 1, 1968

1. M.S. thesis in Electrical Engineering. Mr. Dale Benthrup developed a program for analog to digital conversion of experimental data by the Athena computer. The resulting tape is processed directly by the 360/50 for data analysis. This procedure reduces the data processing time by several fold.

2. Four reports listed below, written by Themis team members and published internally by the Systems Institute. Reports 1 and 2 deal with problems encountered in the formulation of mathematical models. Reports 3 and 5 deal with simulation of environmental parameters. Report No. 3 is concerned with the thermal comfort equation. Report No. 5 with air flow in confined space.

Report No. 1. Estimation of Parameters in Differential Equations from Experimental Data by E. Stanley Lee

A method of determining coefficients for mathematical equations from experimental measurements by isolating meaningful data from randomly appearing information; for example, recognition of intelligible signals through static or interference.

Report No. 2. The Estimation of Variable Parameters in Differential Equations by Quasilinearization by E. Stanley Lee

Report 2 is an extension of Report 1 to describe variable coefficients (parameters varying with time, embedded in randomly appearing information).

<u>Report No. 3</u>. Simulation and Feasibility Study of a Thermal Comfort Equation by E. S. Lee, L. T. Fan, C. L. Hwang and M. A. Shikh

Application of systems techniques to the analysis of the "comfort" equation and its use for optimization of life supports systems.

<u>Report No. 5</u>. Air Flow Models in a Confined Space, A Study in Age Distribution by Michael S. K. Chen, L. T. Fan, C. L. Hwang and E. S. Lee

Method for determining the time required to ventilate a confined space such as tank, light aircraft or helicopter cabins and to optimize the system.

3. Organization of a symposium on circadian rhythms on non-human primates by Dr. Rohles for the Second International Congress of Primatology.

4. Studies on circadian feeding rhythms indicate that feeding rhythms can be entrained by social variables and are independent of the classical exogenous variables of light-dark and temperature; electrolyte excretion in the urine can also be entrained by social factors.

5. Have demonstrated that the water-cooled hood appears to be effective in reducing physiological strain during exposure to high temperatures.

6. Ph.D. thesis in Psychology. Mr. George Masters showed that perceptual-motor performance is facilitated following brief exposures to high thermal stress, but is unaffected when the exposure time is lengthened.

7. Development of a versatile, electronic tracking apparatus used for measuring human performance (response organization, perception and judgment, attention and information processing).

8. Development of apparatus for low velocity air dsitribution data for confined spaces and a procedure for determining the ad quacy of ventilation (see Report 5).

Conclusion

The Project Themis contract has strengthened and expanded the Environmental Research and Training program at Kansas State University. Even though all first year objectives were not achieved, progress is evident and significant. Existing interdisciplinary relationships have been continued and new ones established providing an integrated approach to environmental and life support problems.

The project team attempted to maintain communication with appropriate DOD laboratories but no team members were asked to visit these facilities. Off-campus representatives participated in the formal themis review as mentioned in the introduction. Communication was also established with other off-campus investigators (listed below).

University of Utah, Architectural Psychology - Calvin W. Taylor
Indiana University, Anatomy and Physiology - Robert W. Bullard
Union Carbide Corp., Biological Research - H. R. Schreiner

UNCLASSIFIED
Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author)
Kansas State University
Manhattan, Kansas 66502

2a. REPORT SECURITY CLASSIFICATION
UNCLASSIFIED

2b. GROUP

3. REPORT TITLE
PERFORMANCE AND LIFE SUPPORT IN ALTERED ENVIRONMENTS

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)
Scientific Interim

5. AUTHOR(S) (First name, middle initial, last name)
Ralph G. Nevins

6. REPORT DATE
1 August 1968

7a. TOTAL NO. OF PAGES
68

7b. NO. OF REFS
19

8a. CONTRACT OR GRANT NO. F44620-68-C-0020

b. PROJECT NO. 7921-08

c. 6144501F

d. 681313

9a. ORIGINATOR'S REPORT NUMBER(S)

9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)
AFOSR 68-2096

10. DISTRIBUTION STATEMENT
1. This document has been approved for public release and sale; its distribution is unlimited.

11. SUPPLEMENTARY NOTES
TECH, OTHER

12. SPONSORING MILITARY ACTIVITY
Air Force Office of Scientific Research
1400 Wilson Boulevard (SRLB)
Arlington, Virginia 22209

13. ABSTRACT

THREE MOST SIGNIFICANT SCIENTIFIC OR TECHNOLOGICAL ACCOMPLISHMENTS ARE AS FOLLOWS:

a) Systems Analysis of Optimization of Life-supported Systems
Contributions to the basic theories and procedures for systems analysis and optimization have been significant. The formulation of mathematical models and determination of coefficients from experimental data are primary steps in any analysis. Two new techniques for identification of parameters have been developed for this project, but these methods have general application.

b) Biological Rhythms
A significant portion of the research is devoted to studies of rhythmicity. Initial experiments have shown that feeding rhythms can be entrained by social variables and are independent of the classical exogenous variables of light-dark and temperature; electrolyte excretion in the urine can also be entrained by social factors.

c) Cooling Hood for Hot-Humid Environment
A water-cooled headdress has been tested under several hot-humid conditions with college-age subjects, involving physical and mental work. The physiological stress was less than that indicated when no hood was worn. This work will enable men to work productively in certain hot-humid situations.

DD FORM 1473

UNCLASSIFIED
Security Classification

UNCLASSIFIED

Security Classification

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Systems Analysis of Optimization						
Life-supported Systems						
Biological Rhythms						
Cooling Hood						
Hot-Humid Environment						
Water-cooled headdress						
Physical and Mental work						

UNCLASSIFIED