

AD-A119 136

KANSAS STATE UNIV MANHATTAN INST FOR ENVIRONMENTAL R--ETC F/G 6/19  
DECISION MAKING UNDER HIGH THERMAL STRESS. REPORT NUMBER 1. AN --ETC(U)  
AUG 82 F H ROHLES, S A KONZ, R J KROHN EMW-C-0589

UNCLASSIFIED

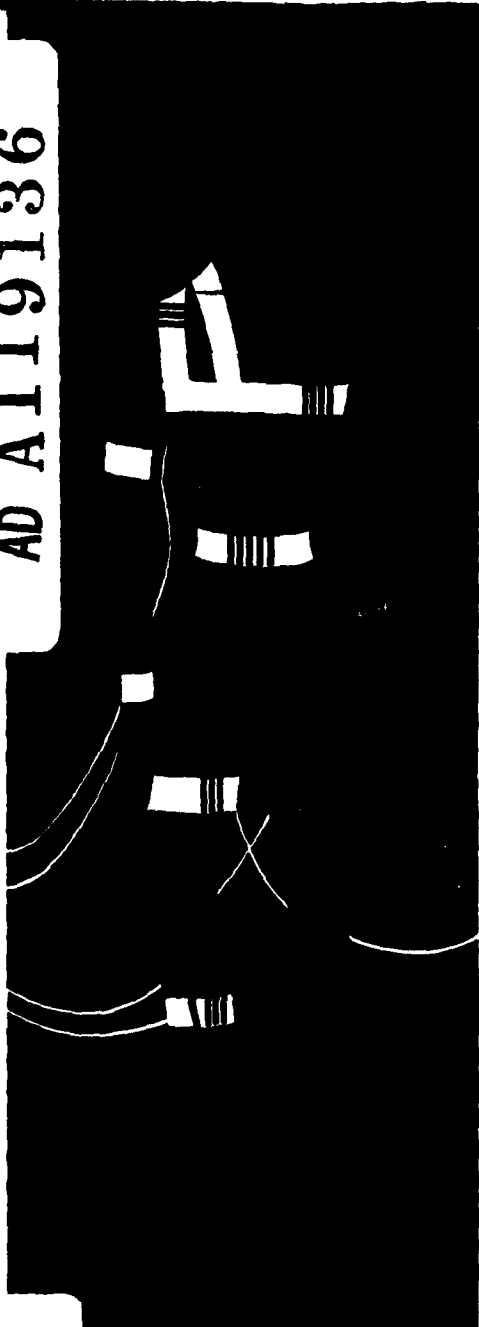
NL

1-1  
2-1  
3-1  
4-1  
5-1  
6-1  
7-1  
8-1  
9-1  
10-1  
11-1  
12-1  
13-1  
14-1  
15-1  
16-1  
17-1  
18-1  
19-1  
20-1  
21-1  
22-1  
23-1  
24-1  
25-1  
26-1  
27-1  
28-1  
29-1  
30-1  
31-1  
32-1  
33-1  
34-1  
35-1  
36-1  
37-1  
38-1  
39-1  
40-1  
41-1  
42-1  
43-1  
44-1  
45-1  
46-1  
47-1  
48-1  
49-1  
50-1  
51-1  
52-1  
53-1  
54-1  
55-1  
56-1  
57-1  
58-1  
59-1  
60-1  
61-1  
62-1  
63-1  
64-1  
65-1  
66-1  
67-1  
68-1  
69-1  
70-1  
71-1  
72-1  
73-1  
74-1  
75-1  
76-1  
77-1  
78-1  
79-1  
80-1  
81-1  
82-1  
83-1  
84-1  
85-1  
86-1  
87-1  
88-1  
89-1  
90-1  
91-1  
92-1  
93-1  
94-1  
95-1  
96-1  
97-1  
98-1  
99-1  
100-1

END  
DATE  
FILMED  
10-82  
DTIC

2

AD A119136



DTIC FILE COPY

Institute for  
Environmental  
Research  
Kansas State  
University  
Manhattan,  
Kansas

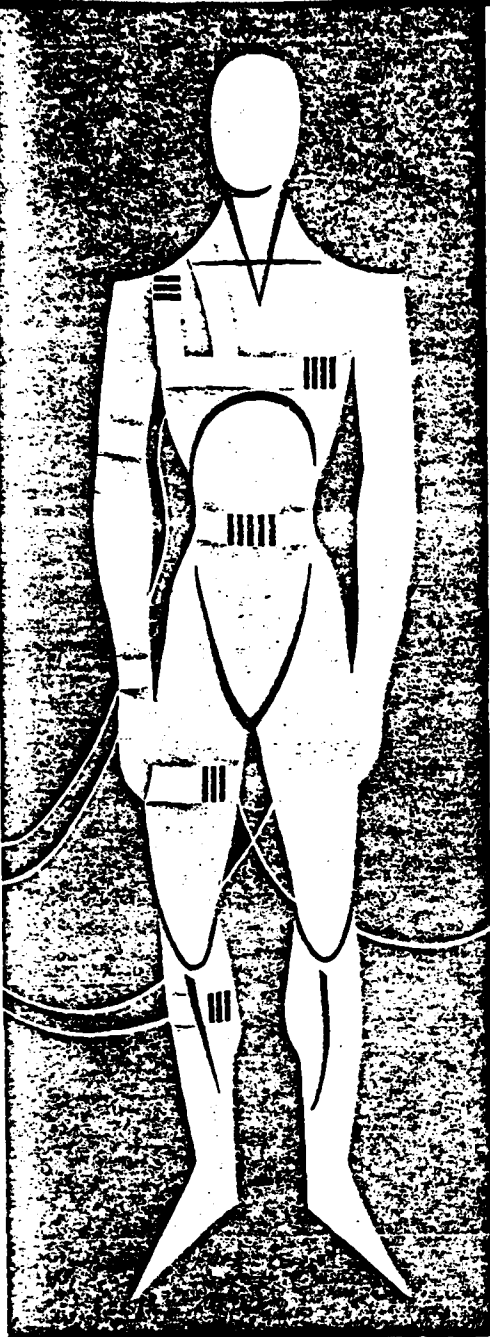
DISTRIBUTION STATEMENT A

Approved for public release;  
Distribution Unlimited

82 09 10 102



DTIC  
ELECTE  
SEP 13 1982  
S D D



# **DECISION MAKING UNDER HIGH THERMAL STRESS**

**Report No. 1 An Annotated Bibliography  
on Environmental Stressors and Behavior**

**Prepared for  
Federal Emergency Management Agency  
National Preparedness Programs Directorate  
Washington, D.C. 20472**

**Contract EMW-C-0589  
FEMA Work Unit No. 1131 B**

**August, 1982**

**Distribution of this report is unlimited.**

**Institute for  
Environmental  
Research  
Kansas State  
University  
Manhattan,  
Kansas**

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

| REPORT DOCUMENTATION PAGE                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                     | READ INSTRUCTIONS<br>BEFORE COMPLETING FORM                                      |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------|----------------------------------------------------------------------------------|
| 1. REPORT NUMBER<br>1                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | 2. GOVT ACCESSION NO.<br>AD-A119136 | 3. RECIPIENT'S CATALOG NUMBER                                                    |
| 4. TITLE (and Subtitle)<br>DECISION MAKING UNDER HIGH THERMAL STRESS. -<br>Report No. 1. An Annotated Bibliography on Environmental Stressors and Behavior                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                     | 5. TYPE OF REPORT & PERIOD COVERED<br>Report, No. 1, -<br>Sept. 1981 - Aug. 1982 |
| 7. AUTHOR(s)<br>Frederick H. Rohles, Jr.<br>Stephan A. Konz<br>Rachel J. Krohn                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                     | 6. PERFORMING ORG. REPORT NUMBER                                                 |
| 9. PERFORMING ORGANIZATION NAME AND ADDRESS<br>Institute for Environmental Research<br>Kansas State University<br>Manhattan, KS 66506                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                     | 8. CONTRACT OR GRANT NUMBER(s)<br>EMW-C-0589                                     |
| 11. CONTROLLING OFFICE NAME AND ADDRESS<br>Federal Emergency Management Agency<br>National Preparedness Programs Directorate                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                     | 10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS<br>Work Unit 1131 B  |
| 14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)<br>Federal Emergency Management Agency<br>National Preparedness Programs Directorate                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                     | 12. REPORT DATE<br>August 1982                                                   |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                     | 13. NUMBER OF PAGES<br>58                                                        |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                     | 15. SECURITY CLASS. (of this report)<br>Unclassified                             |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                     | 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE                                       |
| 16. DISTRIBUTION STATEMENT (of this Report)<br><br>Distribution of this report is unlimited.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                     |                                                                                  |
| 17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                     |                                                                                  |
| 18. SUPPLEMENTARY NOTES                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                     |                                                                                  |
| 19. KEY WORDS (Continue on reverse side if necessary and identify by block number)<br>Decision making; environmental stress; temperature; occupant density; lighting, sleep disturbances; human factors.                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                     |                                                                                  |
| 20. ABSTRACT (Continue on reverse side if necessary and identify by block number)<br>/ This research will study the effects of exposure to the stressors of a simulated survival shelter on decision making. A proposed 5 year effort is summarized that involves a literature search, the development of a test battery to assess the decision making skill, tests in simulated shelters, and the development of strategies to assist in the decision making process. Corollary efforts involve the use of the bicycle ventilating device for charging nickel-cadmium dry cell batteries and relationship between shelter occupant density |                                     |                                                                                  |

DD FORM 1 JAN 73

1473

EDITION OF 1 NOV 65 IS OBSOLETE

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE(When Data Entered)

20.

and shelter occupant numbers. This, the first report of the project, contains an annotated bibliography of the research on the effects upon behavior, of the stressors of temperature, crowding, sleep disturbances, panic, stress, and anxiety. In several searches of the literature a total of 900 articles were identified; from these 113 were selected as being critical to understanding the human response in the survival shelter environment. These together with 36 studies on fallout shelters are reviewed.

In addition, a survey was conducted which identified 93 problem areas for the survival shelter occupant. These fell equally into three main categories: survival shelter, personal, and environment.

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE(When Data Entered)

|                    |                                            |
|--------------------|--------------------------------------------|
| Accession For      |                                            |
| NTIS GRA&I         | <input checked="checked" type="checkbox"/> |
| DTIC TAB           | <input type="checkbox"/>                   |
| Unannounced        | <input type="checkbox"/>                   |
| Justification      |                                            |
| By                 |                                            |
| Distribution/      |                                            |
| Availability Codes |                                            |
| Dist               | Avail and/or<br>Special                    |
| A                  |                                            |

DECISION MAKING UNDER HIGH  
THERMAL STRESS

Report No. 1 An Annotated Bibliography  
on Environmental Stressors and Behavior



Prepared by

Frederick H. Rohles, Jr.  
Stephan A. Konz  
Rachel J. Krohn  
Institute for Environmental Research  
Kansas State University  
Manhattan, Kansas 66506

Prepared for

Federal Emergency Management Agency  
National Preparedness Programs Directorate  
Washington, D.C. 20472  
under  
Contract EMW-C-0589  
FEMA Work Unit No. 1131 B

August, 1982

REVIEW NOTICE: This report has been reviewed in the Federal Emergency Management Agency and approved for publication. Approval does not signify that the contents necessarily reflect the views and policies of the Federal Emergency Management Agency.

Distribution of this report is unlimited.

ABSTRACT

The occupants of the survival shelter will experience several stressors not found in conventional living environments. This report contains an annotated bibliography of the research on the effects upon behavior of the stressors of temperature, crowding, sleep disturbances, panic, stress, and anxiety. In several searches of the literature a total of 900 articles were identified; from these 113 were selected as being critical to understanding the human response in the survival shelter environment. These together with 36 studies on fallout shelters are reviewed.

In addition, a survey was conducted which identified 93 problem areas for the survival shelter occupant. These fell equally into three main categories: survival shelter, personal, and environment.

## TABLE OF CONTENTS

| <u>Section</u>                                                           | <u>Page</u> |
|--------------------------------------------------------------------------|-------------|
| ABSTRACT                                                                 | 11          |
| I. INTRODUCTION                                                          |             |
| Background and Approach                                                  | iv          |
| Literature Survey                                                        | vii         |
| II. Review of the Shelter Studies                                        | 1           |
| III. Review of the Stressors                                             | 14          |
| IV. Critical Human Factors Problems for the<br>Survival Shelter Occupant | 52          |

## Section I

## INTRODUCTION

Background and Approach

With the increased concern over nuclear warfare, a renewed effort is being directed towards the study of behavior in the survival shelter environment. One of these behaviors involves decision making. In October 1981, The Institute for Environmental Research at Kansas State University entered into a proposed 5 year effort with the Federal Emergency Management Agency; the title of the contract was "Decision Making Under High Thermal Stress." The work on this effort is planned to progress through several stages. In the first stage, a search was made of the relevant literature. The second stage involved the development of tasks that measured the decision making process. This is to be followed by tests in simulated survival shelter environments. Finally, strategies will be developed to assist in decision making when this behavior suffered a decrement in accuracy and speed. These strategies then will be incorporated into a manual. Subsequently, the effectiveness of decision-making training will be determined.

At the outset, the initial planning conference on the study emphasized the fact that the thermal constituent of the environment did not represent the survival shelter in its entirety. As a result we expanded our goal to include the stressors of temperature, crowding, air quality, food and water restriction, reduced illumination, and electrical power and sleep disturbances; in particular, the effects of these stressors will be intensified when the occupants are under severe emotional stress. Other human factors problems which were identified involved the selection and training of shelter leaders, the quality of the leadership itself, work schedules and

procedures, the allocation of resources, the monitoring of conditions outside the shelter environment, safety and health, equipment maintenance, problems of communication, shelter management and decision making. This report represents the results of the literature search.

### Decision Making

To handle the decision making aspects, four experts in the field served as either co-investigators or consultants. They were Dr. Kenneth Hammond, University of Colorado; Dr. Leon Rappoport, KSU; Dr. James Shanteau, KSU; and Dr. Paul Slovic, Decision Research - Eugene, Oregon. In the main, they identified 16 components of the decision making task. They were:

1. Basic Cognitive Tasks
  - a. Reaction Time (1)
  - b. Signal Detection (2)
  - c. Memory
    1. Short-term Memory: Digit Span (3)
    2. Long-term Memory: Recognition Task (4)
2. Learning (5)
3. Language Processes (Reading Task) (6)
4. Problem Solving (7)
5. Judgment and Decision Making
  - a. Information Acquisition
    1. Internal Search (8)
    2. External Search (9)
  - b. Diagnosis
    1. Multiple-Cue Probability Task (10)
    2. Probability Estimation and Evaluation (11)
  - c. Probability Estimation and Evaluation
    1. Estimation (12)
    2. Calibration (13)
  - d. Risk Preference and Evaluation (14)
  - e. Cue Utilization (15)
  - f. Choice Elicitation (16)

Since there is no single instrument to measure decision making skills, tasks to measure these 16 components have either been identified or are being developed. When this is completed, the components will be combined into a single test battery. Appropriate statistical procedures, sub-test

intercorrelations, measures of internal consistency, validity and reliability coefficients and partial regression coefficients will be computed for the battery. When this is completed, it will be used in the survival shelter simulation phase. This will be completed by the end of the second year of the project.

#### Corollary Efforts

The Personal Ventilating Kit (PVK) consists of a bicycle-type device which when pedaled by an individual may be used to ventilate a survival shelter. The PVK was developed before the commercial development of the nickel-cadmium re-chargeable dry cell battery which is so common-place today. As a result, we are developing a device which can be incorporated into the PVK unit that will charge nickel-cadmium batteries at the same time as the shelter is being ventilated.

A second corollary program is also planned. At present, 10 square feet per person is being allotted to each shelter occupant. This area is fixed, regardless of the number of occupants involved. Current research, however, has addressed the question of subject density (number of individuals per unit of space) as opposed to social density (the number of people in the group in question). In terms of the survival shelter the question that is generated is "does 10 sq. ft. per person for 20 people represent the same amount of crowding as 10 sq. ft. per person when 200 people are involved?" Beyond the intuitive "no" answer to this question, other problems may surface. These involve performance, group pressures, leadership and attitude. In the corollary effort, social density and spatial density will be addressed as stressors that may affect decision making.

### Literature Survey

This report presents the results of the literature search; its purpose was to determine the current state of the art concerning the human factors aspects of the survival shelter. This report consists of condensation of the relevant research on this problem. Initially, previous shelter studies were reviewed. Then the literature on the stressors in non-shelter environments was reviewed.

### Review of the Shelter Studies

Thirty-six studies concerning fallout shelters were reviewed. The categories and the number of references per category are as follows:

- Shelter environmental studies (11)
- Subsistence and habitability studies (3)
- Prototype design for shelter life support systems (2)
- Shelter management studies (19)
- Shelter systems studies (1)

Section II summarizes the studies in which shelters were inhabited.

### Review of the Stressors

Four literature searches were made to identify journal articles on the stressors. They are summarized as follows: On 28 October 1981, a search of Psychological Abstracts and Social Science Abstracts identified 265 articles pertaining to both decision making and one of the stressors (heat, sleep disturbances, crowding, panic, stress, and anxiety). On 9 December 1981, a search of Psychological Abstracts identified only 3 articles pertaining to at least 2 of the 3 main stressors (crowding, heat effects, and sleep disturbances). On 23 December 1981, a search of Psychological Abstracts identified 419 articles pertaining to crowding. On 30 April 1982, a search of Psychological Abstracts identified 17

articles pertaining to illumination. From other sources, approximately 200 additional articles were identified.

From the above 900 articles, 113 articles were reviewed in detail. The categories and the number of references per category in the file are as follows:

|                          |                              |
|--------------------------|------------------------------|
| Crises (2)               | Realm of control (3)         |
| Crowding (22)            | Fear (3)                     |
| Crowding/confinement (3) | Interpersonal relations (16) |
| Fallout shelters (5)     | Panic (2)                    |
| Heat effects (24)        | Physiological responses (3)  |
| Illumination (1)         | Personal differences (1)     |
| Nuclear War scenario (3) | Sex differences (8)          |
| Sleep disturbances (12)  | Stress (9)                   |
| Aggression (19)          | Task performance (18)        |
| Anxiety (7)              | Decision making (17)         |
|                          | Leadership (8)               |

Most of these articles are summarized in the annotated bibliography contained in Section III.

Finally, a survey was conducted for the purpose of identifying the human factors problems that are critical to the survival shelter occupant. A total of 93 items were identified and rated according to importance. This report is in Section IV.

SECTION II

Review of the Shelter Studies

| Study By         | Place                                                    | Date                                     | N   | Sex | Space/Person |         | Defections | of      |                                           | Ventilation       | Water/<br>Person/<br>Day Consumed | Light | Shelter Management |
|------------------|----------------------------------------------------------|------------------------------------------|-----|-----|--------------|---------|------------|---------|-------------------------------------------|-------------------|-----------------------------------|-------|--------------------|
|                  |                                                          |                                          |     |     | Sq. Ft.      | Cu. Ft. |            | Sq. Ft. | Temperature                               |                   |                                   |       |                    |
| McLukwell, R. H. | U.S. Naval Radiological Defense Laboratory San Francisco | Dec. 3, 1959 to Dec. 17, 1959<br>14 days | 100 | ?   | 12           | ?       | ?          | ?       | Comfortable for entire study<br>74°-84° F | 16 Cfm per person | ?                                 | ?     | ?                  |

**Aim:**

To determine adequacy of a 100 man shelter design.

**Findings:**

1. Average heat output/person 485 BTU/hr per man.
2. 16 Cfm per person adequate ventilation.
3. Ventilation removed 69% of heat.

SUMMARY OF THE STUDIES AT THE UNIVERSITY OF GEORGIA (1962-1965)

A) Shelteree Characteristics:

- 1) Successful methods of publicity and recruitment included news releases, talks to civic groups, newspaper advertisements, and previous shelter occupants.
- 2) Approximately half of the total shelteree population professed knowledge of the location of a community fallout shelter.

B) Shelter Management:

- 1) CDR trained managers furnished the basis for the compilation of a handbook.
- 2) A temporary and permanent staff organization format was found functional.
- 3) A research prototype handbook was tested and found feasible for untrained management.
- 4) The closer the handbook instructions were followed, the more successful the management was.

C) Shadow Staff Procedure:

This procedure should be continued. Valuable information was obtained from this method.

D) Medical Aspects:

- 1) OCD medical kits appeared to be adequate.
- 2) Several other medical supplies were suggested.

E) Nutrition:

Bulgur wafer or cereal food products appeared to be adequate.

F) Sleep:

- 1) Shift sleeping was not effective.
- 2) Bunks were necessary.

G) Recreational and Religious Activities:

- 1) These were found to be very helpful.
- 2) About half of the shelteree time was spent in a lying position.

H) Daily Schedule:

- 1) The different observation techniques were: a) shadow observer, b) daily logs, c) T.V. camera, and d) observation posts.
- 2) It was found that each shelteree should be assigned to some activity.

I) Shelteree Testing:

It was found that healthy men and women could endure two weeks of the isolated, austere environment of a simulated shelter.

| Study By                                                                    | Place                                   | Date                  | N  | Sex                      | Defections | Space/Person |         | Ventilation | Water/Person/Day Consumed  |            | Shelter Management                          |            |
|-----------------------------------------------------------------------------|-----------------------------------------|-----------------------|----|--------------------------|------------|--------------|---------|-------------|----------------------------|------------|---------------------------------------------|------------|
|                                                                             |                                         |                       |    |                          |            | Sq. Ft.      | Cu. Ft. |             | Temp                       | Person/Day | Light                                       | Management |
| Hale, John P.<br>Meagley, Donald E.<br>Smith, Robert W.<br>Davis, Robert L. | American<br>Institute<br>of<br>Research | 30-31<br>July<br>1965 | 28 | 19 of<br>family<br>units | ?          | 10           | ?       | 68-72       | Through air<br>conditioner | ?          | 600W Total,<br>5 incan-<br>descent<br>lamps | Assigned   |
|                                                                             | American<br>Institute<br>of<br>Research | 6-7<br>Aug.<br>1965   | 27 | 16 of<br>family<br>units | ?          | 10           | ?       | 68-72       | Through air<br>conditioner | ?          | 600W Total<br>5 incan-<br>descent<br>lamps  | Emerg      |
|                                                                             | American<br>Institute<br>of<br>Research | 13-14<br>Aug.<br>1965 | 28 | 17 of<br>family<br>units | ?          | 10           | ?       | 68-72       | Through air<br>conditioner | ?          | 600W Total<br>5 incan-<br>descent<br>lamps  | Assigned   |
|                                                                             | American<br>Institute<br>of<br>Research | 20-21<br>Aug.<br>1965 | 28 | 14 of<br>family<br>units | ?          | 10           | ?       | 68-72       | Through air<br>conditioner | ?          | 600W Total<br>5 incan-<br>descent<br>lamps  | Emerg      |

#### Study Characteristics

##### Approach:

- Shelterees underwent programmed emergencies.
- late arrivals
- looter threat
- dust storm
- power failure
- fire threat

##### Study Purpose:

- Determination of shelteree response to simulated environment.
- Identification of aspects for realistic behavior of shelterees.
- Identification of behavior patterns.

##### Findings:

- A symbol of authority for assigned manager is needed.
- Technically competent, authoritarian style of management good.
- Public education desirable.
- Continuous EBS broadcasting.

| Study By                                                               | Place                                          | Date                                           | N                               | Sex | Space/Person |         | Ventilation                                                                       | Water/<br>Person/<br>Day | Consumed Light | Shelter Management |
|------------------------------------------------------------------------|------------------------------------------------|------------------------------------------------|---------------------------------|-----|--------------|---------|-----------------------------------------------------------------------------------|--------------------------|----------------|--------------------|
|                                                                        |                                                |                                                |                                 |     | Sq. Ft.      | Cu. Ft. |                                                                                   |                          |                |                    |
| Rohles, Frederick<br>M. Jr.<br>Nevins, Ralph. C.<br>McNall, Preston E. | Institute<br>of Environ-<br>mental<br>Research | Feb.<br>1966<br>Exact<br>dates<br>not<br>known | 8<br>Divided<br>into 2<br>teams | ?   | ?            | ?       | Subjects<br>exposed to<br>80 to 100 F<br>in the in-<br>crements of<br>5 degrees F | ?                        | ?              | ?                  |

**Aim:**  
Physiological responses to operating  
OCD ventilation units in the shelter  
environment.

**Experimental design:**

Subjects were exposed to DBT's ranging from 80 to 100 degrees F in the increments of 5 degrees at R.H. of 80%. Exposure of subjects was for a period of a maximum of 8 hours. Subjects worked 15 min. and rested 15 min. Levels which were studied for power; 0.05 hp/person, 0.1 hp/person, 2. 0.15 hp/person.

**Conclusions:**

1. Lower limits of stress zones are found as follows:  
100 F DBT at 0.05 hp/person  
95 F for 0.1 hp/person  
95 F for 0.15 hp/person  
Also thermal environments were established which caused no significant amount of thermal stress within eight hours of exposure on healthy persons. The limits were found to be 90, 85, 80 F.
2. The environmental conditions mentioned above established transition zones. Individual differences among subjects caused width of the transition zone to be 9 F ET for low and medium levels of activity, 13 F ET at high levels of activity.

| Study By                                        | Place                                                                            | Date                                                                          | N | Sex | Defections | Space/Person    |                                                                                                                                                                       | Ventilation | Day Consumed | Light | Shelter Management |
|-------------------------------------------------|----------------------------------------------------------------------------------|-------------------------------------------------------------------------------|---|-----|------------|-----------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------|--------------|-------|--------------------|
|                                                 |                                                                                  |                                                                               |   |     |            | Sq. Ft. Cu. Ft. | of Temperature                                                                                                                                                        |             |              |       |                    |
| Mohles, Frederick<br>H. Jr.<br>Navina, Ralph G. | Institute<br>of Environ-<br>mental<br>Research,<br>Kansas<br>State<br>University | March<br>1966<br>Dura-<br>tion-<br>30 min.<br>Exact<br>dates<br>not<br>known. | 8 | ?   | ?          | ?               | Subjects<br>were exposed<br>to different<br>temperature<br>conditions<br>at 95, 98,<br>100, 105,<br>110, 120<br>degree F<br>(dbt) at<br>60%, 70%,<br>80%, 90%<br>R.H. | ?           | ?            | ?     | ?                  |

#### Aim:

To study the effect of high thermal stress on the latency of rectal temperature response.

#### Experimental design:

Eight subjects were exposed to 24 thermal conditions. Duration of the exposure was determined by the length of time required for the rectal temperature to increase 2 degrees F.

#### Conclusions:

1. The criterion of 2°F rise in rectal temperature is a stable index for thermal stress.
2. The higher the effective temperature the shorter the latency of the rectal temperature.
3. Below 91.3 F none of the subjects exhibited a 2 F rise in the rectal temperature, but all of them reached the criterion at 97 F.
4. There was a transition range where some subjects reached the criterion, some did not.

| Study By                                        | Place                                                                            | Date                                             | N  | Sex | Space/Person |         |         | Or                                                                                |             |     | Water/<br>Person/<br>Day Consumed | Light | Shelter Management |
|-------------------------------------------------|----------------------------------------------------------------------------------|--------------------------------------------------|----|-----|--------------|---------|---------|-----------------------------------------------------------------------------------|-------------|-----|-----------------------------------|-------|--------------------|
|                                                 |                                                                                  |                                                  |    |     | Defections   | Sq. Ft. | Cu. Ft. | Temperature                                                                       | Ventilation | Day |                                   |       |                    |
| Ruhles, Frederick<br>H. Jr.<br>Mevius, Ralph G. | Institute<br>of Ecophysio-<br>logical Research,<br>Kansas<br>State<br>University | March<br>1966<br>Exact<br>dates<br>not<br>known. | 8  | ?   | ?            | ?       | ?       | Subjects<br>were<br>exposed<br>to 95,<br>98, 100,<br>105 F<br>(dbt) &<br>80% R.H. | ?           | ?   | ?                                 | ?     | ?                  |
|                                                 |                                                                                  |                                                  | 18 | ?   | ?            | ?       | ?       | Subjects<br>were<br>exposed<br>to 95,<br>98 F for<br>8 hours.                     | ?           | ?   | ?                                 | ?     | ?                  |
|                                                 |                                                                                  |                                                  | 32 | ?   | ?            | ?       | ?       | Subjects<br>were<br>exposed<br>to 95,<br>98 F for<br>8 hours.                     | ?           | ?   | ?                                 | ?     | ?                  |

**Aim:**  
Physiological aspects of crowding  
during exposure to high thermal  
stress.

**Experimental design:**  
Subjects were studied at 95, 98, 100, 105 F  
(dbt) at 80% R.H. for 4 hours in one design.  
  
In second design, subjects were studied at  
95, 98 F and 60%, 70%, 80%, 90% R.H. for 8  
hours.

Three packing conditions were studied.  
1. 8 subjects were studied in the KSU-ASHRAE  
chamber, resulting in 36 sq. ft./person.  
2. 18 subjects were studied in the same  
chamber resulting in 16 sq. ft./person.  
3. 32 subjects were studied in the same  
chamber resulting in 9 sq. ft./person.

**Conclusions:**  
Results did not support the hypothesis that  
under crowded conditions the body temper-  
ature will rise faster than under less  
crowded conditions. It was concluded that  
if crowding has an effect, it is no. a  
physiological one.

| Study By                                                                    | Place                                                                                              | Date                                                                   | N | Sex                  | Defections | Space/Person |                            | Water/<br>Person/<br>Day | Shelter Management       |                                                                        |
|-----------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------|------------------------------------------------------------------------|---|----------------------|------------|--------------|----------------------------|--------------------------|--------------------------|------------------------------------------------------------------------|
|                                                                             |                                                                                                    |                                                                        |   |                      |            | Sq. Ft.      | Cu. Ft.                    |                          | Ventilation              | Light                                                                  |
| Male, John F.<br>Meagley, Donald E.<br>Smith, Robert W.<br>Davis, Robert L. | American<br>Institute<br>of<br>Research,<br>shelter<br>was in a<br>small<br>shell<br>in a<br>lake. | Sept.<br>1966<br>Exact<br>date<br>is not<br>known,<br>24 hr.<br>study. | 6 | 4 males<br>2 females | ?          | 25           | Shelter<br>Height<br>4 ft. | ?                        | Provided<br>from ground. | 1 single<br>75 W bulb                                                  |
|                                                                             |                                                                                                    |                                                                        |   |                      |            |              |                            |                          |                          | Well trained test<br>director himself<br>acted as shelter<br>director. |

#### Study Characteristics

##### Aim:

Study feasibility of using a laboratory  
simulating stress and threat.

##### Approach:

A lab submerged at a depth of 20 feet  
within a lake. Subjects had scuba  
training.

##### Findings:

1. Technologically feasible to involve a  
real threat element.
2. Threat element was moderately anxiety  
producing.
3. Subjects showed marked attentiveness  
to atmosphere monitoring.
4. Responsible shelter manager very stressed  
during occupancy of shelter.

1  
CO  
1

| Study By               | Place                              | Date                        | N   | Sex | Defections | Space/Person |         | Temp. °F. | Ventilation                        | Water/Person/Day Consumed |            | Light | Shelter Management           |
|------------------------|------------------------------------|-----------------------------|-----|-----|------------|--------------|---------|-----------|------------------------------------|---------------------------|------------|-------|------------------------------|
|                        |                                    |                             |     |     |            | Sq. Ft.      | Cu. Ft. |           |                                    | quarts/day                | Person/Day |       |                              |
| Weiss, M. A.<br>Bogdan | General American Research Division | Feb. 1967<br>8 day exercise | 38  | 7   | 1          | 10.5         | ?       | 78°-86° F | Aim: To study effectiveness of PVK | 2.1 to 2.5                | ?          | ?     | Well trained shelter manager |
|                        | General American Research Division | Feb. 1967<br>12 hours       | 100 | 7   | ?          | 9.5          | ?       | 78°-86° F | Aim: To study effectiveness of PVK | 2.1 to 2.5                | ?          | ?     | Trained shelter manager      |
|                        | General American Research Division | Feb. 1967<br>2 days         | 402 | 7   | 215        | 8            | ?       | 78°-86° F | Aim: To study effectiveness of PVK | 2.1 to 2.5                | ?          | ?     | Untrained shelter manager    |

**Aim:**

To evaluate ability of shelters to use:

1. PVK (Pedal Vehicle Kit)
2. Effective Temperature Meters
3. A gas detector
4. A water dispenser

**Findings:**

1. Shelterees can assemble PVK correctly, but cannot deploy it correctly.
2. They should be provided floor plan.
3. Water dispenser and toxic gas detector proved awkward.
4. Effective Temperature meter read with error.

| Study By                                                              | Place                                                                            | Date         | N                                           | Sex  | Defections | Space/Person |         |           | Water/<br>Person/<br>Day | Consumed Light | Shelter Management |
|-----------------------------------------------------------------------|----------------------------------------------------------------------------------|--------------|---------------------------------------------|------|------------|--------------|---------|-----------|--------------------------|----------------|--------------------|
|                                                                       |                                                                                  |              |                                             |      |            | Sq. Ft.      | Cu. Ft. | Temp. °F. |                          |                |                    |
| Bahles, Frederick<br>H. Jr.<br>Nevins, Ralph G.<br>McNail, Preston E. | Institute<br>of Environ-<br>mental<br>Research,<br>Kansas<br>State<br>University | Feb.<br>1967 | Three<br>groups<br>of 8<br>male<br>subjects | Male | ?          | ?            | ?       | ?         | ?                        | ?              | ?                  |

**Aim:**

Water consumption and preference during exposure to shelter environments. Acceptability of stored water (one year) and fresh water.

**Experimental design:**

Three groups of eight male subjects were subjected to 82, 85, 88 degree F, twice. Six 24 hour tests were conducted.

**Conclusions:**

1. Mean water intake is independent of the type of water.
2. Mean water intake increased with increase in ET.
3. Mean water intake was greater for all ET's than OCD specified allotment of one quart per man per day.

| Study By           | Place                                                                                          | Date                                | N  | Sex | Defections | Space/Person |         | Ventilation | Person/<br>Day Consumed                            | Light | Shelter Management                                                            |
|--------------------|------------------------------------------------------------------------------------------------|-------------------------------------|----|-----|------------|--------------|---------|-------------|----------------------------------------------------|-------|-------------------------------------------------------------------------------|
|                    |                                                                                                |                                     |    |     |            | Sq. Ft.      | Cu. Ft. |             |                                                    |       |                                                                               |
| Neagley, Donald E. | American Institute of Research, Batty; Friday noon. Exit: Saturday afternoon. In basement lab. | Aug. 1969<br>Exact dates not known. | 23 | ?   | ?          | ?            | ?       | 85° ET      | Humidifier and heaters used to control environment | ?     | No assigned shelter manager. Late arrival of shelter manager. Intrusion felt. |
|                    | American Institute of Research, same procedure                                                 | Aug. 1969<br>Exact dates not known. | 24 | ?   | ?          | ?            | ?       | 85° ET      | ?                                                  | ?     | Group organized shelter management by itself.                                 |
|                    | American Institute of Research, same                                                           | Aug. 1969<br>Exact dates not known. | 25 | ?   | 1 person   | ?            | ?       | 85° ET      | ?                                                  | ?     | Group leader decided immediately.                                             |

Study Characteristics

Study 1: No experience.  
Study 2: Video information.  
Study 3: Video and experience.

Aim:  
To evaluate effect of prior information on subject performance.

Findings:

1. Informed groups possessed less unwarranted optimism, felt better prepared, conducted setup more efficiently.
2. Information program is beneficial.
3. No group performed well on monitoring radiological instruments.

Discusses radiation baffles.

| Study By                                 | Place                               | Date                             | N                                 | Sex | Deflections | Sq. Ft. Cu. Ft. | Temp. Ventilation           | Water/Person/Day Consumed | Light                                                                                          | Shelter Management |
|------------------------------------------|-------------------------------------|----------------------------------|-----------------------------------|-----|-------------|-----------------|-----------------------------|---------------------------|------------------------------------------------------------------------------------------------|--------------------|
| Rohles, Frederick M.<br>Navins, Ralph G. | Institute of Environmental Research | Jan. 1972 Exact dates not known. | 16 subjects each for seven tests. | ?   | ?           | ?               | 82° F Effective Temperature | ?                         | Objective of the study is to find the amount of water ration to be provided for each occupant. | ?                  |

**Objective:**  
Response of human subjects to reduced levels of water consumption under simulated civil defense shelter conditions.

**Experimental Design:**

Seven tests employing 17 subjects each were run simulating shelter occupancy. Subjects were at sedentary-sleeping activity level in an environment of 82° F ET.

Tests included various occupancy periods for males and females for 1 to 1 1/4 quarts per person per day of water consumption.

\* A computational method was developed for determination of body water pool loss.

\* Nutritional, physiological and psychological testing was carried out to measure subject response to water rations.

**Results:**

1. Subject-weight loss and water budgets are presented.
2. From extrapolation, it was concluded that a water ration of 1 3/4 quarts of water per person per day for 14 days should prevent dehydration of subjects.

| Study By                                   | Place                                                                                                            | Date                                            | N | Sex | Space/Person |         | Defections | Temperature |    | Ventilation | Water/<br>Person/<br>Day Consumed | Light | Shelter Management                                                                      |
|--------------------------------------------|------------------------------------------------------------------------------------------------------------------|-------------------------------------------------|---|-----|--------------|---------|------------|-------------|----|-------------|-----------------------------------|-------|-----------------------------------------------------------------------------------------|
|                                            |                                                                                                                  |                                                 |   |     | Sq. Ft.      | Cu. Ft. |            | °F          | °F |             |                                   |       |                                                                                         |
| Smith, Robert M.<br>Armstrong, Terry<br>K. | American<br>Institute<br>for<br>Research<br>Performance<br>Evaluation<br>Studies,<br>Coral<br>Gables,<br>Florida | Oct.<br>1973<br>Exact<br>dates<br>not<br>known. | ? | ?   | ?            | ?       | ?          | ?           | ?  | ?           | ?                                 | ?     | Project goal was to<br>identify possible<br>selection measures<br>for shelter managers. |

Aim:  
To identify possible selection  
measures for shelter managers.

Technique:  
Habituation of a submerged shelter by  
individuals with little or no previous  
underwater experience. That simulated  
threat and stress in shelters.

Findings:

1. Performance decrement was not significant in the study.
  2. For selection of shelter managers, battery of: (a) MAACL-Adjective Checklist and (b) Minnesota Multiphasic Personality Inventory should be used.
- They are good predictors of performance of individuals in a stressful situation.

### SECTION III

#### Review of the Stressors

| <u>Stressor</u>                 | <u>Page</u> |
|---------------------------------|-------------|
| Anxiety                         | 15          |
| Crisis and Panic                | 17          |
| Crowding                        | 20          |
| Heat and Performance            | 26          |
| Heat and Psychological Response | 39          |
| Illumination                    | 42          |
| Leadership                      | 43          |
| Sleep                           | 46          |
| Stress                          | 50          |

ANXIETY 1.1

| Citation                                                                                                                                                                                                                                               | Task                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | Results                                                                                                                                                                                                                            |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Lazarus, Richard S. <u>Psychological Stress and Coping Process</u> , New York: McGraw-Hill Book Company, 1966.                                                                                                                                         | "In recent years there has been a proliferation of efforts to measure anxiety through self-report." One example is the Manifest Anxiety Scale by Taylor (1953). Other scales have been developed by Bendig, 1956; Cattell and Scheeler, 1960; Dixon, deMourchaux, and Sandier, 1957; Endler, Hunt, and Kosenstein, 1962; Freeman, 1953; Lykken, 1957; Perlman, 1958; Sarason, Davidson, Lighthall, and Waite, 1958; Sarason and Mandler, 1952; and Welsh, 1952, 1956.                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                                                                                                                                                                                                                    |
| D'Augelli, Anthony R. Changes in self-reported anxiety during a small group experience. <u>Journal of Counseling Psychology</u> , 1974, 21(3), 202-205.                                                                                                | Two trained observers rated all subjects during discussion of a meaningful interpersonal problem on critical interpersonal skills, empathic understanding, honesty-emotional openness, and acceptance-warmth. Subjects formed six member groups in which all group members were either rated high or were rated low on interpersonal skills. These groups met several weeks later for a 2-hour, leaderless, sensitivity training session. Subjects took the State Trait Anxiety Inventory (STAI) several times before and after the test sessions.                                                                                                                                                                                                                                                                                                                                                       | "Individuals previously assessed as having high levels of interpersonal skills reported significantly less anxiety at the conclusion of the session; however, they were slightly more anxious before."                             |
| Lukens, H.R. Technique for quickly detecting anxiety. <u>Transaction of the American Nuclear Society and the European Nuclear Society</u> , 1980 International Conference on World Nuclear Energy-Accomplishments and Perspectives, 1980, 35, 158-159. | "This paper concerns the use of skin conductivity to quickly detect anxiety in a manner suitable for routine screening of nuclear power plant operations personnel. ...The instruments used were a skin conductivity meter and a two-part questionnaire. ...The first part of the questionnaire, which consisted of seven nonpersonal questions for calibration purposes, was verbally administered while the subject held the electrodes comfortably in his left hand, and immediately ensuing a SCL (changes in skin conductivity levels) and SCR (skin conductivity responses) were recorded. ...The second part of the questionnaire included two main questions: (a) 'Have you had a recent change in your life?' and (b) 'Have you had a recent problem?' If the answer to either of them was yes, follow-up questions were asked to see if anxiety was confirmed by further instrument readings." | "The instrumental response was above the critical value in both the main question and follow-up phase only in those instances where the subject was burdened by a change or problem perceived as difficult to face and/or manage." |

ANXIETY

1.2

| Citation                                                                                                                                                                                                                                                        | Task                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | Results                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <p>Solomon, Sheldon, Holmes, David S., and McCaul, Kevin D. Behavioral control over aversive events: does control that requires effort reduce anxiety and psychological arousal? <u>Journal of Personality and Social Psychology</u>, 1980, 39(4), 729-736.</p> | <p>This experiment had two levels of effort required and three levels of threat. The task was to repeat a series of numbers in the order in which they had been presented. "A subject in the high-effort condition was told that each series of numbers would have as many digits as he was able to recall earlier. A subject in the low-effort condition was told that each series of numbers would have three less than he was able to recall earlier."</p> <p>"A subject in the avoidable threat condition was informed that receiving shocks would be contingent on his performance on the digit span exercise. ... A subject in the unavoidable threat condition was told that shocks would be administered randomly following each repetition of digits during the performance period. ... A subject in the no-threat condition was simply told his performance and physiological responses would be compared with other subjects who were being exposed to different types of stimulation."</p> <p>The data gathered included pulse volume and pulse rate taken at 30-second periods, and an 18-item anxiety scale.</p> | <p>"Subjects in the no-threat condition or subjects who could control the threat with low effort reported levels of anxiety that were lower than those reported by subjects who could not control the threat or who had to use high effort to control the threat."</p> <p>"Results indicate that control over aversive events is effective for reducing anxiety but only when that control is easy to exercise."</p> <p>When control of the threat "was easy to exercise, subjects reported a level of anxiety that was like that of subjects who were not threatened with the aversive event; but when the control was difficult to exercise, the subjects reported a level of anxiety that was like that of subjects who were threatened with the aversive event but who were unable to exercise control over it."</p> |

CRISIS AND PANIC 2.1

| Citation                                                                | Task                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | Results                                                                                                                                                                                                                        |
|-------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Hombin, Robert L. Leadership and Crises. Sociometry, 1958, 21, 322-335. | "The experimental task involved a modified shuffle-board game which lasted about 30 minutes. ... (Subjects) were given a general but very incomplete idea about the nature and rules of the game. They were told that they were to discover the rules themselves by trying different things and by watching a light board. ... The participants were told that they would be competing with high-school students who had previously participated in a similar experiment; that their cumulative scores and the average cumulative scores of the high-school students would be posted for each of six, 5 minute playing or task periods into which the game was divided." (This motivated the subjects by challenging their ego.) A crisis was produced in half of the groups by changing the rules of the game half way through the game. Then, as soon as the participants learned a new rule, the rule was changed again. | "Leaders have more influence during periods of crisis than during non-crisis periods."<br>"Groups tend to replace their old leader with a new leader if the old leader does not have an obvious solution to a crisis problem." |

General Procedure for the 1st three experiments.

Subjects were seated in separate booths or rooms and were not permitted to talk to each other. The subjects were told that the situation was one where a number of people had to use a single, limited exit to escape from an impending danger within a limited time. Only one person at a time could escape and the threatened penalty for failure to escape was, in most cases, one or more painful electric shocks. Each subject had a switch which they were to move when they wished to escape. A large panel of lights, placed in the front of the room so that all subjects could see it, displayed the actions of all the participants. By watching the light panel, each subject could determine what every other subject was doing at any point in time, whether each had succeeded in escaping, etc.

Experiment I

Groups were made up of 4, 5, 6, and 7 subjects.  
"The low-threat subjects faced no penalty for

Kelley, Harold H., Condry, John C., Jr., Dahlke, Arnold E., and Hill, Arthur H. Collective behavior in a simulated panic situation. Journal of Experimental Social Psychology, 1965, 1, 20-54.

CRISIS AND PANIC

2.2

| Citation | Task                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | Results                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
|----------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|          | <p>failing to escape. ....The medium-threat subjects were shown convincingly that they could be given electric shocks and they were threatened with the penalty of as painful shocks as possible if they failed to escape. The high-threat subjects were in the same situation" except that they received an injection of epinephrine. This was assumed to produce a higher level of anxiety.</p> <p>The time allowed for the entire collection to escape was determined by the flow of red-colored water from one large water bottle to another, in a water version of an hour-glass type timer. This was done so the subjects would have no reliable index of the length of time available. "The amount of water in the bottles was varied to provide twice as much time as was minimally necessary for the given number of subjects to escape."</p> <p>Experiment II</p> <p>"In general, the procedure was similar to that of Experiment I except that the water bottle timer was replaced by a tone which increased in pitch every few seconds, thus portraying the passage of time without giving any information as to when it would terminate." The buttons and panel were different from the first experiment but each subject still had an escape button and could tell what the other subjects were doing and their success in escaping.</p> <p>Experiment III</p> <p>This segment tested how susceptibility to social influence and the ability to express confidence that all members would escape affected collective behavior in a simulated panic. The procedure was similar to that used in Experiment I. High susceptibility to social influence was manipulated by telling subjects that since some of their group had participated in the experiment before and knew how to behave in the situation, they should watch carefully what others were doing. Low susceptibility was manipulated by telling some subjects during a</p> | <p>"The highest degree of concern about the threatened penalty is shown by the females [subjected] in the high [threat] condition. Their uneasiness is significantly higher there than that of the males in the same condition and than their own uneasiness in the medium condition. Apparently adding the epinephrine injection to the threat of shock produced no increment in the anxiety level of the males but did so for the females."</p> <p>"Females succeed in escaping less frequently than do males.</p> <p>"The average percentage escaping varies with size in the following manner: in collections of 4, 77% escape on the average; in collections of 5, 57% escape; in collections of 6, 31% escape; and in collections of 7, 49% escape."</p> <p>Females are more uneasy than males.</p> <p>"Males have a higher rate of escape than the females."</p> <p>"When the clues as to available time are removed, the unexpected efficiency of the 7-man groups [from Experiment I] disappears, and the time required per escape tends to increase with group size."</p> <p>"If members of the collection are oriented toward taking their behavior cues from each other, as compared with an orientation toward making their behavioral decisions independently of one another, the effect upon escape may be either a deleterious one (when at the outset there is generally little optimism about escape) or a salutary one (when the general level of initial optimism is high)."</p> <p>"The availability of a distinctive response for the public expression of confidence greatly increases the percentage of persons who succeed in escaping."</p> |

Citation Task Results

telephone call that they were expected to do well. At the beginning of the experiment, these subjects were reminded of this and told that they should not be swayed by the way others were reacting but should make up their own minds.

The other factor studied was the ability to express confidence that all members would escape. A subject could express confidence by turning on his yellow light for all to see. The yellow light told other subjects that he did not intend to escape immediately and that someone else should use the exit. Two simulated subjects were used to insure that subjects believed confident persons were present.

Subjects were told the penalty for failure to escape would be electric shock.

Klein, Andrew L. Changes in leadership appraisal as a function of the stress of a simulated panic situation. Journal of Personality and Social Psychology, 1976, 34(6), 1143-1154.

Subjects tried to retrieve their wooden cones through the same small hole. The experiment had two levels of stress (threat of shock or of small monetary loss), two levels of leadership authority (elected or appointed), two conditions of leadership ("me-last" or "me-first"), and group success or failure.

Group incoordination (panic) increased under personal threat.

| Citation                                                                                                                                                                                                                      | Task                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | Results                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <p>Griffitt, William and Veitch, Russell. Hot and crowded: Influences of population density and temperature on interpersonal affective behavior. <u>Journal of Personality and Social Psychology</u>, 1971, 17(1), 92-98.</p> | <p>The experiments were conducted at 73.4°F and 93.5°F. Groups of three to five or twelve to sixteen people sat in a room in which there was either 12.72 or 4.06 sq. ft. per person.</p> <p>For the first 45 minutes, subjects performed a series of paper-and-pencil tasks which included a 64-item Repression-Sensitization scale, a series of 6 semantic-differential rating scales, a cancellation task designed as a time filler, and finally a short form of the Novlis Mood Adjective Check List. They were then asked to make judgments about an anonymous stranger by examining the attitude questionnaire of the stranger which had been manipulated to agree with the subject either 25 or 75% of the time. They rated the stranger on the Interpersonal Judgment Scale.</p> | <p>"Attraction responses tended to be more negative under hot than under the normal conditions."</p> <p>"Even though the actual mean effective temperatures across density conditions were identical, subjects rated themselves as warmer in the high-density condition."</p> <p>"Under conditions of high temperature and high population density, personal-affective, social-affective, and non-social-affective responses were found to be significantly more negative than under conditions of comfortable temperature and low population density."</p>                                                                                                                                                                                                                              |
| <p>Loo, Chales M. The effect of special density on the social behavior of children. <u>Journal of Applied Social Psychology</u>, 1972, 2(4), 372-381.</p>                                                                     | <p>Children four and five years old were picked up from their own school in groups of six and driven to the testing center. They were told that the playroom was theirs and that they could play with anything they wanted for about an hour. No adult remained in the room. Each child had either 44.2 or 15 sq. ft. per person.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                    | <p>"While aggression in girls did not significantly differ between densities, aggression in boys was significantly higher in the low-density condition than in the high-density condition."</p> <p>Subjects "interacted with significantly fewer children in the high-density condition than in the low-density condition."</p> <p>"There was a trend toward less time spent in group involvement and more time spent in solitary play in the high-density than in the low-density condition. ...Boys interacted with significantly more children than did girls."</p> <p>"Girls were interrupted to a significantly greater degree than were boys and there was a trend toward greater frequency of interruptions in the high-density condition than in the low-density condition."</p> |
| <p>Loo, Chales. Important issues in researching the effects of crowding on humans. <u>Representative Research in Social Psychology</u>, 1973, 4, 219-226.</p>                                                                 | <p>Loo reviews the literature on "several important yet rarely considered factors involved in researching the effects of crowding and density on humans."</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | <p>He cited Stokols (1972) as defining "density as a physical condition involving the limitations of space, and crowding as an experimental state where the individual perceives a spatial restriction and experiences psychological and physiological stress."</p> <p>"Spatial density research compares the behavior of groups of the same number in spaces of differing sizes while social density research compares the behavior of groups of differing numbers in the same sized space."</p>                                                                                                                                                                                                                                                                                        |

3.2

CROWDING

| Citation                                                                                                                                                                                                | Task                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | Results                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <p>Stokols, Daniel, Ball, Marilyn, Pinner, Berna, and Schopler, John Physical, social and personal determinants of the perception of crowding. <i>Environment and Behavior</i>, March 1973, 87-115.</p> | <p>Groups of eight people having either 16.7 or 5.6 sq. ft. per person were crowded for approximately 70 min. Subjects first filled out a preliminary questionnaire covering their personal background. Then they played a game in which they asked quiz questions of the other group members and kept score. Subjects either competed as a group against other groups or as individuals within the group. Afterwards subjects completed a questionnaire containing semantic differentials pertaining to their feelings during the game.</p> | <p>Adding more doors, adding a bisecting partition, and making the area more rectangular rather than square in shape are architectural features which reduced the feeling of crowdedness.</p> <p>In comparing the studies of density on adults with those on children, there are three important differences. The "first is the degree of structure of the environment, the second is the degree of structure of the activities imposed on the individuals, and the third is the age of the individuals being studied." Whereas studies on children have used unstructured architectures, "studies on adults have used highly structured architectures by providing a chair or desk-chair for each individual. Providing such an architectural structure provides each member with a secure territory of his own. ...Adults are likely to feel less anxiety and fewer feelings of crowdedness since their territory has been marked for them." Children usually are not given things to do when they are studied whereas adults are given activities. Since the degree of crowdedness experienced is determined by the activities of the participants, adults are likely to experience less anxiety than children.</p> |
| <p>Boyang, Carson K. Effects of group size and privacy in residential crowding. <i>Journal of Personality and Social Psychology</i>, 1974, 30(3), 309-392.</p>                                          | <p>Residents of a trailer park completed questionnaires containing items pertaining to personal and trailer data and satisfaction. Each trailer had 960 sq. ft. and the number of occupants ranged from 2 to 5 with 3 or 4 being the most common. Each subject lived in a different trailer. The sample consisted of 33 males and 25 females, and ranged in age from 18 to 30 years.</p>                                                                                                                                                     | <p>"Females, as compared with males, perceived the room to be relatively more confined in the cooperative than in the competitive condition."</p> <p>"Males rated themselves as more aggressive in the small room, whereas females rated themselves as more aggressive in the large room."</p> <p>"Females seemed to express greater favorableness toward a small room than did males."</p> <p>"Only the size of the subjects' families was positively correlated with ratings of living space. Other analyses by age, class, size of hometown, sex, number of years on campus, manner of choosing roommates, length of residency in the trailers, and estimates of discretionary time spent in the trailers did not correlate with ratings of living space or with measures of satisfaction."</p> <p>"The number of occupants accounted for greater variance in living space ratings than did degree of privacy."</p>                                                                                                                                                                                                                                                                                                 |

Results

Task

Citation

"After entering industrialization, urbanization, discrimination and security forces, crowding accounted for 14 percent of the variance in the incidence of civil disorder and 19 percent of the variance in whether or not there were casualties as a result of disorder. People per room accounts for the bulk of the variation in civil aggression. This variable is strongly related to both incidence and intensity of political violence."

A hypothesis that "human crowding, independent of its linkage with SES (social economical status) variables, may be a factor promoting political aggression," was tested using data on civil disorders in sixty-five nations. The measures of crowding used were people per unit of area, dwellings per unit of area, and people per room within the household.

13(6/5), 131-162.

Baum, Andrew and Greenberg, Carl I. Waiting for a crowd: the behavior and perceptual effects of anticipated crowding. *Journal of Personality and Social Psychology*, 1975, 32(4), 671-679.

People were studied to determine how they respond when they think they are going to be crowded in groups of four or ten in a room with 87.5 sq. ft. One subject sat in the room until 2 confederates had arrived. Then the subject rated the room, the confederates, and his own state of being.

"Subjects expecting three other subjects indicated they felt less crowded than did subjects expecting nine others."

"Subjects anticipating crowding sat consistently toward the corner of the room when compared with those not expecting crowding."

"Subjects anticipating crowding looked at the first confederate less than did subjects expecting only three others."

Subjects anticipating crowding liked the first confederate less and the second confederate even less than those not anticipating crowding.

"Subjects anticipating crowding felt that the room was smaller, more stuffy, less comfortable, and less adequate than did subjects not anticipating crowding."

Epstein, Yakov M. and Karlin, Robert A. Effects of acute experimental crowding. *Journal of Applied Social Psychology*, 1975, 5(1), 34-53.

Groups of six males or six females sat for half an hour without talking in a room in which each person had either 2.67 or 99 sq. ft. per person. Then they went into another room where they performed the following tasks: 1) finding A's test--in which they indicated the five words containing the letter "A" out of a column of forty-one words, 2) Guilford's "Creative Uses Task" in which they listed novel uses for four common objects, 3) Tajfel Task which required subjects to allocate points to two individuals, and 4) a 20-trial Prisoner's Dilemma Game. The basic premise was that "women perceive that distress should be shared whereas men perceive that distress should be concealed. In sharing their distress, crowded women should discover that they share a common fate; as a result they will form a cohesive cooperative group. In concealing their distress from each other, crowded men will not form a cohesive group."

On the simple task, "crowded subjects showed an increment in task performance compared with noncrowded subjects." Crowding did not affect the complex task.

"Men were less cohesive in the crowded condition, whereas women were more cohesive."

"Crowded men tended to be more competitive and crowded women were less competitive than their noncrowded counterparts."

"Crowded men tended to perceive that the group discouraged showing one's discomfort whereas crowded women perceived that the group encouraged such a display."

"Crowded women evaluated their group significantly more positive than did noncrowded women. Crowded men and their noncrowded counterparts did not significantly differ from one another."

"It might be argued that the most potent effects of crowding occur after rather than during confinement." This would explain the differences found between the results of Freedman and the present study.

| Citation                                                                                                                                                                                                                                 | Task                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | Results                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <p>Marshall, Joan E. and Heslin, Richard. Boys and girls together: sexual composition and the effect of density and group size on cohesiveness. <u>Journal of Personality and Social Psychology</u>, 1975, 31(5), 952-961.</p>           | <p>Subjects were formed into groups of 4 having either 4 or 17.2 sq. ft. per person or into groups of 16 having either 4.3 or 18 sq. ft. per person. The groups were either all male or all female or half male and half female. For the first 1 1/2 hours, group members worked together putting phrases into paragraphs. After this, subjects completed a questionnaire containing dependent variables which included interpersonal attraction, evaluation of the group as a whole, and their feelings in general. For the next 15 min., subjects worked as a group in thinking of uses for common objects. Finally, subjects who had indicated on their questionnaire that they would like to do a task alone rather than in the group were asked to leave the room. "These subjects did one more common usage item in individual cubicles while the remaining members worked on the same item as a group." The length of the experiment was 2 1/2 hours.</p> | <p>The variables studied were group size, density, composition, and sex. "Members were more attracted to other members in small groups than in large groups. ...The tendency to like other members more in small than in large groups was more pronounced for males than for females." "When persons were in mixed-sex groups, both males and females tended to like the other members more when crowded than when not crowded." "With their own sex, women did not like the other members as much when they were crowded as when they had more space. But men with their own sex liked each other more when they were crowded than when they had more space." "Density did not affect feelings toward the group nor motivate behavior (the percentages leaving the crowded and uncrowded groups were 22% and 23%)." "Group size was a more potent factor than density. In same-sex groups, members of small groups had more positive feelings toward the group and the other members than members of large groups. Further, among same-sex groups, more people in small groups (80%) chose to remain with the group than in large groups (69%). ...When both sexes were together, more (92%) stayed in large groups compared to only 72% staying in small groups." "Males responded more positively in mixed-sex groups than in same-sex groups, while females varied in responses to composition depending on group size. Males felt the same in large and small mixed-sex groups and liked the groups equally. ...whereas females in mixed-sex groups liked large groups better than small groups."</p> |
| <p>Schettino, Andrew P. and Borden, Richard J. Sex differences in response to naturalistic crowding: affective reactions to group size and group density. <u>Journal of Personality and Social Psychology</u>, 1975, 32(4), 671-679.</p> | <p>Students in different-sized classes completed questionnaires early in the semester. Each class had approximately equal numbers of males and females. Included in the data were the number of friends a student had in the class. Twenty-five groups were studied which varied in size from 13 to 279. The density was found by dividing the number of chairs occupied by the number of chairs available. This number varied from 0.22 to 0.96.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | <p>"Males, overall, felt less secure, more crowded, more aggressive, and worse than females." "Significant relation between density and aggressiveness was found for males but not for females." "Group density was correlated with feelings of crowdedness and nervousness for females but not for males." "The present study provides evidence that group density, rather than group size, is the more potent dimension in producing affective reactions in the group setting. Moreover, this is apparently the case over an extensive range of both group size and group density." "The number of friends or acquaintances that a subject indicated were</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |

CROWDING

| Citation                                                                                                                                                                                                              | Task                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | Results                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <p>Baum, Andrew and Kuman, Stuart. Differential response to anticipated crowding: psychological effects of social and spatial density. <i>Journal of Personality and Social Psychology</i>, 1976, 34(1), 526-536.</p> | <p>People were studied to determine how they prepare when they think they are going to be crowded and when they are told a leader will be appointed and the rules explained. Subjects anticipated groups of either five or ten people. The anticipated number of sq. ft. per person was 27, 13.5, or 6.75. The procedure was the same as for Baum and Greenbury (1975).</p>                                                                                                                                                                                                                   | <p>present in the group did not differentially influence judgments on any of the measures."<br/>           "Feelings of crowdedness and nervousness were significantly correlated for [both] men and women."</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
| <p>Atiello, John R., DeRisi, Donna T., Epstein, Yakow M., and Karlin, Robert A. Crowding and the role of interpersonal distance preference. <i>Sociometry</i>, 1977, 40(3), 271-282.</p>                              | <p>Groups of four females, having either 2.5 or 48 sq. ft./person sat in silence in a room for thirty minutes. Afterwards subjects: 1) wrote a sentence describing the environment, 2) took 2 creativity tasks (the unusual uses task and the line completion task), 3) completed a postexperimental questionnaire assessing their perception of the experimental environment, the attraction to their group, self-reported somatic symptoms of stress and reactions to various phases of the experiment, and 4) were tested for stress, determined by measuring skin conductance levels.</p> | <p>"Subjects expecting large-group sessions tended to sit in more peripheral positions than did subjects expecting small groups unless anticipating a structured session. When structured sessions were expected, subjects sat further toward the center of the seating arrangement."<br/>           "Subjects anticipating large, unstructured groups reported greater discomfort than did subjects expecting large, structured groups, but structure expectancy did not influence these ratings when groups were expected to be small."<br/>           "The effects of anticipating large groups on facial regard ... were mediated by structure expectancy and were not influenced by varying room size."<br/>           "Men experienced more crowding and responded more aggressively to high spatial density conditions than did women."</p>    |
|                                                                                                                                                                                                                       |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | <p>"Crowded subjects characterized their fellow group members as more likeable, more similar, less conf., and more willing to share feelings than did their noncrowded counterparts."<br/>           "Crowding which involves close physical proximity produces greater physiological reactivity and somewhat lowers an individual's creative potential following exposure to crowding."<br/>           "For subjects who feel comfortable interacting with others at close distances, crowding does not dramatically increase stress levels. On the other hand, for a person who prefers to interact at greater distances with people, crowding acts as a noticeable stressor."<br/>           "Crowded subjects, regardless of their interpersonal distance preference, showed a lower level of creativity than their noncrowded counterparts."</p> |

3.6

CRIMING

Task

Results

Citation

Keating, John P. and Snowball, Malina Effects of crowding and depersonalization on perception of group atmosphere. Perceptual and Motor Skills, 1977, 44, 431-435.

Groups of nine to twelve females, having 9-12 or 4.5-6 sq. ft. per person were in a room for thirty minutes. While in the group, subjects judged abstract sketches first individually and then as a group.

In order to see if there was any interaction between spatial density and personalization, some groups of subjects were given name tags with their name on it, while other groups of subjects had name tags with a number on it.

The hypothesis that depersonalization would intensify negative perceptions in subjects under high density was not supported. "...Personalization groups were perceived as less friendly and the task was judged as more frustrating by subjects in the personalized conditions than their depersonalized counterparts." A possible explanation is that personalization might have led subjects to expect more satisfaction from the group interaction.

Of the nine dependent measures, only three supported the hypothesis that subjects under high spatial density would perceive discussion groups more negatively than subjects in low density. The "three supporting the density prediction were measures that implied receiving some kind of help from other members of the group."

## HEAT AND PERFORMANCE

4.1

| Citation                                                                                                  | Task                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | Results                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
|-----------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Poplat, R.D. Warmth and performance: An investigation in the tropics. <u>Ergonomics</u> , 1958, 2, 63-68. | Service men who had been living in the tropics for at least 6 months and generally for 1 to 2 years served as subjects for all the following experiments.                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | "Each of the partial scores [total time and distance off the target due to leading, lagging, overshooting or approaching the target] showed a significant increase when the effective temperature was 84°F as compared with 76°F. At the hottest climate of 91°F the errors due mainly to persistent lagging were significantly higher than at 84°F, while the errors of 'leading' decreased significantly. The errors of 'overshooting' and errors of 'approaching' remained approximately unchanged. None of the four partial scores showed a significant change at the coolest climate of 66°F from that at 76°F." |
|                                                                                                           | Experiment 1: Subjects worked in the following dry and wet bulb temperatures: 75°/65°, 85°/75°, 93°/83°, and 100°/90°F. The average air movement was 80 ft/min. The basic effective temperatures of these climates were 66°, 76°, 84°, and 91°F. Subjects worked on a manual tracking task and were in the chamber for 3 hrs. 25 min.                                                                                                                                                                                                                                                                                        |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
|                                                                                                           | Experiment 2: The eight climates in which subjects performed a manual tracking task, "were composed of 4 pairs, the members of each having the same effective temperature, but relative humidities of 80 percent and 20 percent respectively. The dry and wet bulb temperatures of each pair of climates were as follows: 79°/74° and 89°/64°; 85°/80° and 100°/70°; 90°/85° and 110°/75°; 97°/92° and 120°/85°F. Since the average air movement in the chamber was 80 ft/min the basic effective temperature for each pair was 72°, 79°, 84°, and 92°F." Subjects were in the chamber for about one hour and forty minutes. | "It was found that only the difference in temperature had a significant effect ( $p < 0.05$ ), although the effect of the difference in relative humidity was quite large and almost significant."                                                                                                                                                                                                                                                                                                                                                                                                                    |
|                                                                                                           | Experiment 3: Subjects worked at a manual tracking task in four environments having effective temperatures of 76°, 81°, 86°, and 91°F. They worked under two incentive conditions and two tracking speeds and were in the chamber for about two and one-half hours.                                                                                                                                                                                                                                                                                                                                                          | "At each target speed the alignment of the pointers was more accurate in a climate with an effective temperature of 81°F [possibly due to heat acclimatization], was significantly worse when the temperature was both 76° and 86°F. At an effective temperature of 91°F performances were less accurate than at 81°F, but, at the fast speed, accuracy at 91°F was also significantly worse than at 86°F." At both speeds of working, the "climatic effect did not differ significantly under the two incentive conditions."                                                                                         |

HEAT AND PERFORMANCE 4.2

| Citation                                                                                                                                                                                                                             | Task                                                                                                                                                                                                                                                                                                                                                                                                                       | Results                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                                                                                                                                                                                                                                      | Experiment 4: "A subject sat alone in the chamber for two hours during which time he had to remain alert to observe small infrequent changes in a visual display occurring at apparently irregular intervals." The effective temperatures used were 67°, 82°, and 92°F.                                                                                                                                                    | The average number of signals missed in the moderately warm climate (effective temperature of 82°F) was significantly less than in either the cooler or the warmer climate (effective temperatures of 67° and 92°F respectively).                                                                                                                                                                                                                                                                                                                              |
|                                                                                                                                                                                                                                      | Experiment 5: Subjects performed a task which required them to respond rapidly to ever-changing complex visual material. "The task taxed a subject's capacity to make the appropriate responses by limiting the time during which he could perceive and organize the available data." The effective temperature of the climates were 76°, 81°, 86°, and 91°F.                                                              | The optimum climate was the one most similar in warmth to the temperature to which the subjects had been heat acclimatized.                                                                                                                                                                                                                                                                                                                                                                                                                                    |
| Pine, Bernard J., Cohen, Alexander, and Crist, Brian. Effect of exposure to high humidity at high and moderate ambient temperature on anagram solution and auditory discrimination. <u>Psychological Reports</u> , 1960, 7, 171-181. | "Ten subjects were exposed for six-and-one-half-hour periods on four successive days to ambient dry-wet bulb temperatures of 70°/53°F, 70°/68°F, 95°/70.5°F, and 95°/92°F with mild wind. ... Subjects performed an anagram and an auditory discrimination task immediately after entering and just prior to leaving the experimental situation. The intervening time was occupied by group performance of a mental task." | "The results indicate that high humidity at moderate and high ambient temperatures had little, if any, adverse effect upon mental performance as measured by the anagram and auditory discrimination tasks. After more than six hours exposure to the 95°/92°F condition, during which time nearly continuous mental work was performed, subjects scores were as good or better than under much less severe conditions. The results also indicate that there was no adverse effect upon performance due to high ambient temperature irrespective of humidity." |

## Citation

Wing, John F., Upper thermal tolerance limits for unimpaired mental performance. *Aerospace Medicine* 1965, 36(10), 960-964.

## Task

## Results

"At every point the proposed performance curve lies below the recommended physiological tolerance curve of Lovelace and Gage." "There are, of course, certain limitations in the proposed performance curve. First, there are limits on the generality of the curve. It most adequately represents the performance threshold of artificially-acclimatized military personnel during learning or re-acquisition of highly stress-sensitive mental tasks. As such, the curve properly represents the lower-limit of an 'impairment zone.' The threshold for some mental tasks, or for naturally-acclimatized subjects may lie somewhat higher (i.e., in the zone between the present curve and the recommended physiological limit). Secondly, because the curve is plotted in terms of effective temperature, there is the danger of assuming that all the combinations of temperature, humidity and air speed which yield a given effective temperature also produce the same degree of performance decrement. This is undoubtedly not the case. Eventually performance decrements should be separately determined for a large number of combinations of temperature, humidity and air movement and reported in a tri-dimensional chart."

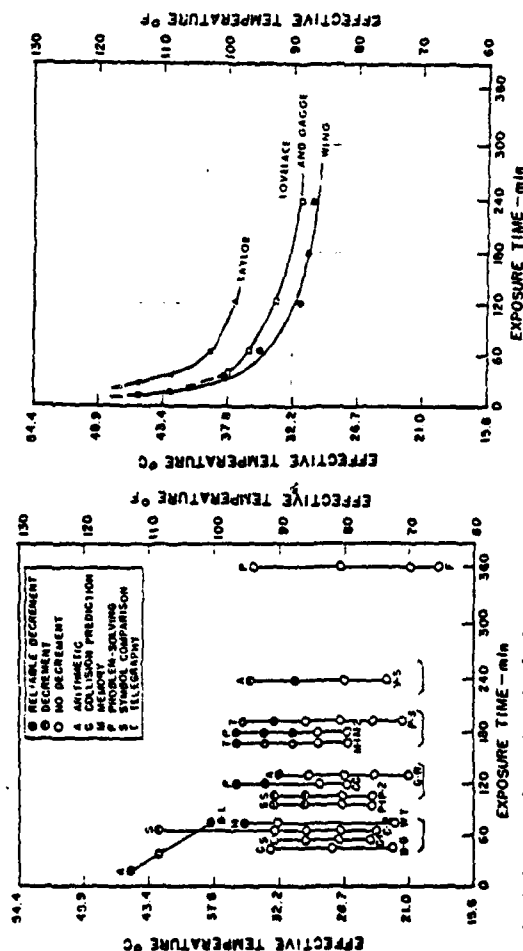


Fig 1. Summary characteristics for the fourteen experiments reviewed in this study. Each experiment is represented by a critical line with the initials of the investigator(s) beneath it. The circles on a line are test temperatures. Solid circles indicate statistically reliable impairment in performance; half-filled circles indicate decrements which were not evaluated (or were improperly evaluated) statistically; and open circles indicate no decrement.

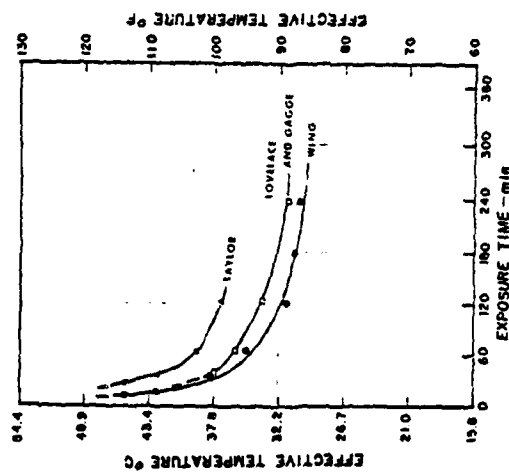


Fig 2. Comparison of the proposed thermal tolerance limit for unimpaired mental performance (Wing) with both the recommended physiological limit (Lovelace and Gage) and the marginal physiological limit (Taylor).

TABLE 1. LOWEST TEST TEMPERATURE YIELDING RELIABLE DECREMENTS AT EACH OF SEVERAL DURATIONS OF EXPOSURE

| Exposure Duration (min) | Effective Temperature (°C) | Experimental Study | Task Affected         | Level of Significance |
|-------------------------|----------------------------|--------------------|-----------------------|-----------------------|
| 60                      | 45.6*                      | Blackley & Lyman   | Mental Addition       | $P < .05$             |
| 120                     | 42.8**                     | Blackley & Lyman   | Mental Addition       | $P < .01$             |
| 180                     | 39.8**                     | Blackley & Lyman   | Mental Addition       | $P < .01$             |
| 240                     | 35.0                       | Wing & Tachibana   | Memory for Words      | $P < .01$             |
| 300                     | 31.2†                      | Corbridge          | Verbal Reasoning      | $P < .05$             |
| 360                     | 30.9                       | McKenzie           | Verbal Reasoning      | $P < .05$             |
| 240                     | 29.6                       | Vincent & Smith    | Coding Task           | $P < .05$             |
| 360                     | 28.1                       | Blackley & Lyman   | Mental Multiplication | $P < .05$             |

\*Estimated duration at which significant impairment first occurred.

\*\*Estimated effective temperatures as reported by the authors.

†Significant only after one subject's "applicable" data were dropped from the analysis.

Underlined value at which impairment would just reach statistical significance.

## HEAT AND PERFORMANCE

4.4

| Citation                                                                                                                                                                                                                                                                             | Task                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | Results                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <p>Lampietro, P.F., Chiles, W.D., Higgins, E.A., Gibbons, H.L., Jennings, A., and Vaughan, J.</p> <p>Complex performance during exposure to high temperatures. (FAA-AH-69-10). Civil Aeromedical Institute Federal Aviation Administration, Oklahoma City, Oklahoma, June, 1969.</p> | <p>"All subjects held private or commercial pilots licenses and all held current Class II or III Medical Certificates. The total number of subjects was 30; their age ranged from 30-51."</p> <p>The subjects performed varying combinations of five tasks. The tasks were two dimensional compensatory tracking, mental arithmetic, meter monitoring, discrimination reaction time, and simple reaction time. The subjects had the opportunity to practice the workloads before the experiment. The experiment was conducted at 35, 38.4, and 18.9°C effective temperature for about 30 minutes. Pre-exposure and post-exposure testing periods, both for 15 minutes at 18.9°C effective temperature, were also included in the experiment.</p> | <p>"The effects of temperature are dependent upon both the workload and the nature of the task. This inference receives support from the fact that none of the simple tasks (reaction time and meter monitoring showed an effect of temperature."</p> <p>The results imply "that a major effect of temperature on manual performance is a decrease in the ability of the subject to decouple movements of the two arms."</p> <p>"The subjects were older than those used in the typical study; they were not acclimatized to heat, and they probably were not in as good physical condition as the subjects in the previous studies. All of these factors would tend to decrease the time for which unimpaired performance could be maintained."</p> <p>"Unimpaired performance can be maintained for a period of 5 minutes at a temperature of 71.1°C and a vapor pressure of 19.9 mm Hg. However, in a strict interpretation of the results, it must be specified that this conclusion holds only for light to moderate workloads involving psychomotor performance."</p> <p>"Decrements in psychomotor performance (tracking) and mental performance (mental arithmetic) when these functions are performed in a time shared manner, will occur fairly quickly after exposure to 71.1°C and a vapor pressure of 19.9 mm Hg. Because of the specific experimental design used, this experiment does not permit ruling out the possibility that decrements with these task combinations will occur immediately upon reaching temperature."</p> |
| <p>Provins, K.A. and Bell, C.R. Effects of heat stress on the performance of two tasks running concurrently. <u>Journal of Experimental Psychology</u>, 1970, <u>85</u>(1), 40-44.</p>                                                                                               | <p>Unacclimatized subjects were given two exposures of 20°/15°C (dry bulb/wet bulb) and one exposure to 40°/35°C with an air movement of approximately 50 ft/min.</p> <p>During the first 45 minutes in the chamber, subjects sat and read magazines. During the next 2 hr. and 10 min. they "performed four 20-min. runs on a peripheral vigilance task concurrently with performance on a five-choice serial reaction time task."</p>                                                                                                                                                                                                                                                                                                          | <p>"The initial effect of exposure to heat in the present study appears to have been beneficial as the errors recorded on the fast-paced serial reaction time task were at their lowest during the first run in the hot climate. However, continued exposure to the heat produced a further significant increase in body temperature and caused a clearly defined deterioration in performance, although results recorded toward the end of the heat exposure were no worse than those recorded in the control runs in the cool climate."</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |

## HEAT AND PERFORMANCE

4.5

## Results

## Task

## Citation

Grether, W.F. Human performance at elevated environmental temperatures. *Aerospace Medicine*, 1973, 44(7), 747-755.

TABLE 1. SUMMARY OF RESULTS FOR TIME ESTIMATION AS AFFECTED BY HEAT EXPOSURE

| Authors                 | Tasks                                                   | Heat Conditions                                                            |         | Major Findings                                                         |
|-------------------------|---------------------------------------------------------|----------------------------------------------------------------------------|---------|------------------------------------------------------------------------|
|                         |                                                         | Heat                                                                       | Cooling |                                                                        |
| Buckley (1966)          | Counting at 1/sec                                       | Scuba diving in water at 14° C, causing lowered body temp                  |         | Slower counting after cold water exposure                              |
| Ball (1963)             | Judgement of metronome rate, counting, and tapping rate | Elevation of body temperature by immersion of legs in hot water            |         | Correlation of body temperature with time judgement                    |
| Reil and Provins (1963) | Counting at 1/sec rate                                  | Exposure to 92°F for 1.25 hr                                               |         | About 16% decrease in time to count to 100                             |
| Fox et al. (1967)       | Counting and tapping at specified rates                 | Subject in vapor barrier suit and body temp elevated about 2°C by air flow |         | Time judgement speeded up by elevated body temperature                 |
| Francis (1927)          | Tapping                                                 | Elevation of body temperature by diathermy                                 |         | Consistent increase in tapping speed with increase in body temperature |
| Houghland (1933)        | Counting at 1/sec                                       | Elevation of body temperature by illness and diathermy                     |         | Consistent increase in counting rate with increase in body temperature |
| Kleber et al. (1963)    | Estimation of 1/sec periods                             | Exposure to 106°F moist heat, causing body temp rise of 1.3-1.6°F          |         | About 21% reduction in time judged as 1/sec                            |

"A number of other investigators have shown a consistent relation between elevation of body temperature and such tasks as estimation of time duration, speed of counting at a 1/second rate, and speed of tapping. The results are summarized in Table 1."

TABLE II. SUMMARY OF DATA ON REACTION TIME AS AFFECTED BY HEAT EXPOSURE

| Authors                        | Tasks                                                                       |                      | Heat Conditions                                                                                                                  |                                                                       | Major Findings                                             |  |
|--------------------------------|-----------------------------------------------------------------------------|----------------------|----------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------|------------------------------------------------------------|--|
|                                | Simple visual reaction time                                                 | Choice reaction time | Subjects in impermeable suit on treadmill, with and without water cooling — temperatures 30° to 50°C; exposure duration variable | Reaction time not affected by temperature conditions                  |                                                            |  |
| Bauer and Shvarts (1971)       |                                                                             |                      | ET 65° & 95°F, 2 hr exposure                                                                                                     |                                                                       | Increased misses of peripheral lights during heat exposure |  |
| Brazill (1958)                 | Choice reaction time to lights at 20°, 50°, & 80° in right & left periphery |                      |                                                                                                                                  |                                                                       |                                                            |  |
| Gretler <i>et al.</i> (1971)   | Choice reaction time                                                        |                      | ET 72° & 88°F, 95-min exposures                                                                                                  | Reaction time increased during heat exposure                          |                                                            |  |
| Fraser & Jackson (1955)        | Serial reaction test                                                        |                      | Ambient, 90° & 104°F, 90-95% rel hum, 1- & 2 hr exposure                                                                         | Small but sig. increase in reaction time at max heat level            |                                                            |  |
| Kleinman <i>et al.</i> (1978)  | Simple and choice reaction times to lights                                  |                      | Diurnal variation in body temperature                                                                                            | Shorter reaction times in afternoon when body temperature was highest |                                                            |  |
| Loringood <i>et al.</i> (1967) | Simple visual reaction time                                                 |                      | Ambient and 125.6°F with 25-40% relative humidity, 60 min exposure before testing                                                | Shorter reaction times during heat exposure                           |                                                            |  |
| Morhead & Barnes (1969 & 1970) | Reaction time measured during helicopter flight                             |                      | Variety of operational temperatures up to 118°F                                                                                  | Reaction time increased at high temperatures                          |                                                            |  |
| Paylor (1959)                  | Serial reaction test                                                        |                      | Cool, 100°F with low humidity, & 90°F with high humidity — exposure duration about 1 hr                                          | Poorer performance during heat condition                              |                                                            |  |
| Bailey & Parker (1967)         | Simple visual auditory reaction time                                        |                      | Ambient and ET 86°F for 6 hr                                                                                                     | Shorter reaction times during heat exposure                           |                                                            |  |

"It seems quite reasonable that heat exposure could speed up simple reactions while causing slower performance on more complex reaction time tasks."



TABLE IV. SUMMARY OF DATA ON TRACKING TASKS AS AFFECTED BY HEAT EXPOSURE

| Authors                   | Tasks                                                                   | Heat Conditions                                    | Major Findings                                                                   |
|---------------------------|-------------------------------------------------------------------------|----------------------------------------------------|----------------------------------------------------------------------------------|
| Burill (1958)             | 1-D pursuit tracking                                                    | ET 65°, 92°F, 2-hr exposure                        | Poorer performance during heat exposure                                          |
| Carpenter (1950)          | 1-D pursuit tracking with weighted control                              | ET 78°, 81°, 87°, 92°F 1-hr exposure before test   | Performance impaired as temperature increased                                    |
| Gardner et al. (1971)     | 2-D compensatory tracking                                               | ET 70° & 98°F, 95-min exposures                    | Slight performance decrement during heat exposure                                |
| Hamprino et al. (1969)    | 2-D compensatory tracking, combined with mental arithmetic & monitoring | 75°, 140°, 160°F, 30-min exposures                 | Performance impaired at highest temperature                                      |
| MacKworth (1948)          | 1-D pursuit tracking with weighted control                              | ET 79°, 81°, 87.5°, 92°F, 3-hr exposures           | Poorer performance at higher temperatures                                        |
| McDonald & Barnes (1970)  | Flight of helicopters                                                   | Variety of operational temperatures up to 118°F    | Pilot performance decreased at high temperatures                                 |
| Pepler (1953)             | 1-D pursuit tracking                                                    | Exp 1, ET 66°, 76°, 84°, 91°F, 2-hr exposures      | Performance impaired as temperature increased                                    |
| Pepler (1953)             | 1-D pursuit tracking, two levels of incentive                           | Exp 6, ET 76°, 81°, 86°, 91°F, 2-hr exposures      | Performance greatly affected by level of incentive, only slightly by temperature |
| Pepler (1959)             | 1-D pursuit tracking                                                    | ET 65°, 92°F about 1-hr exposure                   | Poorer performance during heat condition                                         |
| Pepler (1959)             | 1-D pursuit tracking                                                    | 116°F/101°F, 30-min exposures                      | Tracking error increased during time of exposure                                 |
| Ridley & Parker (1967)    | 2-D pursuit & 2-D compensatory tracking                                 | Ambient and ET 86°F, 6-hr exposure                 | Apparently performance not affected by heat                                      |
| Talbot & Wehrkamp (1954)  | Rotary pursuit test                                                     | 50°, 70°, 85°, 100°F, 20-min exposures before test | Poorer performance at both low and high temperatures                             |
| Waters & Smith (1946)     | Two-hand balance test                                                   | ET 72°, 80°, 87°F, 2 3/4-hr exposures              | Performance impaired at highest temperature                                      |
| Waters & MacKworth (1945) | Transfer of balls in rotating dish                                      | Ambient & ET 91°F                                  | Poorer performance during exposure to heat                                       |

"With minor exceptions, the tracking studies are quite consistent in showing poorer performance as the temperature level increases. Fig. 2 shows, however, that the performance changes lower around zero unit if the ET reaches about 85°F. At higher temperatures there is considerable scatter in the data points, but the general trend is definitely downward."

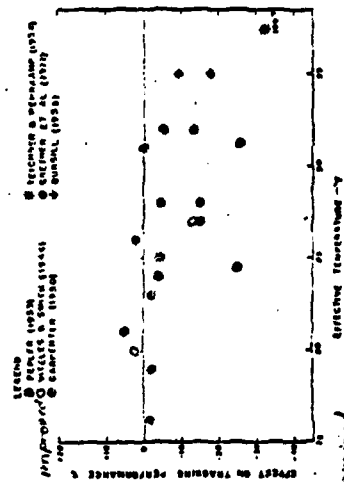


Fig. 2. Summary of tracking data plotted as percent change in performance with increase in Effective Temperature.

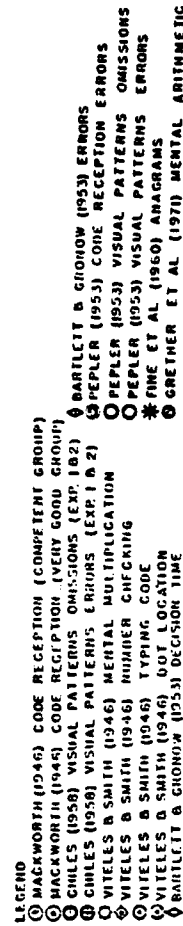
## HEAT AND PERFORMANCE

4.9

TABLE V. SUMMARY OF DATA ON COGNITIVE AND SOME SKILLED TASKS AS AFFECTED BY HEAT EXPOSURE

| Authors                   | Tasks                                               | Heat Conditions                                                                           | Major Findings                                                                        |
|---------------------------|-----------------------------------------------------|-------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------|
| Alm and Jones (1967)      | Digit span, coding, letter repetition, intelligence | ET 113° & 319°C, 100 min exposure                                                         | Generally little effect from heat, except for increased speed on intelligence test    |
| Bartlett & Groswen (1953) | Judgment of collision course                        | Ambient, 80°/70°F, 90°/80°F, & 100°/70°F, 1-hr exposures                                  | No effect of heat on decision time and errors                                         |
| Blackley & Lyman (1950)   | Mental arithmetic and number checking               | 160°, 200° & 235°F, exposure time limited by physiological tolerance                      | Generally performance decreased as physiological limit was approached                 |
| Blackley & Lyman (1951)   | Flight simulation                                   | 160°, 200°, & 235°F, exposure time limited by physiological tolerance                     | Errors increased as physiological limit was approached                                |
| Chiles (1958)             | Matching of visual patterns                         | ET 76°, 81°, 86°, 91°F, 55-min exposures                                                  | No consistent effects of heat on performance                                          |
| Fine et al. (1960)        | Anagram solving                                     | 70°F/51°F, 70°F/68°F, 93°F/70.5°F, & 95°F/92°F, 6-1/2 hr exposures                        | No effect of heat on performance                                                      |
| Ghorel & Kim (1962)       | Multiplication of numbers                           | ET from 70° to 90.1°F, 2 hr exposures                                                     | Some increase in errors at highest temperature                                        |
| Grether et al. (1971)     | Mental arithmetic                                   | ET 70° & 81°F, 95-min exposures                                                           | No effects of temperature on performance                                              |
| Hampton et al. (1960)     | Mental arithmetic                                   | 75°, 140°, & 160°F, 30-min exposures                                                      | Significant performance decrement at highest temperature                              |
| Hampton et al. (1972)     | Flight simulation                                   | 77°F (45% rel hum), 110°F (22% rel hum), & 140°F (11% rel hum), 30-min exposures          | Pilot performance decreased at higher temperatures                                    |
| Kamison & Helander (1972) | Digit symbol coding                                 | Exposure to sauna bath                                                                    | No differences in performance before and after sauna bath                             |
| Mackworth (1946)          | Reception of Morse code                             | ET from 79° to 97°F, 3-hr exposures                                                       | Increase in errors with increasing temperature. Sharp increase at highest temperature |
| Moskowitz & Barnes (1970) | Flight of helicopter                                | Operational cockpit temperatures up to 110° & 118°F                                       | Pilot performance decreased, and variability increased at higher temperatures         |
| Pepler (1953)             | Morse code reception                                | Temperatures from 80°F/70°F to 105°F/95°F, 3-hr exposures, subjects acclimated to tropics | Increased errors at higher temperatures during afternoon sessions                     |
| Pepler (1953)             | Matching of visual patterns                         | ET 76°, 81°, 86°, & 91°F, 90-min exposures                                                | Some increase in errors with increase in temperature                                  |
| Vitelles & Smith (1946)   | Mental multiplication                               | ET 71°F, 5-1/2 hr exposures                                                               | No consistent effect of temperature on performance                                    |

Fig. 3. Summary of cognitive test data plotted as percent change in performance with increase in Effective Temperature.



"As can be seen from the summary in Table V, the types of tests cover a broad range of complex tasks. All of them involve a considerable amount of reasoning, judgment, or other kinds of central nervous system activities."

"As for the other plots of vigilance and tracking performance, cognitive performance scores remain approximately normal or even surpass normal levels until ET exceeds 85°F. Above 85°F ET the data fall into two clusters. Most of the data points continue to cluster near or just below the normal performance line. There is another cluster of data points showing performance decrements of 30% or greater. All of the data in this smaller cluster came from two studies--by Mackworth using Morse code reception, and Pepler using complex decision-making involving matching of visual patterns....The wide scatter in the data points in Fig. 3 can probably be attributed to variations in the nature of the studies and to the normal variability in such performance measurements."

"Probably the most consistent and important finding in the studies covered by this review is the lack of reliable performance decrements in the range of temperature between the comfort zone and about 85°F ET. At environmental temperatures higher than this, significant performance decrements were found in most studies. The trend of performance decrements against temperature can be seen most clearly in Fig. 1, 2, and 3. These findings would seem to be of considerable practical importance for setting of environmental tolerance limits. They would seem to be very important, also, from a theoretical standpoint, and lead one to search for a possible physiological explanation. Is it possible that 85°F ET represents the approximate upper limit for physiological compensation to maintain normal body temperature? Are the decrements in performance above 85°F ET a reflection of a rise in internal temperature because the compensatory capabilities of the body have been exceeded?

"The preceding questions appear to have an affirmative answer. A study by Lind is particularly relevant. While exposed to a considerable range of environmental temperatures, three nude subjects performed light (180 kcal/hr), medium (300 kcal/hr), or heavy (420 kcal/hr) work on a treadmill. Among the recorded measures was equilibrium rectal temperature, the stable body temperature reached after 30 min to an hour of exposure. A curve for Lind's three subjects, drawn from his data for the medium work condition, is shown in Fig. 4. There is clearly a plateau up to about 80°F ET, at which point there is an upward inflection of the curve. For the light work the upward trend begins at about 83°F ET. Clearly, the range of Effective Temperatures in which Lind's subjects could maintain a stable rectal temperature agrees very well with the range in which normal human performance is maintained, as shown in this review."

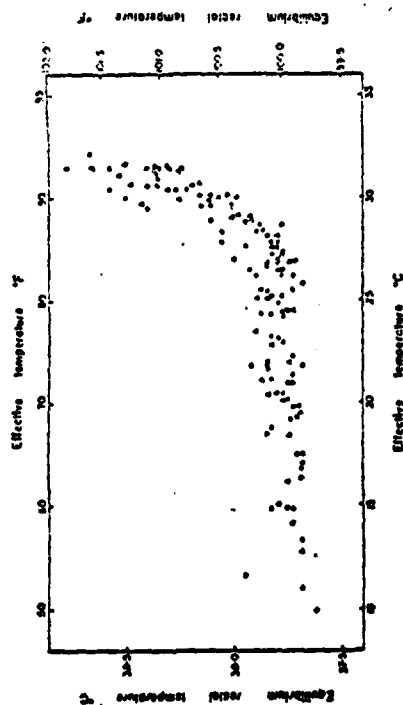


Fig. 4. The levels of rectal temperature equilibrium of three subjects exposed to climates with ET values ranging from 10° to 31.5°C (50° to 88.8°F). From Lind (1963).

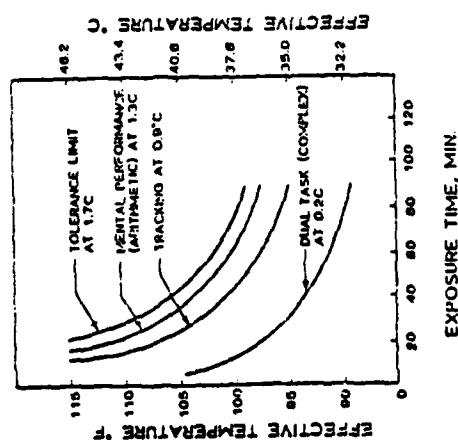
# HEAT AND PERFORMANCE 4.11

| Citation                                                                                                                                                               | Task                                                                                                                                                                                                                                                                                                                                                                                      | Results                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Ramsey, J. and Morrissey, S. Isodecrement curves for task performance in hot environments. <u>Applied Ergonomics</u> , June 1978, 9(2), 66-72.                         | Literature on tracking, visual and auditory reaction time, visual vigilance, eye-hand co-ordination, choice reaction time, mental tasks and complex tasks was reviewed. Predictive isodecrement models and boundary conditions for each set of tasks were generated.                                                                                                                      | "Curves of both reaction time and mental tasks show that increases in time and/or temperature increase the likelihood of impaired performance. On the other hand the tracking, complex, and vigilance tasks all show isodecrement curves which are primarily dependent upon temperature alone; this is not to imply that the normal vigilance and other task decrements which occur over time are not present, but rather that the set of curves depict significant changes in performance due to temperature at any given time."                                                                                                                                                                                                                                                                                       |
| Hancock, P.A. Mental performance impairment in heat stress. <u>Proceedings of the Human Factors Society--24th Annual Meeting</u> , 1980, 363-366.                      | "This review of mental performance in heat stress suggests that decrement in mental task proficiency is a function of imminent thermo-physiological collapse. Such a position is in direct contrast to the proposal of Wing ... who states that the temperature duration curve for mental performance lies well below a comparable physiological tolerance curve at every point in time." |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
| Hancock, P.A. Heat stress impairment of mental performance: A revision of tolerance limits. <u>Aviation, Space, and Environmental Medicine</u> , 1981, 52(3), 177-180. | Hancock reviewed the articles used by Wing in determining his heat stress tolerance curve to propose an alternative interpretation.                                                                                                                                                                                                                                                       | "This review of mental performance in heat stress suggests that decrement in mental task proficiency is a function of imminent thermophysiological collapse. This position is in direct contrast to the statement by Wing that the temperature duration curve for mental performance lies well below a comparable physiological tolerance curve at every point in time."<br><br>"The current curvilinear description may be robust in terms of morphology although susceptible to alteration in absolute level from various factors. Among these, acclimatization, subject motivation, and specific task motor skill may serve to elevate the curve, while concurrent exercise and increasing task response complexity may act to depress the curve, reducing the absolute level at which decrement would first occur." |

## Citation

Manscock, P.A. The limitation of human performance in extreme heat conditions. Proceedings of the Human Factors Society--25th Annual Meeting, 1981, 74-78.

## Task



## Results

The curves give the exposure time at an effective temperature that results in the indicated body temperature rise. They also give the increase in body temperature that are the thresholds for performance decrements on dual or complex tasks, tracking, and mental (arithmetic) performance. These temperature limits "are not immutable relationships but rather, are subject to alteration from subject variables (i.e., sex, somatotype, acclimatization, motivation, concomitant exercise and specific task skill). One factor that emerges as influential in limiting impairment onset is required task response complexity. Both response selection and response execution vary systematically across the three behavior task categories. The suggestion is advanced that there is an inverse relationship between task response complexity and core temperature increase which connotes efficient performance limitation. This currently awaits experimental investigation."

Fig. Performance in heat declines as body temperature rises. The curves give the length of time at a temperature to achieve the indicated body temperature rise. Thus 90 min in a 35 C effective temperature environment will give a rise of body temperature of about 0.9 C; at this rise, tracking performance will begin to decline.

The study examined the effects of induced cortical hyperthermia on central and peripheral visual reaction time. Reaction time was studied in a task in which subjects pressed the button corresponding to the number of lights illuminated on one of three panels. The experimental heat conditions were control, placebo, and heat. Heat, to induce cortical hyperthermia, was administered by means of a heat helmet.

Manscock, P.A. and Dirkin, G.R. Central and peripheral visual choice-reaction time under conditions of induced cortical hyperthermia. Perceptual and Motor Skills, 1982, 54, 395-402.

"Reaction time under cortical heat stress was slower than both the placebo and the control condition and...the placebo condition was also reliably slower than the control condition."

"Rates of errors were lower for the heat condition than the control condition. ...Current results suggest that performance variation is related to a speed-accuracy trade-off where subjects became more conservative by slowing response and reducing errors as cortical temperature was elevated."

# HEAT AND PERFORMANCE 4.13

| Citation                                                                                                                                                                                                                                                                                                                                                                                                                                        | Task                                                                                                                                                                                                                                                                                                                                                                                                                     | Results                                                                                              |    |    |    |    |     |    |    |    |    |    |      |    |   |   |    |    |      |    |    |    |    |    |      |    |    |    |    |    |                                                                                                                                                                                                    |             |            |      |    |      |   |      |    |      |    |                                                                                                                                                                                                                                                                                                                                                                                                                               |             |            |    |    |    |    |      |    |   |    |    |    |      |    |    |    |    |    |      |    |    |    |    |    |      |    |    |    |   |    |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------|----|----|----|----|-----|----|----|----|----|----|------|----|---|---|----|----|------|----|----|----|----|----|------|----|----|----|----|----|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------|------------|------|----|------|---|------|----|------|----|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------|------------|----|----|----|----|------|----|---|----|----|----|------|----|----|----|----|----|------|----|----|----|----|----|------|----|----|----|---|----|
| Meese, G.B., Rok, R., Lewis, M.I., and Wynn, W.P. The effects of moderate cold and heat stress on the potential work performance of industrial workers. The subjects were exposed to two series of conditions. The cold series was run at 6°, 12°, 18°, and 24°C. The hot series was run at 20°, 26°, 32°, and 38°C. The two series differed in the temperature and in the clothing worn by the subjects. A number of simulated tasks were run. | The objective was to study the effects of moderate cold and heat stress on the potential work performance of industrial workers. The subjects were exposed to two series of conditions. The cold series was run at 6°, 12°, 18°, and 24°C. The hot series was run at 20°, 26°, 32°, and 38°C. The two series differed in the temperature and in the clothing worn by the subjects. A number of simulated tasks were run. | The results of the study are given below.                                                            |    |    |    |    |     |    |    |    |    |    |      |    |   |   |    |    |      |    |    |    |    |    |      |    |    |    |    |    |                                                                                                                                                                                                    |             |            |      |    |      |   |      |    |      |    |                                                                                                                                                                                                                                                                                                                                                                                                                               |             |            |    |    |    |    |      |    |   |    |    |    |      |    |    |    |    |    |      |    |    |    |    |    |      |    |    |    |   |    |
| Cold Series: The following is a summary of the temperatures at which subjects had their best performance for the cold series on different tasks.                                                                                                                                                                                                                                                                                                | Hot Series: The following is a summary of the overall significant best performance for the hot series on the different tasks.                                                                                                                                                                                                                                                                                            | The temperature distribution of best performance, irrespective of significance is as follows.        |    |    |    |    |     |    |    |    |    |    |      |    |   |   |    |    |      |    |    |    |    |    |      |    |    |    |    |    |                                                                                                                                                                                                    |             |            |      |    |      |   |      |    |      |    |                                                                                                                                                                                                                                                                                                                                                                                                                               |             |            |    |    |    |    |      |    |   |    |    |    |      |    |    |    |    |    |      |    |    |    |    |    |      |    |    |    |   |    |
| Occurrence of best performance (percentage)                                                                                                                                                                                                                                                                                                                                                                                                     | Occurrence of best performance (percentage)                                                                                                                                                                                                                                                                                                                                                                              | Occurrence of best performance (percentage)                                                          |    |    |    |    |     |    |    |    |    |    |      |    |   |   |    |    |      |    |    |    |    |    |      |    |    |    |    |    |                                                                                                                                                                                                    |             |            |      |    |      |   |      |    |      |    |                                                                                                                                                                                                                                                                                                                                                                                                                               |             |            |    |    |    |    |      |    |   |    |    |    |      |    |    |    |    |    |      |    |    |    |    |    |      |    |    |    |   |    |
| <table><tr><th>Temperature</th><th>All Groups</th><th>BM</th><th>BF</th><th>WM</th><th>WF</th></tr><tr><td>6°C</td><td>19</td><td>18</td><td>11</td><td>11</td><td>34</td></tr><tr><td>12°C</td><td>10</td><td>3</td><td>3</td><td>21</td><td>10</td></tr><tr><td>18°C</td><td>31</td><td>45</td><td>41</td><td>29</td><td>15</td></tr><tr><td>24°C</td><td>40</td><td>33</td><td>46</td><td>33</td><td>41</td></tr></table>                    | Temperature                                                                                                                                                                                                                                                                                                                                                                                                              | All Groups                                                                                           | BM | BF | WM | WF | 6°C | 19 | 18 | 11 | 11 | 34 | 12°C | 10 | 3 | 3 | 21 | 10 | 18°C | 31 | 45 | 41 | 29 | 15 | 24°C | 40 | 33 | 46 | 33 | 41 | <table><tr><th>Temperature</th><th>Occurrence</th></tr><tr><td>20°C</td><td>19</td></tr><tr><td>26°C</td><td>8</td></tr><tr><td>32°C</td><td>62</td></tr><tr><td>38°C</td><td>12</td></tr></table> | Temperature | Occurrence | 20°C | 19 | 26°C | 8 | 32°C | 62 | 38°C | 12 | <table><tr><th>Temperature</th><th>All Groups</th><th>BM</th><th>BF</th><th>WM</th><th>WF</th></tr><tr><td>20°C</td><td>15</td><td>9</td><td>16</td><td>18</td><td>21</td></tr><tr><td>26°C</td><td>22</td><td>13</td><td>19</td><td>24</td><td>28</td></tr><tr><td>32°C</td><td>42</td><td>61</td><td>42</td><td>48</td><td>21</td></tr><tr><td>38°C</td><td>20</td><td>17</td><td>23</td><td>9</td><td>31</td></tr></table> | Temperature | All Groups | BM | BF | WM | WF | 20°C | 15 | 9 | 16 | 18 | 21 | 26°C | 22 | 13 | 19 | 24 | 28 | 32°C | 42 | 61 | 42 | 48 | 21 | 38°C | 20 | 17 | 23 | 9 | 31 |
| Temperature                                                                                                                                                                                                                                                                                                                                                                                                                                     | All Groups                                                                                                                                                                                                                                                                                                                                                                                                               | BM                                                                                                   | BF | WM | WF |    |     |    |    |    |    |    |      |    |   |   |    |    |      |    |    |    |    |    |      |    |    |    |    |    |                                                                                                                                                                                                    |             |            |      |    |      |   |      |    |      |    |                                                                                                                                                                                                                                                                                                                                                                                                                               |             |            |    |    |    |    |      |    |   |    |    |    |      |    |    |    |    |    |      |    |    |    |    |    |      |    |    |    |   |    |
| 6°C                                                                                                                                                                                                                                                                                                                                                                                                                                             | 19                                                                                                                                                                                                                                                                                                                                                                                                                       | 18                                                                                                   | 11 | 11 | 34 |    |     |    |    |    |    |    |      |    |   |   |    |    |      |    |    |    |    |    |      |    |    |    |    |    |                                                                                                                                                                                                    |             |            |      |    |      |   |      |    |      |    |                                                                                                                                                                                                                                                                                                                                                                                                                               |             |            |    |    |    |    |      |    |   |    |    |    |      |    |    |    |    |    |      |    |    |    |    |    |      |    |    |    |   |    |
| 12°C                                                                                                                                                                                                                                                                                                                                                                                                                                            | 10                                                                                                                                                                                                                                                                                                                                                                                                                       | 3                                                                                                    | 3  | 21 | 10 |    |     |    |    |    |    |    |      |    |   |   |    |    |      |    |    |    |    |    |      |    |    |    |    |    |                                                                                                                                                                                                    |             |            |      |    |      |   |      |    |      |    |                                                                                                                                                                                                                                                                                                                                                                                                                               |             |            |    |    |    |    |      |    |   |    |    |    |      |    |    |    |    |    |      |    |    |    |    |    |      |    |    |    |   |    |
| 18°C                                                                                                                                                                                                                                                                                                                                                                                                                                            | 31                                                                                                                                                                                                                                                                                                                                                                                                                       | 45                                                                                                   | 41 | 29 | 15 |    |     |    |    |    |    |    |      |    |   |   |    |    |      |    |    |    |    |    |      |    |    |    |    |    |                                                                                                                                                                                                    |             |            |      |    |      |   |      |    |      |    |                                                                                                                                                                                                                                                                                                                                                                                                                               |             |            |    |    |    |    |      |    |   |    |    |    |      |    |    |    |    |    |      |    |    |    |    |    |      |    |    |    |   |    |
| 24°C                                                                                                                                                                                                                                                                                                                                                                                                                                            | 40                                                                                                                                                                                                                                                                                                                                                                                                                       | 33                                                                                                   | 46 | 33 | 41 |    |     |    |    |    |    |    |      |    |   |   |    |    |      |    |    |    |    |    |      |    |    |    |    |    |                                                                                                                                                                                                    |             |            |      |    |      |   |      |    |      |    |                                                                                                                                                                                                                                                                                                                                                                                                                               |             |            |    |    |    |    |      |    |   |    |    |    |      |    |    |    |    |    |      |    |    |    |    |    |      |    |    |    |   |    |
| Temperature                                                                                                                                                                                                                                                                                                                                                                                                                                     | Occurrence                                                                                                                                                                                                                                                                                                                                                                                                               |                                                                                                      |    |    |    |    |     |    |    |    |    |    |      |    |   |   |    |    |      |    |    |    |    |    |      |    |    |    |    |    |                                                                                                                                                                                                    |             |            |      |    |      |   |      |    |      |    |                                                                                                                                                                                                                                                                                                                                                                                                                               |             |            |    |    |    |    |      |    |   |    |    |    |      |    |    |    |    |    |      |    |    |    |    |    |      |    |    |    |   |    |
| 20°C                                                                                                                                                                                                                                                                                                                                                                                                                                            | 19                                                                                                                                                                                                                                                                                                                                                                                                                       |                                                                                                      |    |    |    |    |     |    |    |    |    |    |      |    |   |   |    |    |      |    |    |    |    |    |      |    |    |    |    |    |                                                                                                                                                                                                    |             |            |      |    |      |   |      |    |      |    |                                                                                                                                                                                                                                                                                                                                                                                                                               |             |            |    |    |    |    |      |    |   |    |    |    |      |    |    |    |    |    |      |    |    |    |    |    |      |    |    |    |   |    |
| 26°C                                                                                                                                                                                                                                                                                                                                                                                                                                            | 8                                                                                                                                                                                                                                                                                                                                                                                                                        |                                                                                                      |    |    |    |    |     |    |    |    |    |    |      |    |   |   |    |    |      |    |    |    |    |    |      |    |    |    |    |    |                                                                                                                                                                                                    |             |            |      |    |      |   |      |    |      |    |                                                                                                                                                                                                                                                                                                                                                                                                                               |             |            |    |    |    |    |      |    |   |    |    |    |      |    |    |    |    |    |      |    |    |    |    |    |      |    |    |    |   |    |
| 32°C                                                                                                                                                                                                                                                                                                                                                                                                                                            | 62                                                                                                                                                                                                                                                                                                                                                                                                                       |                                                                                                      |    |    |    |    |     |    |    |    |    |    |      |    |   |   |    |    |      |    |    |    |    |    |      |    |    |    |    |    |                                                                                                                                                                                                    |             |            |      |    |      |   |      |    |      |    |                                                                                                                                                                                                                                                                                                                                                                                                                               |             |            |    |    |    |    |      |    |   |    |    |    |      |    |    |    |    |    |      |    |    |    |    |    |      |    |    |    |   |    |
| 38°C                                                                                                                                                                                                                                                                                                                                                                                                                                            | 12                                                                                                                                                                                                                                                                                                                                                                                                                       |                                                                                                      |    |    |    |    |     |    |    |    |    |    |      |    |   |   |    |    |      |    |    |    |    |    |      |    |    |    |    |    |                                                                                                                                                                                                    |             |            |      |    |      |   |      |    |      |    |                                                                                                                                                                                                                                                                                                                                                                                                                               |             |            |    |    |    |    |      |    |   |    |    |    |      |    |    |    |    |    |      |    |    |    |    |    |      |    |    |    |   |    |
| Temperature                                                                                                                                                                                                                                                                                                                                                                                                                                     | All Groups                                                                                                                                                                                                                                                                                                                                                                                                               | BM                                                                                                   | BF | WM | WF |    |     |    |    |    |    |    |      |    |   |   |    |    |      |    |    |    |    |    |      |    |    |    |    |    |                                                                                                                                                                                                    |             |            |      |    |      |   |      |    |      |    |                                                                                                                                                                                                                                                                                                                                                                                                                               |             |            |    |    |    |    |      |    |   |    |    |    |      |    |    |    |    |    |      |    |    |    |    |    |      |    |    |    |   |    |
| 20°C                                                                                                                                                                                                                                                                                                                                                                                                                                            | 15                                                                                                                                                                                                                                                                                                                                                                                                                       | 9                                                                                                    | 16 | 18 | 21 |    |     |    |    |    |    |    |      |    |   |   |    |    |      |    |    |    |    |    |      |    |    |    |    |    |                                                                                                                                                                                                    |             |            |      |    |      |   |      |    |      |    |                                                                                                                                                                                                                                                                                                                                                                                                                               |             |            |    |    |    |    |      |    |   |    |    |    |      |    |    |    |    |    |      |    |    |    |    |    |      |    |    |    |   |    |
| 26°C                                                                                                                                                                                                                                                                                                                                                                                                                                            | 22                                                                                                                                                                                                                                                                                                                                                                                                                       | 13                                                                                                   | 19 | 24 | 28 |    |     |    |    |    |    |    |      |    |   |   |    |    |      |    |    |    |    |    |      |    |    |    |    |    |                                                                                                                                                                                                    |             |            |      |    |      |   |      |    |      |    |                                                                                                                                                                                                                                                                                                                                                                                                                               |             |            |    |    |    |    |      |    |   |    |    |    |      |    |    |    |    |    |      |    |    |    |    |    |      |    |    |    |   |    |
| 32°C                                                                                                                                                                                                                                                                                                                                                                                                                                            | 42                                                                                                                                                                                                                                                                                                                                                                                                                       | 61                                                                                                   | 42 | 48 | 21 |    |     |    |    |    |    |    |      |    |   |   |    |    |      |    |    |    |    |    |      |    |    |    |    |    |                                                                                                                                                                                                    |             |            |      |    |      |   |      |    |      |    |                                                                                                                                                                                                                                                                                                                                                                                                                               |             |            |    |    |    |    |      |    |   |    |    |    |      |    |    |    |    |    |      |    |    |    |    |    |      |    |    |    |   |    |
| 38°C                                                                                                                                                                                                                                                                                                                                                                                                                                            | 20                                                                                                                                                                                                                                                                                                                                                                                                                       | 17                                                                                                   | 23 | 9  | 31 |    |     |    |    |    |    |    |      |    |   |   |    |    |      |    |    |    |    |    |      |    |    |    |    |    |                                                                                                                                                                                                    |             |            |      |    |      |   |      |    |      |    |                                                                                                                                                                                                                                                                                                                                                                                                                               |             |            |    |    |    |    |      |    |   |    |    |    |      |    |    |    |    |    |      |    |    |    |    |    |      |    |    |    |   |    |
| BM = Black Male<br>BF = Black Female<br>WM = White Male<br>WF = White Female                                                                                                                                                                                                                                                                                                                                                                    |                                                                                                                                                                                                                                                                                                                                                                                                                          | 32°C was found to be the optimum temperature for the best performance for the majority of the tasks. |    |    |    |    |     |    |    |    |    |    |      |    |   |   |    |    |      |    |    |    |    |    |      |    |    |    |    |    |                                                                                                                                                                                                    |             |            |      |    |      |   |      |    |      |    |                                                                                                                                                                                                                                                                                                                                                                                                                               |             |            |    |    |    |    |      |    |   |    |    |    |      |    |    |    |    |    |      |    |    |    |    |    |      |    |    |    |   |    |
| The best performance was at 18° or 24°C 81 percent of the time.                                                                                                                                                                                                                                                                                                                                                                                 |                                                                                                                                                                                                                                                                                                                                                                                                                          |                                                                                                      |    |    |    |    |     |    |    |    |    |    |      |    |   |   |    |    |      |    |    |    |    |    |      |    |    |    |    |    |                                                                                                                                                                                                    |             |            |      |    |      |   |      |    |      |    |                                                                                                                                                                                                                                                                                                                                                                                                                               |             |            |    |    |    |    |      |    |   |    |    |    |      |    |    |    |    |    |      |    |    |    |    |    |      |    |    |    |   |    |

| Citation                                                                                                                                                                                                               | Task                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | Results                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Rohles, Frederick H. Environmental psychology: A bucket of worms. <i>Psychology Today</i> , 1967, 1, 55-63.                                                                                                            | The time required for the rectal temperature of subjects to rise 2°F was measured when subjects were exposed to a range of temperatures in groups of 8, 18, 32, and 48. Almost all the subjects were "high-school dropouts, juvenile delinquents, parolees, and those awaiting the draft. When these people were subjected to high temperatures in groups of 48, there was continual arguing, needling, agitating, jibing, fist-fighting, threatening, and even an attempted knifing. At lower temperatures or in small groups, this behavior diminished. However, when graduate students were similarly tested, later that fall, there was no aggressive behavior even at the highest heat and crowding levels." | "Subjects in the angry condition directed higher levels of aggression against the confederate than those in the nonangry group, and those in the model condition directed stronger attacks against this person than those in the no-model group."                                                                                                                                                                                                                                                                                         |
| Griffitt, William Environmental effects on interpersonal affective behavior: Ambient effective temperature and attraction. <i>Journal of Personality and Social Psychology</i> , 1970, 15(3), 240-244.                 | "In the experiment subjects responded with respect to attraction to an anonymous stranger on the basis of inspection of the stranger's responses to a 44-item attitude scale. Subjects responded to a stranger whose attitudes were in agreement with their own on either 25% or 75% of the issues. The attraction responses were obtained under one of two temperature-humidity conditions [67.5° and 90.6° effective temperature]."                                                                                                                                                                                                                                                                             | "Attraction responses were more negative under the hot condition than under the normal condition and more positive toward an agreeing than a disagreeing stranger."                                                                                                                                                                                                                                                                                                                                                                       |
| Griffitt, William and Veitch, Russell Hot and crowded: Influences of population density and temperature on interpersonal affective behavior. <i>Journal of Personality and Social Psychology</i> , 1971, 17(1), 92-98. | Subjects were exposed to two effective temperatures and population densities to examine the effects on social-affective behavior. The effective temperatures used were 73.4° and 93.5°F. The population densities used were groups of 3 to 5 having an average of 12.73 square feet per person and groups of 12 to 16 with an average of 4.06 square feet per person. The subjects performed paper and pencil tasks and made judgments about an anonymous stranger.                                                                                                                                                                                                                                               | Subjects rated themselves as being warmer in the high density than in the low density even though the actual mean effective temperatures across density conditions were identical.<br>"Under conditions of high temperature and high population density, personal-affective, social-affective, and non-social-affective responses were found to be significantly more negative than under conditions of comfortable temperature and low population density."                                                                              |
| Baron, Robert A. and Bell, Paul A. Aggression and heat: Mediating effects of prior provocation and exposure to an aggressive model. <i>Journal of Personality and Social Psychology</i> , 1975, 31(5), 825-832.        | Subjects were exposed to "two levels of ambient temperature (cool, hot), two levels of prior anger arousal (nonangry, angry), and two levels of exposure to the behavior of an aggressive model (no model, model)." The temperature ranged from 73.2° to 74.0°F in the cool environment and from 92.4° to 95.5°F in the hot environment. In the nonangry condition, the subjects were rated in highly un-                                                                                                                                                                                                                                                                                                         | "Subjects in the angry condition directed higher levels of aggression against the confederate than those in the nonangry group, and those in the model condition directed stronger attacks against this person than those in the no-model group."<br>"High ambient temperatures served to facilitate later aggression by individuals in the nonangry condition but actually appeared to inhibit such behavior by subjects in the angry group. Further, with respect to this latter finding, there was also some indication that high tem- |

# HEAT AND PSYCHOLOGICAL RESPONSE 5.2

| Citation                                                                                                                                                                                                                               | Task                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | Results                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Baron, Robert A. and Bell, Paul A. Aggression and heat: The influence of ambient temperature, negative affect, and a cooling drink on physical aggression. <i>Journal of Personality and Social Psychology</i> , 1976, 31(3), 245-255. | Subjects were exposed to "two levels of ambient temperature (cool, hot), two levels of personal evaluation (positive, negative), and the presence of absence of a drink." Temperatures averaged 71.8° to 72.5°F in the cool environment and 92.2° to 93.5°F in the hot environment. Personal evaluations were similar to those given in Baron and Bell, 1975. Subjects were either provided or not provided with a cooling drink immediately prior to their opportunity to aggress against the victim. | peratures were more effective in reducing subsequent aggression by subjects in the angry-no model group than by those in the angry-model condition."<br><br>It was found that angry subjects exposed to uncomfortably warm environmental conditions were significantly more eager for the study to end than nonangry individuals exposed to similar conditions. Based on this finding and some comments made by subjects in postexperimental interviews, it seems reasonable to suggest that "subjects in the hot-angry group found the experimental situation so unpleasant and aversive that escape or minimization of present discomfort became the dominant tendency in their behavior of the shocks they employed and they may have reduced the intensity of these attacks in order to avoid any delays which might result from their use of strong shocks."                                                                                                                                                                                                                                                                                                                                           |
| Bell, Paul A. and Baron, Robert A. Aggression and heat: The mediating role of negative affect. <i>Journal of Applied Social Psychology</i> , 1976, 6(1), 18-30.                                                                        | Subjects "were exposed to a very positive or a very negative personal evaluation from a confederate who held attitudes similar or dissimilar to their own and were then provided with an opportunity to aggress against this person by means of electric shock. Half of the subjects participated under comfortably cool                                                                                                                                                                               | "In general, subjects receiving negative evaluations directed stronger attacks against this person than subjects receiving positive evaluations."<br><br>"In the no-drink condition, high ambient temperatures significantly facilitated aggression by subjects receiving positive evaluations but inhibited such behavior by subjects receiving negative assessments. In contrast, in the drink condition, high ambient temperatures failed to enhance aggression by subjects receiving positive evaluation and produced a reduction in aggression by those receiving negative assessments of only borderline significance."<br><br>"It seems possible that the relationship between the level of negative affect experienced by subjects and the relative dominance of aggression in their response hierarchies is curvilinear in nature. Up to some determinable point, aggression may become increasingly dominant as negative affect rises. Beyond this point, however, the tendency to engage in such behavior may decrease as other responses incompatible with aggression (e.g. escaping from the extremely aversive situation, minimization of present discomfort) become increasingly prepotent." |

"High ambient temperatures significantly facilitated aggression against a confederate from whom a positive personal evaluation was received and against a confederate holding similar attitudes to those of the subject."

"The present findings suggest that moderate levels of negative affect,

HEAT AND PSYCHOLOGICAL RESPONSE 5.3

| Citation | Task                                                                            | Results                                                                                                                                                                                                                                                                                                                                        |
|----------|---------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|          | (72-74°F) and half under uncomfortably hot (93-95°F) environmental conditions." | Whether produced by high ambient temperatures, dissimilar attitudes, or anger-provoking personal evaluations, tend to facilitate subsequent aggressive behavior. However, more extreme levels of negative affect, such as those which may be produced by combinations of several sources of such reactions, tend to inhibit overt aggression." |

6.1

ILLUMINATION

Results

Task

Citation

Schiffenbauer, Allen I.,  
Brown, Janet E., Perry,  
Pamela L., Shulack, Louise  
K., and Zanzola, Alice M.  
The relationship between  
density and crowding.  
some architectural mod-  
ifiers. Environment and  
Behavior, March 1977,  
9(1), 3-14.

The study was done on a dormitory housing females.  
All rooms were identical in size (16 x 9 ft.) and  
housed two females. Residents completed a question-  
naire designed to assess resident feelings concerning  
the size, crowdedness, and amount of light.

"Rooms which received a great deal of sunlight were judged as lighter  
and less crowded than rooms which received less sunlight. These light,  
uncrowded rooms were not, however, seen as larger."

## Citation

## Task

## Results

Hamblin, Robert L. Leadership and crises. *Sociometry*, 1958, 21, 322-335.

Groups of 3 played a modified shuffleboard game. They were "given a general but very incomplete idea about the nature and rules of the game. They were told that they were to discover the rules themselves by trying different things and by watching a light board."

Subjects were told they were competing with a group of high school students who had previously participated in a similar experiment and that they as college students were expected to do better. This was to motivate them. In order to create a crisis, for half of the groups, half way through the game the rules were changed so that what had been legal was now illegal. Also, as soon as the participants learned a new rule, the rule was changed again.

"Leaders have more influence during periods of crisis than during non-crisis periods."  
"Groups tend to replace their old leader with a new leader if the old leader does not have an obvious solution to a crisis problem."

Blake, Robert, R. and Moulton, Jane Strygley  
Perceived characteristics of elected representatives. *Journal of Abnormal and Social Psychology*, 1961, 62(3), 693-695.

Groups of eight spent approximately 12 hrs. in in-group activity. Each group then spent about 3 hrs. developing its own approach to the solution of a problem that involved producing a statement of ways to improve labor-management relations. Each group chose a representative to explain and clarify the group's solution to other groups' representatives. The representatives then ranked the solutions from "best to worst." The group chose its representative by having its members rank the other members of the group.

The group members gave each other personal "feedback" via judgments regarding how each person's behavior had been experienced by all the others according to 24 different items. The items covered the person's social tactfulness, intellectual competence, and procedural skill. The ratings were in private.

The results showed that group members "who are most preferred by their peers as representatives are distinguished from those who are not chosen in terms of being seen as possessing greater intellectual competence and procedural skill." The highly preferred representatives are not seen as possessing greater social tactfulness than members who are not chosen.

Representatives "are seen as being personally 'strong' in the sense of dominating the group, resisting conformity pressures, and facing up to problems rather than running away from them."

# LEADERSHIP

7.2

| Citation                                                                                                                                                                                                                                            | Task                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | Results                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <p>Julian, James W., Hollander, Edwin P., and Regula, C. "Robert Endorsement of the group spokesman as a function of his source of authority, competence, and success. <u>Journal of Personality and Social Psychology</u>, 1969, 11(1), 42-49.</p> | <p>Four person discussion groups developed a defense for a fictitious friend supposed to have been accused of cheating. A group spokesman then supposedly presented the defense before a board of inquiry. The choice of a spokesman, by election or appointment and by level of perceived competence, as well as his subsequent success, were controlled by the experimenter. Perceived competence was based on the frequency of contribution to the discussion which lasted 20 minutes. Group members evaluated the spokesman before and after receiving the verdict given by the board of inquiry. Members also indicated whether they would like to keep the same spokesman.</p> | <p>"There was a tendency to evaluate the elected spokesman in more positive terms than the appointed man. He was judged as having contributed more, as being better qualified, and as more accepting."</p> <p>"For the appointed spokesman, endorsement depended merely on some indication that the 'system worked,' that is, that it resulted in either a competent choice or a successful outcome. For the elected spokesman however, endorsement depended upon both a competent choice and a successful outcome. This result may be interpreted as supporting the general position that election builds higher demands by group members on the leadership role. When the spokesman was appointed, members were more readily satisfied, and responded positively to any sign of a positive result. When he was elected, members failed to support him if he was seen as incompetent or unsuccessful."</p> <p>Depending upon the members' perception of the leaders initial competence, elected leaders were more vulnerable to a withdrawal of endorsement when they had been unsuccessful in representing the group.</p> |

Hollander, Edwin P. and Julian, James W. Studies in leader legitimacy, influence and innovation. Advances in Experimental Social Psychology, 1970, 5, 33-69.

## Part 1

Four true subjects and a confederate were organized into a group. The confederate always became the leader, either by appointment or by a contrived election. The task was to choose which one of three stimulus lights on the wall went off first. Subjects were in visual isolation from each other. They were told that the leader "would report his judgment first on any trial to the group via a signal panel; he would then take account of the other members' judgments communicated to him and would report to the experimenter what he took to be the 'group judgment'; and finally he would decide the distribution of winnings within the group."

## Part 2

Subjects were formed into discussion groups. Leaders were either "elected" or "appointed." "...half of the leaders were told that they were the 'top choice' for the leader position and would lead 'Team A' and the other half were told they were the 'third choice' and would lead 'Team C.'" The teams discussed 10 problems faced by cities and ranked 4 action pro-

"Leaders seen as relatively more competent at the task were significantly more influential than were leaders seen as less competent. Effects of other leader characteristics, although not significant, are shown in trends toward greater influence exerted by the elected leader as compared with the appointed leader and the greater apparent influence of the self-oriented leader as compared with the group-oriented leader."

"Elected leaders deviated from their teams considerably more than appointed leaders, and in each case the presence of strong endorsement tended to increase this deviation."

LEADERSHIP 7.3

Results

Task

grams to alleviate them. Team leaders were separated from their teams. After receiving the rankings of the action programs, the leader was to decide which of them should be put into action.

Klein, Andrew L. Changes in leadership appraisal as a function of the stress of a simulated panic situation. Journal of Personality and Social Psychology, 1976, 34(6), 1143-1154.

The variables tested were: 2 levels of stress (threat of shock or of small monetary loss); 2 levels of leadership authority (elected or appointed); 2 conditions of leadership ("me-last" or "me-first"); and group success or failure. The procedure was as follows. Six subjects (including 2 confederates) were run as a group. After all had arrived, a leader was either "appointed" or "elected" with one of the confederates always becoming leader. Subjects tried to get their wooden cones out of a box. If they failed (which they never did) they were shocked or lost \$.25. (Subjects were given a painful sample shock of 5 mA before the experimental trial and promised that the one following failure to escape would be eight times more painful.) The leader was given 5 seconds to explain his plan for escape. He gave the order in which people were to leave with himself either being first or last.

"Shock was much more threatening than the fear of monetary loss."  
"Leaders are seen as more competent as stress increases."

The leader who goes first, and therefore uses his power to protect himself and to further jeopardize his followers, is seen more positively in all respects than the martyr-type leader who goes last.

Elected leaders were "given more attribution of responsibility than appointed leaders. This relationship only holds under low-stress situations; otherwise the difference in evaluation narrows and reverses its relationship."

## Results

## Task

## Citation

Taub, John M. and Berger, Ralph J. Extended sleep and performance: the Rip Van Winkle effect. *Psychonomic Science*, 1969, 16(4), 204-205.

"Performance on the vigilance task was significantly poorer after 11 hrs. of sleep than after 8 hrs. of sleep for both scores. ...Although the mean score on the calculation task was higher following the 8 hr. sleep condition than after the 11 hr. sleep condition, this difference was not statistically significant."

Taub, John M., Globus, Gordon G., Phosibus, Eric, and Brury, Robert. Extended sleep and performance. *Nature*, 1971, 233, 142-143.

Habitual 7-8 hr. sleepers were tested under 2 sleep conditions: 8 hrs. and 11 hrs. Upon waking, subjects performed 3 tasks: a 50 min. calculation task in which they added 100 columns of 5 two digit numbers, a 45 min. pinball task, and a 45 min. version of the Wilkinson vigilance task.

"Accuracy on the subject-paced calculation task was insensitive to changes in amount of sleep, whereas the experimenter-paced pinball and vigilance tasks proved to be sensitive measures of impaired performance following manipulation of sleep variables."

Webb, Wilse B., Agnew, Herman W. Jr., and Williams, Robert L. Effect on sleep of a sleep period time displacement. *Aerospace Medicine*, 1971, 42(2), 152-155.

Studied the effects of sleep displacement. Subjects slept from 0800 to 1600 and performed tasks from 1100 to 0700 for 4 days. Subjects "were studied during four baseline night sleep periods (2300 to 0700) followed by four-day sleep periods (0800 to 1600) and two night sleep periods (2300 to 0700)." They performed the Wilkinson Vigilance Task and the Wilkinson Addition Task.

No changes in the amount of stages 2, 3, 4, and REM sleep either in absolute amounts or percentages were found. The distribution of REM sleep within the sleep periods shifted.

Taub, John M. and Berger, Ralph J. Performance and mood following variations in the length and timing of sleep. *Psychophysiology*, 1973, 10(6), 559-570.

Ten subjects, regular 2400-0800 sleepers, slept in each of the following 5 sleep conditions and one adaptation night: 2100-0800 extended, 2100-0500 advanced-shift, 2400-0800 habitual, 0300-0800 deprivation, and 0300-1100 delayed shift.

The first task was a 5 min. addition task in which subjects heard 2 digits, added them together, added 8 to the sum, and wrote down the answer. The second task was an audio-vigilance task. Tones occurred at 2 sec. intervals, superimposed on a background of 85 dB white noise. The subjects pressed a telegraph key as soon as a "signal", a shorter tone, was detected.

After finishing the audio-vigilance task, subjects completed a mood scale in which they described their present mood by giving their first reaction to pairs of words.

"Negative affect was greater following the experimental conditions than after the H [habitual] condition [2400-0800]."

"There was a tendency for mood to be more depressed after sleep deprivation than after sleep extension."

"Anger-hostility mood scores were higher in the morning after the D [deprivation] and E [extended sleep] conditions than after the AS [advanced-shift] and DS [delayed-shift sleep] conditions."

"Significant decrements in performance and mood occurred following the experimental conditions compared with the H [habitual] condition at midday or late afternoon when testing time was held constant."

"Since there were no notable differences between the effects of altered sleep length and shifted sleep time it would seem that the overall deficits in performance and mood were primarily due to changes in times of retiring."

Results

Task

Citation

Webb, Wilae B. and Agnew, R.S., and Colquhoun, W.P. Sleep and Dreams, Introduction to General Psychology: A Self-Selection Textbook. Dubuque, Iowa: Wm. C. Brown Company Publishers, 1973.

"Several factors influence the extent to which sleep loss results in an impairment of performance. First, if the task is long (more than 30 minutes), it is likely to be sensitive to sleep loss. Second, if the subject has knowledge of his results, the effect of sleep loss is minimal. The more difficult a task is, the more sensitive it is to sleep loss. And, finally, if the subject can pace himself at a task, it is unlikely to show sleep loss effects."

Poulton, E.C., Edwards, R.S., and Colquhoun, W.P. The interaction of the loss of a night's sleep with mild heat: task variables. Ergonomics, 1974, 17(1), 59-73.

Subjects performed three tasks, tracking with peripheral lights, a five choice task, and an auditory vigilance task, under three different conditions. The conditions were working in 33°C effective temperature, after 1 night without sleep, and with the two stresses combined.

"Loss of sleep produces reliable overall deteriorations in all the measures of performance with all 3 tasks, except for false detections in the vigilance tasks."

"Mild heat produces reliable overall deteriorations only in the tracking, on gaps and percent errors in the 5 choice tasks, and on detections in the vigilance task."

"For detections at the start of the vigilance task, the combined effect of the loss of sleep and the heat is smaller than either of the separate effects. Whereas at the end of the task the combined effect is larger than either of the separate effects."

"The tracking with peripheral lights and the vigilance task show only one or two reliable deteriorations at the start of the task. With these two tasks the full statistically reliable effects of the loss of sleep and of the heat take time to develop." With the 5 choice task "both the loss of sleep and the heat produce reliable decrements during the first 5 min. on 2 out of 3 measures."

Higgins, E.A. (et.al.) The effects of a 12-hour shift in the wake-sleep cycle on physiological and biochemical responses and on multiple task performance. (FAA-AM-75-10). Civil Aeromedical Institute Federal Aviation Administration, Oklahoma City, Oklahoma, October 1975.

"Fifteen male paid volunteers (ages 20 to 28) were studied in three groups of five each. The first 4 days of the experiment they slept nights (2230 to 0600) and worked days. On the fifth night, they slept only 3 hours (2100 to 2400) before starting a 10-day period in which the wake-sleep cycle was altered by 12 hours."

"According to the subjective sleep survey, the total quantity and quality of sleep did not change significantly when the wake-sleep cycle was altered."

"According to the subjective fatigue index, the total fatigue for the awake periods was not significantly changed; however, the times within days for greatest fatigue were altered and 9 days were required for a complete reversal of the daily pattern."

"Of the physiological parameters measured, those that make the most rapid response to stress replenished in the shortest period of time after the shift. From shortest to longest mean replacement times, these were: heart rate, norepinephrine, epinephrine, potassium, sodium, internal body temperature, and 17-ketogenic steroids."

Results

Task

Citation

Higgins, E.A. (et al)  
Physiological, biochemical, and multiple-task performance responses to different alterations of the wake-sleep cycle.  
(FAA-M-76-11) Civil Aeronautical Institute  
Federal Aviation Administration, Oklahoma City, Oklahoma, November 1976.

"Three groups, each comprising five healthy, male, paid volunteers (ages 21 to 30), were studied for 11 days. Baseline data were collected for 3 days, during which subjects adhered to a day/night routine; i.e., sleeping from 2230 to 0600. On the fourth day each group took a 'flight' in a altitude chamber. Following the flight day, subjects in the first group (Group I) slept from only 0230 to 0600 and then returned to the baseline routine; subjects in the next group (Group II) had their day extended by 6 hours and began a new routine of sleeping from 0430 to 1200 for the remainder of the study; subjects in the third group (Group III) had their day compressed by 6 hours and slept from 2030 to 2400 only that fourth night and then began a new routine of sleeping from 1630 to 2400 for the final 7 days of the study."

Collins, William E. Some effects of sleep deprivation on tracking performance in static and dynamic environments.  
Journal of Applied Psychology, 1977, 62(5), 567-573.

"The influence of 34 and 55 hours of sleep deprivation on scores derived from manually tracking the localizer needle on an aircraft instrument was assessed under both static (no motion) and dynamic (whole body angular acceleration) laboratory conditions."

Hartley, L. and Shirley, E. Sleep-loss, noise and decisions. Ergonomics, 1977, 20(5), 481-489.

Subjects were tested under 3 sleep schedules. The schedules were: 8 hrs. of sleep between 2300 and 1700, 4 hrs. of sleep between 0100 and 0500, and 4 hrs. of sleep between 1300 and 1700. "Subjects experienced each sleep condition for 2 nights and 2 days on 3 successive weekends."  
Subjects discriminated between a signal and a non-signal flash of light. They were tested for one hour

"According to the physiological and biochemical measurements, there was little difference between the two 6-hour-change groups (Groups II and III), both of which required longer rephasing times than did the group that experienced sleep loss but no time change (Group I). The psychomotor performance test indicated the greatest change in the group whose day was shortened by 6 hours (Group III). The Multiple Task Performance Battery (MTPB) indicated the greatest deficit in performance for Group III and the best fastshift performance for Group II."

"In both experiments, significant decrements in dynamic tracking performance were uniformly obtained after 24 hours and more of sleep loss. Static tracking scores were less consistently affected; that is, sleep deprived subjects showed a marked increase in tracking error during the morning session after a night without sleep--probably influenced by a circadian effect--but they recovered sufficiently to be not significantly different from control subjects during the late afternoon sessions in both experiments."

"The ingestion of 10 mg of d-amphetamine after approximately 53 hours of sleep loss produced a sharp drop in errors for both static and dynamic tracking."

The general trend "is for sleep-loss to have its greatest adverse effect at the end of the test."

"Sleep loss appears to lead to an increase in the riskiness of cautious performance whereas normal sleep appears to lead to an increase in the cautiousness of cautious performance, during work."

Although there was no three way interaction of noise, sleep-schedule and time on task the effect of noise on the sleep loss conditions tended to increase the setting of the most cautious criterion.

8.4

SLEEP

| Citation                                                                                                                                                                                                         | Task                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | Results                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <p>3 times a day for both days of each sleep schedule. All the subjects had 3 to 4 hours of practice on the vigilance test before the experiment began. White noise at 70 dB or 95 dB accompanied each test.</p> | <p>"Sleep loss appeared to cause both changes in discriminability and setting of the cautious criterion, over time on task."</p> <p>The data "suggests that noise following normal sleep reduces the amount of evidence acquired from the stimulus, much as sleep loss does. Both stresses are similar in that respect. But noise following sleep loss opposes this decline in the intake of evidence from the task."</p> <p>The most that can be said between the 4 hours of daytime sleep (4D) vs 4 hours of night-time sleep (4N) is that "changes in confident hits and false alarms, discriminability and in the placement of the cautious criterion, during sleep-loss, tend to be greater in the 4N than in the 4D group."</p> | <p>"For every task, the three conditions which permitted sleep yielded higher scores (better performance) than did the two sleep deprivation conditions, and scores on the control day were numerically the best for every task except tracking."</p> <p>"Under at least some conditions of sleep deprivation, both aircraft noise and heavy workloads appear to maintain performance at higher levels than do quiet conditions and light workloads. However, both of these sets of performance scores are inferior to those attained under the same conditions following a night of sleep."</p> |
| <p>Collins, William E. Some effects of sleep deprivation and aircraft noise on complex performance. Presented at the 1981 Annual Meeting of the Aerospace Medical Association, San Antonio, Texas, May 1981.</p> | <p>"Subjects were tested as two crews of five persons each for 3-hour periods under five separate conditions: (i and ii) 24 hours of sleep deprivation, presence of aircraft noise, with and without the use of ear plugs; (iii and iv) normal sleep, presence of aircraft noise, with and without the use of ear plugs; and (v) normal sleep, ordinary laboratory room (ambient) noise, without the use of ear plugs."</p> <p>The noise level was 101 dBC.</p>                                                                                                                                                                                                                                                                       |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |

## STRESS 9.1

## Results

## Task

## Citation

- Lazarus, Richard S. Psychological Stress and Coping Process, New York: McGraw-Hill Book Company, 1966.
- "The Taylor (1953) scale of manifest anxiety, which has been the most used in experimental stress research, includes questions that touch upon varying kinds and levels of response. For example, there are questions dealing with physiological signs or correlates of anxiety as experienced by the individual, chronic affective states described by such words as 'apprehension' or 'anxiety,' anxiety-producing cognitions, and interpersonal attitudes commonly found in the anxious clinical patient."
- "Another widely employed anxiety questionnaire is that of Sarason and Mandler (1952)." The Sarason and Mandler scale is "designed to be specific to test-taking situations while the Taylor scale is designed to measure generalized anxiety."
- "A check list developed by Nozlis and Nowlis (1956) has a number of factor-analyzed scales which are presumably independent. The measured affects (or mood variables) are concentration, aggression, pleasantness, activation-deactivation, egotism, social affection, depression, and anxiety." There are other check lists by Clyde (1963), Jacobs, Capek, and Meechan (1959), and Zuckerman, Lubin, Vogel, and Valerius (1964).

Wherry, Robert J., Jr. and Curran, Patrick M. A model for the study of some determiners of psychological stress: Initial experimental research. Organizational Behavior and Human Performance, 1966, 1, 220-231.

The authors present a model of the determiners of psychological stress. They "felt that most, if not all, of the variance of what is generally understood by the concept of 'threatening' could be subsumed under 3 elements." These elements are the perceived probability that the event would occur, the perceived proximity of the event, and the perceived unpleasantness of the event if it occurs. They felt that these 3 elements must be controlled in order to accurately research threat.

In this experiment, electric shock was the threat because it was credibly threatening, actually safe, and ethically acceptable. Perceived probability of the event occurring was controlled by stating it. The perceived proximity of the event was controlled by having a count down to the point where a shock could be given. The perceived unpleasantness of the event was controlled by giving the subjects sample shocks at the beginning of the experiment.

Subjects performed a four-choice, color discrimination task. They were presented with one of four stimuli and were to select the corresponding response key. The task was self-paced. The percent correct of the responses in each 20-second period were the measures of performance.

Performance during the early part of the session was apparently facilitated by anticipatory physical threat stress (APTS). Then, as time zero approached, "the APTS increased beyond an optimal amount, and performance deteriorated. These results would support a hypothesis that APTS is curvilinearly related to performance."

The data suggests that performance deterioration will be reduced in situations if the event occurs when the subject expects it and does not occur when he perceives it as unlikely to happen."

The data suggests that less deterioration will "be expected from individuals whose previous exposures had been under high threat perceptions."

"Even when the amount of threat is carefully equated for all subjects, some will be more susceptible than will others."

## Results

## Task

## Citation

Fontaine, Craig W. Behavior-  
al and psychoneuroline ef-  
fects of working in a  
stressful environment.  
Transactions of the  
American Nuclear Society  
and the European Nuclear  
Society 1980 International  
Conference on World  
Nuclear Energy-  
Accomplishments and  
Perspectives, Nov. 16-  
21, 1980, 35, 170.

"The human physiological system responds to the stress by increasing the flow of both epinephrine and norepinephrine. However, only epinephrine excretion was found to be statistically significant. Importantly, this increase in epinephrine excretion was found to be linearly related to the experimental stress levels."

"It was determined that the cognitive, motor, and information utilization tasks were greatly impaired while perceptual functioning proved to be resistant to all levels of stress."

"It was determined that females deal with stress in a far more physiologically economic manner, while displaying job performance which was no different from that of males."

Solomon, Sheldon, Holmes,  
David S., and McCaul,  
Kevin D. Behavioral  
control over aversive  
events: Does control  
that requires effort  
reduce anxiety and  
psychological arousal?  
*Journal of Personality  
and Social Psychology*,  
1980, 39(4), 729-736.

The experiment was a 3 x 2 x 2 factorial experiment. The factors were (unavoidable threat, avoidable threat, no threat) x (low effort, high effort) x (anticipation period, performance period). The experimenter found the maximum number of digits the subject would listen to and then repeat back in the order in which they had been presented. To manipulate effort, the number of digits the subject had to repeat was varied. In order to manipulate the level of threat, the subject was told that shocks would be administered randomly, that he could avoid being shocked by repeating the digits correctly, or by not mentioning shocks. Data was taken during an anticipation period and a performance period. The data collected included an 18 item anxiety scale, pulse volume, and pulse rate.

"Exercising control over an aversive event decreased subjects' anxiety but that decrease occurred only when the control was easy to exercise."

"The ability to exercise control over an aversive event decreased subjects' physiological arousal during the time that the subjects simply anticipated the event."

"Actually exercising control over an aversive event did not result in a lower level of physiological arousal."

In summary, "it appears that the use of personal control that involves active involvement may not be effective for reducing subjective and/or physiological stress if the control is difficult to exercise or if the aversive situation is one in which most time is spent confronting/controlling rather than anticipating."

SECTION IV

Critical Human Factors Problems for the  
Survival Shelter Occupant

## Critical Human Factors Problems for the Survival Shelter Occupant

### Introduction

The literature surveys that uncovered the research in the two previous sections emphasized the many factors that needed to be considered for the survival shelter occupant. Moreover, the factors were so diverse that there was a need to synthesize, in a brief yet meaningful compilation, a priority listing of the problems considered critical to shelter habitability. As a result, a survey was conducted to identify these problems. This report presents results of this survey.

### Procedure

Four individuals who worked closely on the development of the annotated bibliographies in Sections I and II of this report and 7 from the Federal Emergency Management Agency in Washington listed as many factors as they could recall that they considered critical to survival shelter habitability. From this exercise, 93 different items were identified. Following this, 6 individuals who were involved in the present project rated the importance of these items on a scale of 1 to 9 (1 was unimportant and 9 was very important). The Appendix gives mean ratings for each of the 93 items.

### Results and Discussion

The items were divided into three categories: environment, shelter, and personal. A breakdown according to these categories is presented in Table 1 for the 23 items (representing one-fourth of the items) having mean ratings of 7 or higher.

Table 1. Critical Items for Shelter Habitability

| <u>Environment</u> | (6 items; mean rating, 7.5)              | <u>Mean rating</u> |
|--------------------|------------------------------------------|--------------------|
|                    | 1. Radiation sensing equipment           | (9.0)              |
|                    | 11. Air movement/ventilation             | (7.5)              |
|                    | 12. Temperature                          | (7.3)              |
|                    | 20. Humidity                             | (7.0)              |
|                    | 21. Illumination                         | (7.0)              |
|                    | 22. Sq. ft. per person                   | (7.0)              |
| <u>Shelter</u>     | (11 items; mean rating, 7.6)             |                    |
|                    | 2. Waste and sanitation facilities       | (8.5)              |
|                    | 4. Medical facilities                    | (8.0)              |
|                    | 5. Quality of leadership                 | (8.0)              |
|                    | 6. Water amount                          | (8.0)              |
|                    | 7. Communication equipment               | (7.8)              |
|                    | 8. Strength of leadership                | (7.7)              |
|                    | 15. Pedal Vehicle Kit (PVK)              | (7.3)              |
|                    | 16. Access to outside communication      | (7.2)              |
|                    | 17. Failure of vital instruments         | (7.2)              |
|                    | 18. Shelter ready for occupancy          | (7.0)              |
|                    | 23. Amount of leadership                 | (7.0)              |
| <u>Personal</u>    | (6 items; mean rating, 7.5)              |                    |
|                    | 3. Presence or absence of family members | (8.2)              |
|                    | 9. Type of sickness                      | (7.6)              |
|                    | 10. Overall health                       | (7.5)              |
|                    | 13. Fear of unknown                      | (7.3)              |
|                    | 14. Length of stay - known/unknown       | (7.3)              |
|                    | 18. Pre-existing personal problems       | (7.1)              |

In examining this table, note that Section II of this report specifically identified research in the environmental areas of temperature, illumination, and crowding. In turn, leadership, which was mentioned in three of the shelter items, was also one of the topics of the literature survey. The personal items are addressed in the articles on stress,

anxiety and crises. Articles on sleep and sleep disturbances also are listed even though the two "problem items" related to sleep were rated 6.2 and 6.0 respectively, in order of importance. Note that there were 11 items related to the shelter itself but only 6 items were listed in the personal and environmental categories. Moreover, each of these categories shared equal importance with mean overall ratings of 7.5.

In summary, the results of this survey point out areas where planning emphasis and research are needed. As such, it should serve as a guide for shelter designers, shelter leaders and trainees of shelter leaders.

APPENDIX

Mean Ratings of the Factors Considered  
to be Critical to Shelter Occupants

| <u>Rating</u> | <u>Item</u>                                    |
|---------------|------------------------------------------------|
| 9.0           | Radiation sensing equipment                    |
| 8.5           | Waste & sanitation facilities                  |
| 8.2           | Presence or absence of family members          |
| 8.0           | Medical facilities                             |
| 8.0           | Quality of leadership                          |
| 8.0           | Water amount                                   |
| 7.8           | Communication equipment                        |
| 7.7           | Strength of leadership                         |
| 7.6           | Type of sickness                               |
| 7.5           | Overall health                                 |
| 7.5           | Air movement/ventilation                       |
| 7.3           | Temperature                                    |
| 7.3           | Fear of unknown                                |
| 7.3           | Length of stay, known or unknown               |
| 7.3           | Pedal Vehicle Kit (PVK)                        |
| 7.2           | Access to outside communications               |
| 7.2           | Failure or condition of vital instruments      |
| 7.1           | Pre-existing personal problems                 |
| 7.0           | Shelter readiness for occupancy                |
| 7.0           | Humidity                                       |
| 7.0           | Illumination                                   |
| 7.0           | Square feet per person                         |
| 7.0           | Amount of leadership                           |
| 6.8           | CO <sub>2</sub> , CO, & O <sub>2</sub> changes |
| 6.8           | Shelter rules and how they are determined      |
| 6.7           | Tools for repair of PVK                        |
| 6.7           | Operation of PVK                               |
| 6.7           | Rules concerning weapons                       |
| 6.6           | Food amount                                    |
| 6.6           | Number of people in group                      |
| 6.6           | Cubic feet per person                          |

6.6 Renewable vs. non-renewable light source  
6.6 Fire fighting equipment  
6.6 Similarity of thinking between the group & the leader  
6.5 Familiarity with Civil Defense procedure  
6.3 Type and quality of personal possessions  
6.3 Quality of communications within the shelter  
6.2 Mental & emotional maturity  
6.2 Crowbar or other tools in case you have to force your way out  
6.1 Drug dependencies  
6.1 Smokers vs. non-smokers  
6.1 Sleep deprivation  
6.1 Democracy - autocracy  
6.1 Availability of handbook  
6.1 Rationing vs. no rationing  
6.0 Length of time in which to prepare for occupancy  
6.0 Sleep patterns  
6.0 Water quality  
6.0 Night watch  
6.0 Having something to do vs. boredom  
6.0 Lack of psychological support  
5.8 Noise  
5.6 A feeling of not being in control, having no responsibility  
or authority  
5.6 Frequency of problem solving, decision making tasks  
5.6 Type of emergency broadcasts  
5.6 Threat of fire  
5.5 Food quality  
5.5 Monitoring communication  
5.5 Monitoring temperature & radiation sensing equipment  
5.5 Assigned vs. elected leader  
5.5 Simulation of 'shelter danger'  
5.3 Proximity to other shelters  
5.3 Lack of privacy  
5.3 Cleanliness of room  
5.3 Sleeping facilities (bunks, mattresses)  
5.2 Cleanliness of occupants  
5.1 Range of ages  
5.1 Friends - strangers ratio

5.1 Temperature sensing equipment  
5.1 Odor  
5.1 1-way vs. 2-way communication  
5.1 Shadow observers as agitators  
5.0 Pre-occupancy processing duration  
5.0 Furniture  
5.0 Bathing facilities  
4.8 Male - Female ratio  
4.8 Training during occupancy  
4.8 Late arrivals  
4.8 Threat of looters  
4.6 Availability of reading material  
4.6 Awareness of being observed  
4.6 Absence of pets  
4.3 Recreation  
4.3 Exercise  
4.1 Storage facilities  
4.1 Religious (activities)  
4.1 Too much exercise  
4.0 Change of clothes  
4.0 Amount of wall space vs. total space  
3.6 Season of the year  
3.5 Rural vs. urban population  
3.3 Ethnic background  
2.8 Religious background

## DISTRIBUTION LIST

(Number of Copies - One unless otherwise indicated)

Federal Emergency Management Agency  
Research Office  
Attn: Assistant Associate Director  
National Preparedness Programs  
Washington, D. C. 20472 (60)

Assistant Secretary of the Army (R&D)  
Attn: Assistant for Research  
Washington, D. C. 20306

Defense Technical Information Center  
Cameron Station  
Alexandria, Virginia 22314 (12)

Oak Ridge National Laboratory  
Attn: Librarian  
P. O. Box X  
Oak Ridge, Tennessee 37830

Mr. Phillip M. Smith  
Associate Director  
Natural Resources & Comm. Services  
Office of Science and Technology Policy  
Executive Office Bldg.  
Washington, D. C. 20500

Los Alamos Scientific Laboratory  
Attn: Document Library  
Los Alamos, New Mexico 87544

The RAND Corporation  
ATTN: Document Library  
1700 Main Street  
Santa Monica, CA 90401

Chief of Naval Research  
Washington, D. C. 20306

Mr. Thomas Watermann  
IITRI  
10 West 35th Street  
Chicago, Illinois 60616 (2)

Emergency Technology Division  
Oak Ridge National Laboratory  
Attn: Librarian  
Oak Ridge, Tennessee 37830

Director  
Lovelace Foundation  
5200 Gibson Boulevard, S.E.  
Albuquerque, New Mexico 87108

Commanding Officer  
U.S. Naval C.E. Laboratory  
Attn: Document Library  
Port Hueneme, CA 93401

Director, Army Matericals and Mechanic  
Research Center  
Attn: Technical Library  
Watertown, Massachusetts 02172

Civil Engineering Center AF/PRECET  
Wright Patterson Air Force Base  
Ohio 45433

Air Force Weapons Laboratory  
Attn: SUL Technical Library  
Kirtland Air Force Base  
Albuquerque, New Mexico 87117

Mr. Lewis V. Spencer  
Room C313-Building 245  
Washington, D. C. 20234

Mr. Samuel Kramer, Chief  
Office of Federal Building Technology  
Center for Building Technology  
National Bureau of Standards  
Washington, D. C. 20234

Director, U.S. Army Engineer  
Waterways Experiment Station  
P. O. Box 611  
Attn: Document Library  
Vicksburgh, Mississippi 39180

Director, U.S. Army Ballistic  
Research Laboratory  
Attn: Document Library  
Aberdeen Proving Ground, MD 21005

Dr. William Chenault  
Human Sciences Research Inc.  
Westgate Industrial Park  
7710 Old Springhouse Road  
McLean, VA 22102

Mr. Raymond Alger  
SRI International  
Menlo Park, California 94025

Mr. John Rempel  
Center for Planning and Research  
2483 E. Bayshore  
Palo Alto, CA 94303

Mr. James Bech Associates  
4216 Los Palos Avenue  
Palo Alto, California 94306

Dr. John Cockayne  
Senior Scientist  
Science Applications, Inc.  
1710 Goodridge Drive  
P. O. Box 303  
McLean, VA 22101

Mr. Leo A. Schmidt  
Institute for Defense Analyses  
Program Analysis Division  
400 Army-Navy Drive  
Arlington, Virginia 22202

Applied Research and Associates  
Attn: Cornelius J. Higgins  
2601 Wyoming Blvd., Suite H-1  
Albuquerque, New Mexico 87112

Mr. Kenneth Kaplan  
Management Science Associate  
P. O. Box 239  
Los Altos, California 94022

Mr. Stanley Martin  
SRI International  
Menlo Park, California 94025

Mr. Anatole Longinow  
College of Engineering  
Valparaiso University  
Valparaiso, Indiana 46383

Dr. Clarence R. Mehl  
Division 1112  
Sandia National Laboratories  
Box 5800  
Albuquerque, New Mexico 87185

AFWL/Civil Engineering Division  
Kirtland Air Force Base  
New Mexico 87117

Mr. Jud Leech  
BDM Corporation  
1801 Randolph Road, S.E.  
Albuquerque, New Mexico 87106

GARD Inc.  
7449 N. Natchez Ave.  
Niles, IL 60648

Mr. Donald A. Bettge  
Office of Civil Preparedness  
National Preparedness Programs  
Federal Emergency Management Agency  
Washington, D. C. 20472

Mr. W. L. Huff  
USAE Waterways Experiment Station  
Post Office Box 631  
Vicksburg, Mississippi 39180

Mr. Richard Laurino  
Center for Planning and Research  
2483 East Bayshore - Suite 104  
Palo Alto, California 94303

Director, Defense Nuclear Agency  
Attn: Tom Kennedy  
Washington, D. C. 20305

Director, Defense Nuclear Agency  
Attn: Technical Library  
Washington, D. C. 20305

Mr. Carl Wiehle  
Defense Intelligence Agency  
Attn: CKW DB-4C2  
Washington, D. C. 20301

Mr. C. Wilton  
Scientific Service Inc.  
517 East Bayshore Drive  
Redwood City, California 94060 (2)

Mr. Fred Sauer  
Physics International Company  
2700 Merced Street  
San Leandro, California 94577

Dikewood Corporation  
1613 University Boulevard, N. E.  
Albuquerque, New Mexico 87102

Harvey G. Ryland  
Ryland Research, Inc.  
5266 Hollister Avenue - Suite 324  
Santa Barbara, California 93111

Mr. Ed L. Hill  
Research Triangle Institute  
P. O. Box 12194  
Research Triangle Park, NC

Bell Telephone Laboratories  
Attn: Mr. E. Witt  
Mr. R. May  
Mr. J. Foss  
Whippany Road  
Whippany, N.J. 07981 (3)

Chief of Engineers  
Department of the Army  
Attn: ENGEME-RD  
Washington, D. C. 20314

Mr. Walmer (Jerry) Strobe  
5600 Columbia Pike - Suite 101  
Bailey's Crossroads, Virginia 22041

Mr. Joseph E. Minor  
Texas Technological College  
Lubbock, Texas 79408

H. L. Murphy Associates  
P. O. Box 1727  
San Mateo, California 94401

Prof. R. K. Pefley  
University of Santa Clara  
Santa Clara, California 95053

Dr. Barry Bowman  
Lawrence Livermore National Laboratory  
University of California  
P. O. Box 808  
Livermore, CA 94550

Mr. William Taylor  
Ballistic Research Laboratories  
Aberdeen Proving Grounds, MD 21005 (2)

Dr. Ben Sussholz  
R1/2094  
TRW  
One Space Park  
Redondo Beach, California 90278

UNCLASSIFIED

DECISION MAKING UNDER HIGH THERMAL STRESS - Report No. 1 An  
Annotated Bibliography on Environmental Stressors and  
Behavior

by F. H. Rohles, Jr., S. A. Konz and R. J. Krohn  
Institute for Environmental Research, Kansas State  
University, Manhattan, Kansas 66506  
August 1982, 58 pages, FEMA Work Unit 1131 B

Abstract This research will study the effects of exposure to the stressors of a simulated survival shelter on decision making. A proposed 5 year effort is summarized that involves a literature search, the development of a test battery to assess the decision making skill, tests in simulated shelters and the development of strategies to assist in the decision making process. Corollary efforts involve the use of the bicycle ventilating device for charging nickel-cadmium dry cell batteries and relationship

between shelter occupant density and shelter occupant numbers. This, the first report of the project, contains an annotated bibliography of the research literature on the effects upon behavior of the stressors of temperature, crowding, sleep disturbances, panic, stress, and anxiety. In several searches of the literature a total of 900 articles were identified; from these 113 were selected as being critical to understanding the human response in the survival shelter environment. These together with 36 studies on fallout shelters are reviewed.

In addition, a survey was conducted which identified 93 problem areas for the survival shelter occupant. These fell equally into three main categories: survival shelter, personal, and environment.

UNCLASSIFIED

DECISION MAKING UNDER HIGH THERMAL STRESS - Report No. 1 An  
Annotated Bibliography on Environmental Stressors and  
Behavior

by F. H. Rohles, Jr., S. A. Konz and R. J. Krohn  
Institute for Environmental Research, Kansas State  
University, Manhattan, Kansas 66506  
August 1982, 58 pages, FEMA Work Unit 1131 B

Abstract This research will study the effects of exposure to the stressors of a simulated survival shelter on decision making. A proposed 5 year effort is summarized that involves a literature search, the development of a test battery to assess the decision making skill, tests in simulated shelters and the development of strategies to assist in the decision making process. Corollary efforts involve the use of the bicycle ventilating device for charging nickel-cadmium dry cell batteries and relationship

between shelter occupant density and shelter occupant numbers. This, the first report of the project, contains an annotated bibliography of the research literature on the effects upon behavior of the stressors of temperature, crowding, sleep disturbances, panic, stress, and anxiety. In several searches of the literature a total of 900 articles were identified; from these 113 were selected as being critical to understanding the human response in the survival shelter environment. These together with 36 studies on fallout shelters are reviewed.

In addition, a survey was conducted which identified 93 problem areas for the survival shelter occupant. These fell equally into three main categories: survival shelter, personal, and environment.

between shelter occupant density and shelter occupant numbers. This, the first report of the project, contains an annotated bibliography of the research literature on the effects upon behavior of the stressors of temperature, crowding, sleep disturbances, panic, stress, and anxiety. In several searches of the literature a total of 900 articles were identified; from these 113 were selected as being critical to understanding the human response in the survival shelter environment. These together with 36 studies on fallout shelters are reviewed.

In addition, a survey was conducted which identified 93 problem areas for the survival shelter occupant. These fell equally into three main categories: survival shelter, personal, and environment.

#### UNCLASSIFIED

DECISION MAKING UNDER HIGH THERMAL STRESS - Report No. 1 An  
Annotated Bibliography on Environmental Stressors and Behavior

by F. H. Rohles, Jr., S. A. Konz and R. J. Krohn  
Institute for Environmental Research, Kansas State  
University, Manhattan, Kansas 66506  
August 1982, 58 pages, FEMA Work Unit 1131 B

Abstract This research will study the effects of exposure to the stressors of a simulated survival shelter on decision making. A proposed 5 year effort is summarized that involves a literature search, the development of a test battery to assess the decision making skill, tests in simulated shelters and the development of strategies to assist in the decision making process. Corollary efforts involve the use of the bicycle ventilating device for charging nickel-cadmium dry cell batteries and relationship

between shelter occupant density and shelter occupant numbers. This, the first report of the project, contains an annotated bibliography of the research literature on the effects upon behavior of the stressors of temperature, crowding, sleep disturbances, panic, stress, and anxiety. In several searches of the literature a total of 900 articles were identified; from these 113 were selected as being critical to understanding the human response in the survival shelter environment. These together with 36 studies on fallout shelters are reviewed.

In addition, a survey was conducted which identified 93 problem areas for the survival shelter occupant. These fell equally into three main categories: survival shelter, personal, and environment.

#### UNCLASSIFIED

DECISION MAKING UNDER HIGH THERMAL STRESS - Report No. 1 An  
Annotated Bibliography on Environmental Stressors and Behavior

by F. H. Rohles, Jr., S. A. Konz and R. J. Krohn  
Institute for Environmental Research, Kansas State  
University, Manhattan, Kansas 66506  
August 1982, 58 pages, FEMA Work Unit 1131 B

Abstract This research will study the effects of exposure to the stressors of a simulated survival shelter on decision making. A proposed 5 year effort is summarized that involves a literature search, the development of a test battery to assess the decision making skill, tests in simulated shelters and the development of strategies to assist in the decision making process. Corollary efforts involve the use of the bicycle ventilating device for charging nickel-cadmium dry cell batteries and relationship

DECISION MAKING UNDER HIGH  
THERMAL STRESS

Report No. 1 An Annotated Bibliography  
on Environmental Stressors and Behavior

Prepared by  
Frederick H. Rohles, Jr.  
Stephan A. Konz  
Rachel J. Krohn  
Institute for Environmental Research  
Kansas State University  
Manhattan, Kansas 66506

Prepared for  
Federal Emergency Management Agency  
National Preparedness Programs Directorate  
Washington, D.C. 20472  
under  
Contract EMW-C-0589  
FEMA Work Unit No. 1131 B

August, 1982

REVIEW NOTICE: This report has been reviewed in the Federal Emergency Management Agency and approved for publication. Approval does not signify that the contents necessarily reflect the views and policies of the Federal Emergency Management Agency.

Distribution of this report is unlimited.

## Summary

With the increased concern over nuclear warfare, a renewed effort is being directed towards the study of behavior in the survival shelter environment. One of these behaviors involves decision making. In October 1981, The Institute for Environmental Research at Kansas State University entered into a contract with the Federal Emergency Management Agency; the title of the contract was "Decision Making Under High Thermal Stress." The work on this contract was planned to progress through several stages. In the first stage, a search was to be made of the relevant literature. The second stage involved the development of tasks that measured the decision making process. This was to be followed by tests in simulated survival shelter environments. Finally, strategies would be developed to assist in decision making when this behavior suffered a decrement in accuracy and speed. These strategies then would be incorporated into a manual. Subsequently, the effectiveness of decision-making training would be determined.

Because the thermal constituent of the environment was too limited, we expanded our goal to include the stressors of temperature, crowding, air quality, food and water restriction, reduced illumination, and electrical power and sleep disturbances; in particular, the effects of these stressors will be intensified when the occupants are under severe emotional stress.

### Decision Making

To handle the decision making aspects, four experts in the field served as either co-investigators or consultants; they identified 16 components of the decision making task.

Since there is no single instrument to measure decision making skills, tasks to measure these 16 components have either been identified or are being developed. When this is completed, the components will be combined into a single test battery. When this is completed, it will be used in the survival shelter simulation phase. This will be completed by the end of the second year of the project.

### Corollary Efforts

The Personal Ventilating Kit (PVK) consists of a bicycle-type device which when pedaled by an individual may be used to ventilate a survival shelter. The PVK was developed before the commercial development of the

nickel-cadmium re-chargeable dry cell battery which is so common-place today. As a result, we are developing a device which can be incorporated into the PVK unit that will charge nickel-cadmium batteries at the same time as the shelter is being ventilated.

A second corollary program is also planned. At present, 10 square feet per person is being allotted to each shelter occupant. This area is fixed, regardless of the number of occupants involved. Current research, however, has addressed the question of subject density (number of individuals per unit of space) as opposed to social density (the number of people in the group in question). In terms of the survival shelter the question that is generated is "does 10 sq. ft. per person for 20 people represent the same amount of crowding as 10 sq. ft. per person when 200 people are involved?" Beyond the intuitive "no" answer to this question, other problems may surface. These involve performance, group pressures, leadership and attitude. In the corollary effort, social density and spatial density will be addressed as stressors that may affect decision making.

This report presents the results of the literature search; it contains an annotated bibliography of the research on the effects upon behavior of the stressors of temperature, crowding, sleep disturbances, panic, stress, and anxiety. In several searches of the literature a total of 900 articles were identified; from these 113 were selected as being critical to understanding the human response in the survival shelter environment. These together with 36 studies on fallout shelters are reviewed.

In addition, a survey was conducted which identified 93 problem areas for the survival shelter occupant. These fell equally into three main categories: survival shelter, personal, and environment.

MEI  
-8