TEMPERATURE-TIME EFFECTS ON FEMALE PERFORMANCE OF SEDENTARY TASKS

by

SADASHIV BANTVAL PAI, B.E.

A THESIS

IN

INDUSTRIAL ENGINEERING

Submitted to the Graduate Faculty
of Texas Tech University in
Partial Fulfillment of
the Requirements for
the Degree of

MASTER OF SCIENCE

IN

INDUSTRIAL ENGINEERING

Approved

Accepted

May, 1976

HC
805
T3
1976
No. 17
cop. 2

AE-805

ACKNOWLEDGEMENTS

I would like to thank Dr. J. D. Ramsey, Professor of Industrial Engineering, for his patience and continued guidance during the preparation of the thesis.

I also would like to thank Professor W. D. Sandel and Dr. C. L. Burford for their helpful criticism and valuable suggestions. Also, appreciation is expressed to the staff and students in the Department of Industrial Engineering who participated in gathering the data.

TABLE OF CONTENTS

		Page
ACKNOWLEDGEMENTS		ii
LIST OF TABLES		iv
LIST OF FIGURES		viii
I.	INTRODUCTION	1
	Statement of the Problem	
	Purpose and Scope	
	Review of the Literature	
II.	RESEARCH PROCEDURE	33
	Experimental Variables	
	Experimental Tasks and Equipment	
	Statistical Design	
	Experimental Procedure	
III.	RESULTS AND DISCUSSION	53
	Temperature-Time Effects	
	Session Effect	
	Subjective Responses	
	Environmental Conditions	
IV.	SUMMARY, CONCLUSIONS AND RECOMMENDATIONS FOR FUTURE RESEARCH	90
	Summary	
	Conclusions	
	Suggestions for Future Research	
V.	LIST OF REFERENCES	111
VI.	APPENDIX	115

LIST OF TABLES

Table		Page
1.	WBGT LEVELS SELECTED FOR THIS STUDY AND THE CORRESPONDING DRY BULB AND WET BULB TEMPERATURES	35
2.	THE SEQUENCE FOR LIGHT STIMULI FOR THE REACTION TIME TASK	40
3.	EXPECTED MEAN SQUARES (2T-8C ANALYSIS, N=15)	48
4.	EXPECTED MEAN SQUARES (3T-6C ANALYSIS, N=15)	49
5.	EXPECTED MEAN SQUARES (4-T2C ANALYSIS, N=15)	49
6.	ORDER OF EXPOSURE OF GROUPS TO THE DIFFERENT WBGT LEVELS	50
7.	SUBJECTIVE RESPONSES	81
8.	ENVIRONMENTAL MEASUREMENTS	88
9.	ANALYSIS OF VARIANCE FOR PURSUIT TRACKING TASK: 2T-8C ANALYSIS	116
10.	ANALYSIS OF VARIANCE FOR PURSUIT TRACKING TASK: 3T-6C ANALYSIS	116
11.	ANALYSIS OF VARIANCE FOR PURSUIT TRACKING TASK: 4T-2C ANALYSIS	117
12.	ANALYSIS OF VARIANCE FOR EYE-HAND COORDINATION TASK: 2T-8C ANALYSIS	117
13.	ANALYSIS OF VARIANCE FOR EYE-HAND COORDINATION TASK: 3T-6C ANALYSIS	118
14.	ANALYSIS OF VARIANCE FOR EYE-HAND COORDINATION TASK: 4T-2C ANALYSIS	118
15.	ANALYSIS OF VARIANCE FOR REACTION TIME TASK: 2T-8C ANALYSIS	119

16. ANALYSIS OF VARIANCE FOR REACTION TIME TASK: 3T-6C ANALYSIS..... 119

17. ANALYSIS OF VARIANCE FOR REACTION TIME TASK: 4T-2C ANALYSIS..... 120

18. ANALYSIS OF VARIANCE FOR MULTIPLICATION TASK (SPEED): 2T-8C ANALYSIS..... 120

19. ANALYSIS OF VARIANCE FOR MULTIPLICATION TASK (SPEED): 3T-6C ANALYSIS..... 121

20. ANALYSIS OF VARIANCE FOR MULTIPLICATION TASK (SPEED): 4T-2C ANALYSIS..... 121

21. ANALYSIS OF VARIANCE FOR MULTIPLICATION TASK (PERCENT ERROR): 2T-8C ANALYSIS..... 122

22. ANALYSIS OF VARIANCE FOR MULTIPLICATION TASK (PERCENT ERROR): 3T-6C ANALYSIS..... 122

23. ANALYSIS OF VARIANCE FOR MULTIPLICATION TASK (PERCENT ERROR): 4T-2C ANALYSIS..... 123

24. ANALYSIS OF VARIANCE FOR HEART RATE: 2T-8C ANALYSIS..... 123

25. ANALYSIS OF VARIANCE FOR HEART RATE: 3T-6C ANALYSIS..... 124

26. ANALYSIS OF VARIANCE FOR HEART RATE: 4T-2C ANALYSIS..... 124

27. ANALYSIS OF VARIANCE FOR ORAL TEMPERATURE: 2T-8C ANALYSIS..... 125

28. ANALYSIS OF VARIANCE FOR ORAL TEMPERATURE: 3T-8C ANALYSIS..... 125

29. ANALYSIS OF VARIANCE FOR ORAL TEMPERATURE: 4T-2C ANALYSIS..... 126

30. ANALYSIS OF VARIANCE FOR PURSUIT TRACKING TASK: SESSION EFFECT..... 126

31. ANALYSIS OF VARIANCE FOR EYE-HAND COORDINATION TASK: SESSION EFFECT..... 127

32. ANALYSIS OF VARIANCE FOR REACTION TIME TASK: SESSION EFFECT..... 127

33. ANALYSIS OF VARIANCE FOR MULTIPLICATION TASK (SPEED): SESSION EFFECT..... 128

34. ANALYSIS OF VARIANCE FOR MULTIPLICATION TASK (PERCENT ERROR): SESSION EFFECT..... 128

35. CELL MEANS AND STANDARD DEVIATIONS FOR PURSUIT TRACKING TASK: 2T-8C ANALYSIS..... 129

36. CELL MEANS AND STANDARD DEVIATIONS FOR PURSUIT TRACKING TASK: 3T-6C ANALYSIS..... 129

37. CELL MEANS AND STANDARD DEVIATION FOR PURSUIT TRACKING TASK:4T-2C ANALYSIS..... 129

38. CELL MEANS AND STANDARD DEVIATIONS FOR HEART RATE:2T-8C ANALYSIS..... 130

39. CELL MEANS AND STANDARD DEVIATIONS FOR HEART RATE: 3T-6C ANALYSIS..... 130

40. CELL MEANS AND STANDARD DEVIATIONS FOR HEART RATE: 4T-2C ANALYSIS..... 130

41. CELL MEANS AND STANDARD DEVIATIONS FOR ORAL TEMPERATURE: 2T-8C ANALYSIS..... 131

42. CELL MEANS AND STANDARD DEVIATIONS FOR ORAL TEMPERATURE: 3T-6C ANALYSIS..... 131

43. CELL MEANS AND STANDARD DEVIATIONS FOR ORAL TEMPERATURE: 4T-2C ANALYSIS..... 131

44. CELL MEANS AND STANDARD DEVIATIONS FOR PURSUIT TRACKING:2T-8C ANALYSIS..... 132

45. CELL MEANS AND STANDARD DEVIATIONS FOR EYE-HAND COORDINATION TASK: 2T-8C ANALYSIS..... 132

46. CELL MEANS AND STANDARD DEVIATIONS FOR REACTION TIME TASK: 2T-8C ANALYSIS..... 133

47. CELL MEANS AND STANDARD DEVIATIONS FOR ORAL TEMPERATURE: 2T-8C ANALYSIS..... 133

48. CELL MEANS AND STANDARD DEVIATIONS FOR PURSUIT TRACKING: 3T-6C ANALYSIS..... 134

49. CELL MEANS AND STANDARD DEVIATIONS FOR EYE-HAND COORDINATION TASK: 3T-6C ANALYSIS..... 134

50. CELL MEANS AND STANDARD DEVIATIONS FOR REACTION TIME TASK: 3T-6C ANALYSIS..... 135

51. CELL MEANS AND STANDARD DEVIATIONS FOR HEART RATE: 3T-6C ANALYSIS..... 135

52. CELL MEANS AND STANDARD DEVIATIONS FOR ORAL TEMPERATURE: 3T-6C ANALYSIS..... 136

53. CELL MEANS AND STANDARD DEVIATIONS FOR PURSUIT TRACKING: 4T-2C ANALYSIS..... 136

54. CELL MEANS AND STANDARD DEVIATIONS FOR EYE-HAND COORDINATION TASK: 4T-2C ANALYSIS..... 136

55. CELL MEANS AND STANDARD DEVIATIONS FOR MULTIPLICATION (SPEED): 4T-2C ANALYSIS..... 137

56. CELL MEANS AND STANDARD DEVIATIONS FOR HEART RATE: 4T-2C ANALYSIS..... 137

57. CELL MEANS AND STANDARD DEVIATIONS FOR PURSUIT TRACKING TASK: SESSION EFFECT..... 137

58. CELL MEANS AND STANDARD DEVIATIONS FOR EYE-HAND COORDINATION TASK: SESSION EFFECT..... 138

59. CELL MEANS AND STANDARD DEVIATIONS FOR MULTIPLICATION (SPEED): SESSION EFFECT..... 138

LIST OF FIGURES

Figure		Page
1.	Upper limits of exposure for unimpaired mental performance (NIOSH, 1972).....	3
2.	Subject performing the reaction time task.....	41
3.	Subject performing the pursuit tracking task..	41
4.	Subject performing the eye-hand coordination task.....	43
5.	Subject performing the multiplication task....	43
6.	Plan of the layout of the task stations in the environmental chamber and the layout of the monitoring equipment.....	51
7.	Pursuit tracking task, time on target vs WBGT level.....	57
8.	Pursuit tracking task, time on target vs cycle.....	60
9.	Eye-hand coordination task, tracing time vs cycle.....	62
10.	Reaction time task, reaction time vs cycle....	64
11.	Multiplication task, speed vs cycle.....	67
12.	Heart rate vs WBGT level.....	69
13.	Heart rate vs cycle.....	71
14.	Heart rate, interaction of time and temperature.....	72
15.	Oral temperature vs WBGT level.....	74
16.	Oral temperature vs cycle.....	75
17.	Oral temperature, interaction of time and temperature.....	76
18.	Session effect, performance on tasks vs session.....	78

19. Summary of performance on pursuit tracking task (female)..... 94

20. Reaction time task, male vs female performance..... 96

21. Multiplication task, male vs female performance..... 97

22. Eye-hand coordination task, male vs female performance..... 98

23. Summary of performance on pursuit tracking task (male vs female)..... 102

24. Summary of performance on eye-hand coordination task (male vs female)..... 103

25. Summary of performance on reaction time task (male vs female)..... 104

26. Summary of performance on multiplication task (male vs female)..... 105

CHAPTER I

INTRODUCTION

Statement of the Problem

Today one-third of the world's labor force is made up of women. In the United States nearly 40% of the workers are female ("Words and Figures," 1975). Industrial tasks such as sewing garments, reading gauges, operating cranes, taking inventory, assembling small electronic components, scheduling or clerical tasks may be classified as sedentary tasks. Heat stress caused by exposure to hot environments is a common problem in many industries. Since a significant part of the industrial work force is female, a scientific study concerning the effect of temperature on the sedentary task performance of the female worker becomes important.

As individuals begin to work in hot environmental conditions, their performance can decrease due to physiological stress. For this reason many research studies have been conducted on people working in hot environmental conditions in an effort to establish some upper limits on exposure to heat stress. Most research, however, has

been conducted on male subjects and very little research has been conducted with female subjects.

The number of women in the work force is increasing every day, and women are taking jobs in fields in which they have not previously been allowed to enter. Hence, the study of performance and physiological responses of the female to hot working conditions is an increasingly relevant research need.

The National Institute for Occupational Safety and Health (NIOSH) has proposed heat stress standards which establish limits of temperature-time for sedentary tasks as shown in Figure 1 (National Institute for Occupational Safety and Health, 1972). Combinations of temperature-time above the curve represent conditions under which deterioration in performance may be expected. The temperature-time combinations below the curve represent conditions under which no deterioration in performance is to be expected. These proposed standards do not differentiate between the performance of men and women. As will be shown later in the review of the previous research studies, perceptual motor performance and physiological responses of men and women working in hot environments are quite variable, and there are often contradictions in reported differences. This research will concentrate on the sedentary task performance of

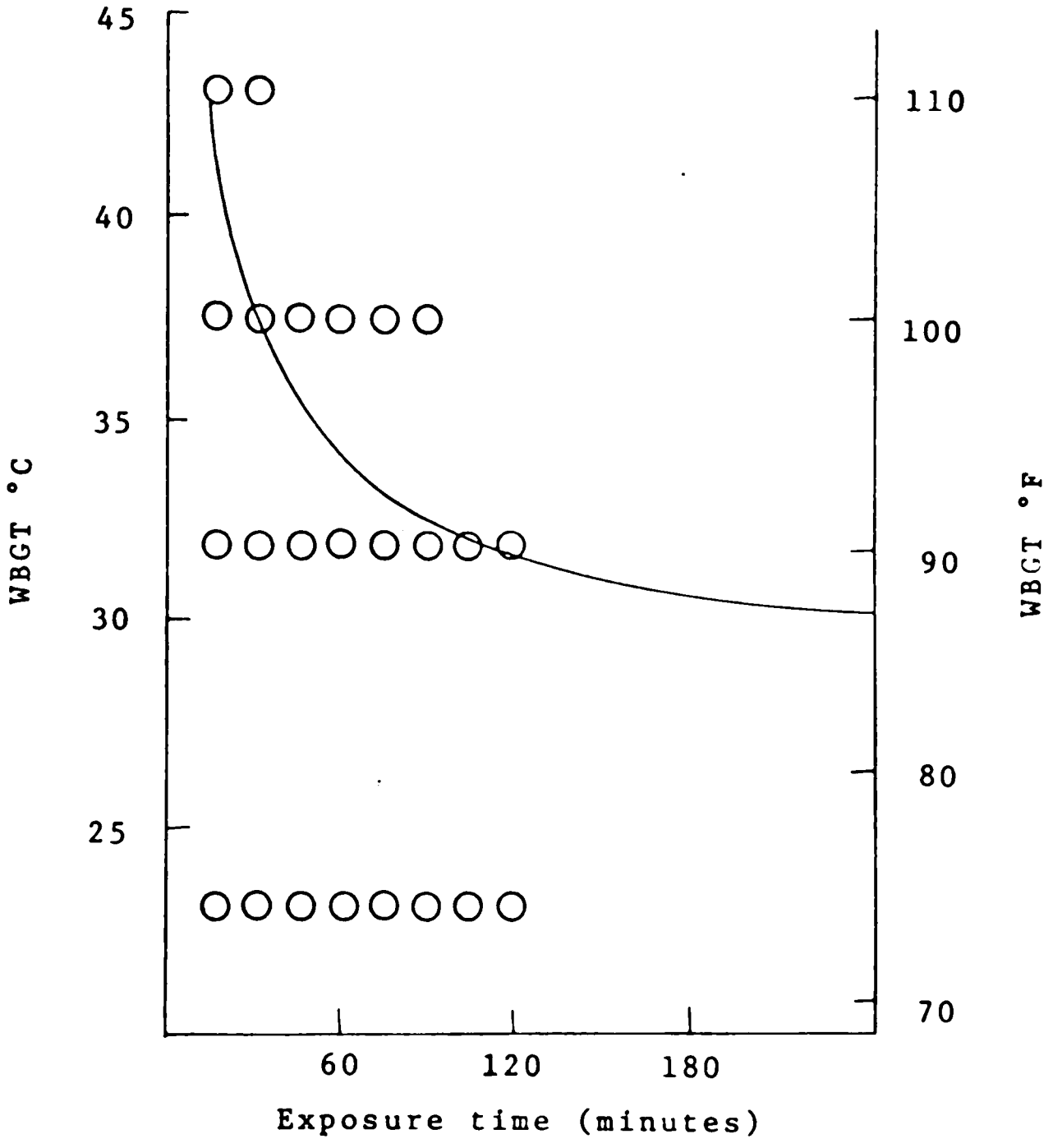


Figure 1. Upper limits of exposure for unimpaired mental performance (NIOSH, 1972). Circles represent conditions tested in this study.

females working in hot conditions as specified by the NIOSH heat stress proposals.

Purpose and Scope

The purpose of this research is to study the perceptual-motor performance of females working in hot environmental conditions in an attempt to evaluate the temperature-time limits for work in heat proposed by the National Institute for Occupational Safety and Health (NIOSH).

To assess differences between sexes, if any, performance data of females will be compared with that of male subjects which were collected concurrently during an investigation using the same research procedure.

Performance will be measured using four different sedentary tasks at four levels of temperature. The specific conditions to be investigated are summarized below and will be discussed in detail later.

A. Four sedentary tasks:
    1. Reaction time
    2. Pursuit tracking
    3. Eye-hand coordination
    4. Multiplication
B. Ambient temperatures of:
    1. 74°F (23.3°C) Wet Bulb Globe Temperature
    2. 90°F (32.2°C) Wet Bulb Globe Temperature

3. 100°F (37.8°C) Wet Bulb Globe Temperature
4. 110°F (43.3°C) Wet Bulb Globe Temperature

C. The exposure times for different WBGT levels are:

1. 74°F WBGT - 120 minutes (eight 15-minute cycles)
2. 90°F WBGT - 120 minutes (eight 15-minute cycles)
3. 100°F WBGT - 90 minutes (six 15-minute cycles)
4. 110°F WBGT - 30 minutes (two 15-minute cycles)

Review of the Literature

Human Response to Hot Environments

The level of achieved performance (Henschel, 1971) is determined by a number of interacting factors. The environment contributes only a part to the total interaction. The factors which may bring about optimum performance (or conversely, the deterioration of performance) are grouped into three categories: (1) environmental factors, (2) human factors, and (3) task factors.

The impact of the environment depends upon the amount it deviates from neutral conditions, the duration of the exposure and the amount and type of protective devices in use (e.g., clothing).

The impact of human factors is more complex. The human factors usually contribute a major role in the total environment-man-task situation. But the quantitative effect of these human factors is not known to a great extent. Much more research is required in this area.

The characteristics of the task, the level of performance required, the effect desired, and the skills involved are all concerned in determining whether deterioration in performance is likely to occur under a specific level of stress. If the demands of the task are well within the capacity of the individual, deterioration of performance is unlikely. But it is very difficult to adequately quantify the demands of the task and capacities of the individual with sufficient precision so that a demand-strain relationship may be developed.

When thermal environmental factors deviate from neutral conditions, they constitute either a heat stress or a cold stress. Since it takes a vast amount of monetary investment to create and maintain artificial environments, it is not economically feasible for all the people in the world to enjoy controlled environmental conditions. In industries such as ferrous and non-ferrous metal smelting, agriculture, glass, mining, or construction, it is not possible to control environmental conditions. Hence, not all people can avoid hot environmental conditions.

The important parameters of thermal balance in the human body can be summarized by the following simplified equation (Gagge, 1935):

$$S = M \pm R \pm C - E$$

where S = Storage: nagative (-) values indicate decreasing storage of heat; positive values indicate an increasing storage of heat

M = Matabolic heat production; always positive (+)

R = Radiation: (+) positive values indicate surrounding surface area of high temperature adding heat to the body by radiation; (-) negative values when these surfaces are of lower temperature than the body temperature

C = Convection: positive (+) when air temperature exceeds that of the body surface; negative (-) when it is lower than that of skin

E = Evaporation: always negative (-) as it removes heat from the body.

The direction of the flow of heat by convection, evaporation, and radiation depends on these environmental conditions:

1. Air temperature
2. Temperature of the surrounding objects
3. Humidity
4. Air circulation

Heat stress leads to noticeable physiological reactions in human beings which have been well documented: dilation of skin blood vessels to increase the flow of blood to the surface, sweating to facilitate heat dissipation due to evaporation, and increased skin temperature to decrease the temperature differential between the body and the environment.

In most cases a deterioration of performance, either physically or mentally or both is experienced with an increase in heat stress. The best way to avoid heat stress, when the controlling of the environmental conditions is not possible, seems to be to limit man's time of exposure to the hot environment.

Perceptual-motor performance as well as physical work performance, deteriorates when the level of thermal stress reaches some minimal level. In general, deterioration increases as the degree of thermal stress is increased. The discrepancies between different estimates of minimal thermal stress required to produce measureable deterioration of perceptual-motor function, which have been reported by various investigators, have been partially explained by Henschel (1971) on the basis of arousal theory.

Arousal theory states that for each stimulus-reaction situation, (e.g., the task performed in a study), there should be an optimal stimulus strength which would result

in maximum performance. If the stimulus is either progressively reduced or increased from the optimal, performance would be expected to progressively decrease. Under conditions where the primary task stimulus is less than optimal, the addition of another stimulus, such as thermal stress, may increase arousal and produce better performance. If the primary task stimulus is already higher than optimal, a thermal stress could cause further deterioration. If this concept is applicable, then for each different stimulus-performance situation, there would be a different minimal thermal stress level at which performance decrements would first appear. According to Henschel (1971) in most of the perceptual-motor task studies, the minimal effective thermal stress occurs between effective temperature levels of 84°F (28.9°C) and 90°F (32.2°C).

The effect of temperature and exposure duration on the perceptual-motor performance of males has been the subject of interest to many investigators. Wing (1965) reviewed fourteen experiments performed in various laboratories and proposed a curve establishing upper limits of exposure duration and temperature for unimpaired mental performance. These experiments represented different combinations of exposure time and effective temperature. The results of these studies indicated that the upper limit for unimpaired mental performance varies systematically with

exposure duration. Wing has proposed a curve by taking into account the exposure duration and the lowest temperature yielding significant impairments. The main limitations to this curve, as expressed by Wing himself, are that: (1) "The curve represents the performance threshold of artificially acclimatized military personnel" and (2) "The curve is plotted in terms of effective temperature and given effective temperature can be obtained by different combinations of temperature, humidity and air volocity." This paper by Wing served as the basic reference document for the sedentary task limits proposed by NIOSH (1972).

In their review of research literature, Ramsey et al. (1975) evaluated 26 different investigations of sedentary work tasks in heat. Evaluation of these studies revealed that the limits proposed by Wing were not supported consistently by reported research results. Ramsey et al. (1975) studied the performance on four sedentary tasks at temperatures of 85°F (29.4°C) WBGT, 95°F (35°C) WBGT, and 105°F (40.6°C) WBGT for work periods of up to two hours. Results of these experiments were compared with limits recommended for Occupational Safety and Health regulations. At 105°F (40.6°C) WBGT, only the reaction time task showed a significant decrement during the first 45 minutes. At the 95°F (35°C) WBGT level, there were three task-time combinations

which indicated a partial or slight decrement, significant at the .10 level. The multiplication attempted (i.e., speed of multiplication) at 15 and at 45 minutes showed slightly lower scores than obtained at 85°F (29.4°C) WBGT. The number of pins missed (i.e., accuracy) in the pin insertion task showed slight decrement at the one-hour duration task at 95°F (35°C) WBGT compared to the 85°F (29.4°C) WBGT base line. Ramsey et al. (1975) concluded by saying that "The relationship between time in the heat and level of heat is not a single line, but rather a range of temperatures associated with each time, or inversely, a range of times associated with each temperature within which the likelihood of performance impairment is increased. Additionally, the compensating and adaptive nature of man would support a higher temperature limit for brief work bouts."

Vigilance Tasks

One of the tasks in this research study requires responding to visual stimulus by means of a hand-held button. This task contains an element of vigilance or monitoring performance. The vigilance task is one of the perceptual-motor tasks most commonly studied. Halcomb and Blackwell (1969) report over 24 studies on vigilance, but most of these studies did not differentiate between males and females and none investigated the effect of heat on vigilance.

All the studies support the fact that vigilance performance deteriorates with time. But there is a controversy about sex difference in vigilance performance. Hardesty et al. (1963), McCormack (1960), Smith et al. (1967) report no difference between the sexes. On the other hand, Waag et al. (1973), Coules and Avery (1966), and Whittenburg et al. (1956) report the existence of a significant sex difference. Waag et al. (1973) point out two important facts: (1) none of the above studies had sex difference as a major variable, (2) sample size was small, hence not powerful statistically.

McCormack (1960) had 10 male and 10 female subjects in his study. Each subject participated in two 35-minute sessions which were separated by a period of seven days. Each subject's task was to depress a micro-switch immediately after seeing a light flash. The signals were presented at random intervals. The interval effects and interval-sex interaction were not statistically significant, indicating that response time was invariant with the length of inter-stimulus intervals for both male and female subjects.

Hardesty et al. (1963) tested vigilance performance using six independent groups with a modified version of the Mackworth clock test. Five males and five females served

as subjects in each group. No significant sex difference was found.

Smith et al. (1967), in their visual vigilance study, simulated an industrial inspection task in which subjects were alerted to possible targets by a semi-automatic detection device. Male and female subjects performed equally well and results did not agree with Whittenburg et al. (1956). Smith et al. suggested that possible sex differences are task-specific. They also suggest that sex differences merit further attention.

Whittenburg et al. (1956) employed 12 female and 15 male college subjects for their study. The apparatus used required subjects to detect and respond to the jumps of a clock pointer which moved in discrete jumps every two seconds. Each subject was tested for two hours under conditions of relative isolation. Statistical analysis of the mean differences between female and male subjects for each one-half hour period showed them to differ significantly on the last two one-half hour periods, with female subjects being superior to male subjects during the last hour.

Coules and Avery (1966) had 5 female and 7 male subjects in their study. Subjects were required to respond, from a viewing distance of 18 inches, to the appearance of a one-fourth inch outlined square displayed in the center of a CRT display by pressing a standard telegraph key. The

stimulus square was presented at random interstimulus intervals. The total time for each session was 40 minutes. Results showed that, under knowledge of results, fast mean reaction time (males) was correlated with high skin conductance. Under the no-knowledge of results condition, females showed slower mean reaction time than males. However, the mean reaction time scores of males under the no-knowledge condition were significantly lower than under knowledge of results. It was concluded that males, in contrast to females, respond differentially to knowledge of results in simple reaction time studies.

Waag et al. (1973) studied the monitoring performance of 220 males and 220 females. The subjects monitored a visual display for a duration of one hour. The task consisted of detecting periodic signals occurring events. The subjects responded by pushing a miniature push button placed in the end of a bicycle hand grip. Signals, responses, and event numbers were recorded using a digital printout counter. Two response measures were obtained: (1) percent correct detections and (2) the number of false alarms. Females detected fewer signals than males (in fact, about 10% less) and committed more false alarms (at least initially).

Eye-Hand Coordination Tasks

Two of the tasks in this research study are eye-hand coordination tasks. The rotary pursuit task requires a large motor response, whereas the maze task requires a small motor response.

Geblwiczowa (1973), Darden and Shappnell (1972), Freischlag (1973) and Noble and Noble (1972) studied the performance of men and women on the rotory pursuit task. The first two studies above report the female as superior, whereas the later two studies report the male as superior.

Geblwiczowa (1973) studied motor learning on the pursuit rotor and the influence of reminiscence on performance. Ten female and ten male undergraduates were each given 10 trials, lasting one minute each. During a 10-minute interval between the 5th and 6th trial, the subjects completed a questionnaire. The rest during the interval improved performance by 13.8% with males and 18.8% with females, this improvement being statistically significant only for the female group. The difference between the two sexes was attributed to reactive inhibition.

Darden and Shappnell (1972) tested the performance of males and females on three motor tasks using nine males and nine females as subjects. Star tracing, tapping, and rotory pursuit were the tasks used under two conditions, which involved working while looking in a mirror to cause

a reversal effect of images, and then working without the mirror. Results revealed no differences between the males and females on the tasks performed without the mirror. However, the females performed significantly better on the same tasks while looking in a mirror. This study describes females as superior.

In a study by Freischlag (1973), 60 male and 60 female subjects competed with opposite and same sex opponents on a rotory pursuit tracking task. Training sessions were conducted to minimize the effect of learning on the data. The competitive motive was induced by offering a monetary reward to every three subjects for the highest individual score achieved under three treatments. Testing was conducted against a same sex opponent, an opposite sex opponent, and with no opponent present. The subjects were required to track a target with a stylus moving at 45 rpm in a clockwise direction during trials of 30-second duration. Thirty-second rest intervals were provided between consecutive trials and amount of time-on-target was recorded to nearest tenths of a second. Here males performed better than females ($p < .01$).

Noble and Noble (1972), studied the tracking skill of 84 men and 84 women with both separate and combined visual and auditory feedback in two experiments. The subjects were undergraduates, all right handed. The findings were:

(1) visual feedback (V) was significantly superior to auditory feedback (A); (2) response guidance (narrow track) was highly effective as compared with the standard (no track) turntable; (3) men were significantly more proficient than women in conditions V and V + A; (4) condition V + A was only slightly superior to condition V; (5) auditory feedback while tracking blind was not relevant to the acquisitions of pursuit skill under these conditions; and (6) all differences were attributed to performance rather than to learning variables. The findings of these two investigators are contradictive to the findings of Geblwizowa (1973) and Darden and Shappnell (1972). The fact that the variables and conditions used in these four studies are different from one another is probably responsible in part for these apparent discrepencies.

Star tracing, tapping and mechanical cancellation tasks require small motor responses. Darden and Shappnell (1972) and Kumar and Mathur (1969) both report females as superior.

Kumar and Mathur (1969) in their study had 40 male and 40 female subjects. The subjects performed: (1) a mechanical cancellation task and (2) a mental task involving simple arithmetic. Their performance was studied under noise produced by two high-pitched electric bells. It was found that with female subjects noise had a facilitating

effect on the mechanical task, and did not cause deterioration in performance on the mental arithmetic task. With male subjects, deterioration in performance was found significant in both the tasks.

As can be seen from the above studies, significant sex difference is often present in perceptual motor performance. Sex differences have been evaluated using many variables: time, noise, effects of reversal, rest, types of feedback and even monetary rewards. One of the major variables in this study will be the effect of temperature, a variable which has not been widely reported in the perceptual motor task studies of females.

Menstrual Cycle and Performance

Finkelstein (1887) conducted a study on 20 women, 19 to 33 years old. He found the following changes occurring during the menstrual cycle concerning the visual field: (1) a concentric narrowing of the field of vision, (2) a regular demunition of the visual fields for green, red, yellow, and blue, and (3) perversion of perception of green (which is then seen yellow). Lorenzetti (1926) confirmed Finkelstein's results for the color fields. Lorenzetti also reported a case of visual disturbance occurring during mentruation and pregnancy which prevented the subject from doing fine hand work.

A study by Lanfair and Smith (1974) used eye-hand coordination tasks with 7 women, ages 20 to 42, as subjects. Three subjects were not on any type of menstrual regulating medication and two subjects were using oral contraceptives. Data on eye-hand coordination were collected using the O'Conner tweezer dexterity test. The findings of this study, according to the author, supported previous findings that the visual field is reduced during the pre-menstrual and menstrual flow days.

Redgroove (1971) said that in studies concerning the effect of menstrual cycle on performance, the background of capacity and job demands are also important. Lanfair and Smith (1974) further suggest that if the quality of performance depends primarily on the visual capability of the individual; for example, automobile driving, warning signal detection, paced visual inspection, etc.; the aspect of error arising from menstrual cycle may become important. Lanfair and Smith (1974) conclude by suggesting that more research be carried out in this direction since there is not sufficient evidence to demonstrate the effect of menstrual cycle on performance.

Heat Stress Studies on Females

There have been relatively few studies on the heat reactions of females compared to the number of studies that exist on the heat reactions of the male. One of the first

studies which concentrated on physiological responses of females to hot environments was performed by Hardy (1941), who studied the relationship between skin temperature and the onset of sweating in women.

Most performance deteriorates when the level of thermal stress reaches some minimal level. The rate of deterioration increases as the amount of thermal stress is increased. The minimal thermal stress required to adversely affect the performance depends on the length of exposure to the stress, demands of the task and the capabilities of the individual. The physiological indices such as heart rate, deep body temperature and sweat rate vary with the thermal conditions of the surrounding environment. The above physiological indices become important in predicting the thermal stress developed, and hence the deterioration in performance.

In most of the past research, the heat reactions of the female concerns physical work performance or heat acclimatization. The changes in physiological responses of females under various thermal environments, as reported in various literatures, will be briefly discussed.

Heart Rate

Studies by Astrand (1956), Brouha et al. (1960), Hertig et al. (1963), Wyndham et al. (1965), and Weinman et al. (1967) all report increased heart rate with time and

temperature. Increases in pulse rate were more intense in hot, humid conditions than in hot, dry conditions. The pulse rate rose to a maximum value, depending on the work load, and then leveled off. Men tested under similar thermal conditions also showed the same pattern, but pulse rates for females were significantly higher than for males in all the studies reported except the study by Weinman et al. (1967). The sex difference was more significant under hot, humid conditions than hot, dry conditions. In most cases the sex difference was not significant in hot, dry conditions, but females reached the maximal values more rapidly than the males in all studies.

Brouha et al. (1960) studied the reactions of men and women during muscular activity and recovery in various environments. Five women, 20-38 years old, performed these experiments. The work consisted of pedaling a magnetic brake bicycle ergometer (Krogh's model) in time with a metronome. The three environmental conditions were:

1. 77°F/25°C and 43% relative humidity (or normal room temperature)
2. 99°F/37.2°C and 25% relative humidity (or warm, dry conditions)
3. 90°F/32.2°C and 82% relative humidity (or warm, humid conditions)

Six men, aged 30-58, also performed in the experiments. In terms of work per kilogram of body weight, submaxial and maximal work rates averaged 7.0 and 11.8 kg-m/min, respectively, for the men and 6.0 and 11.9 kg-m/min, respectively, for women. The work rate in kilogram-meters per minute was less for women than for men. Heart rates were significantly higher than those under normal condition for all phases of work and rest for both men and women, with the exception of at the onset of exercise. In warm, dry conditions the increase in heart rate was lower. There were small but persistent quantitative differences in the responses of the heart rates of the two sexes. The author concluded by saying, "The differences ranged from 5% - 16%, which may be attributed to sex, especially since the women performed less work."

A study by Hertig et al. (1963) also agrees with the above findings. Nine women participated in daily two-hour walks in the heat for two to three weeks. The main object of the study was to see how well the women became acclimatized to heat. To minimize the diurnal variations, a subject was always exposed at the same time of the day. The exercise consisted of a level treadmill walk at 4.8 km/hr for two hours. Three thermally neutral temperature walks (at 21°C [69.8°F]) were followed by 10 hot exposures at 45/25.5°C (113/77.9°F) (dry bulb/wet bulb, 15mm Hg vapor

pressure), then one at 50/26.5°C (122/79.7°F) and a final exposure at 21°C (69.8°F). The acclimatization regime of Hertig et al. consisted of 10 two-hour exposures. Work load consisted of a level treadmill walk at 5.6km/hr. Environmental conditions were set at 40.5/30°C (104.9/86°F) (27mm Hg vapor pressure), t_{globe} = 40.5°C (104.9°F) and air speed about 15m/min. Before entering the chamber, the subjects rested for 40 minutes in a 24°C (75.2°F) environment. Exercise was divided into four alternating periods of 30, 20, 30, and 20 minutes. Walking was interrupted after each period for a sufficient time to permit assessment of physiological parameters. The skin temperature, pulse rate, and rate of sweating were monitored. Although physiological improvement occurred each subsequent day, the pulse rates for females at any point were higher than for males. At 50°C (122°F), even though men were walking at the rate of 5.6 km/hr and women at 4.8 km/hr, females had higher pulse rates.

A study concerning the heat reactions of male and female Caucasians by Wyndham et al. (1965) gives an excellent picture of the physiological responses of the female working in hot environments. Twenty-six female and 30 male Caucasians were tested at work levels of 1.0 liter of oxygen consumption per minute in 90°F (32.23°C) wet bulb temperature, 93°F (33.89°C) dry bulb temperature, and 80

ft/min (24.4m/min) air velocity for comparative heat reactions in the unacclimatized state. The work consisted of stepping at the rate of 12 steps/min giving a continuous work rate of 1560ft-lb/min. To attain a uniform work rate, the height of the step was set in relation to the body weight of the individual producing an oxygen consumption of approximately 1 liter/min. The heart rates for females and males decreased significantly after acclimatization. As reported earlier, the heart rates of females rose to very high levels much more rapidly than males.

In contradiction to all the above studies, a study by Weinman et al. (1967) reports lower pulse rates for females than males. Ten healthy young subjects, 5 men and 5 women, underwent a series of experiments which involved walking on a treadmill for four hours under conditions of 33.9°C (93°F) dry bulb, 32.6°C (90.7°F) wet bulb, and 88% RH. Two similar experiments under temperate ambient conditions served as a basis for evaluating the influence of the work in humid heat and that of the work itself. The pulse rates between the individual periods were significantly higher for men than for women when evaluated by Student's t-test. But the increments in heart rates of females were faster than those of men; and with continued exposure, the women's pulse rates showed a smaller increase than did the men's. There was no clear-cut difference in the maximum pulse

rates attained between either men and women or between the first and the second temperature experiments. But as reported by all the other investigators, females reached their maximal values more rapidly than males.

Rectal Temperature

Research studies by Hertig et al. (1963), Weinman, et al. (1967), and Wyndham et al. (1965) all report increases in rectal temperatures with the increases in environmental temperature and work. Wyndham et al. (1965) and Weinman et al. (1967) report significantly higher rectal temperatures for females than males. But this difference was present only in the hot environments and was not significant under normal conditions. Hertig et al. (1963) reports no differences in the rectal temperatures of males and females.

Wyndham et al. (1965) also reported that the rectal temperatures rose much more rapidly for females than males. The difference was most significant in the unacclimatized state. However, after acclimatization there was not much difference due to sex.

Wienman et al. (1967) found that initial resting values of rectal temperatures tended to be lower in men than in women, but this difference was not significant statistically. During work in the moist heat, the values of the rectal temperatures of both groups increased with

each 30-minute period, this increase being distinctly higher in the males and diminishing in both groups in the later exposures. These decreases in rectal temperatures were statistically significant for females only.

On the whole, there is a significant rise in rectal temperatures of both females and males when working in hot environments and the sex difference seems to be present only under hot-moist conditions.

Skin Temperature

Skin temperatures of females working in hot conditions were studied by Hardy et al. (1947), Hertig et al. (1963), Weinman (1967), and Morimoto et al. (1967). All studies report an increase in skin temperature with increases in ambient temperatures. Hardy et al. (1947) reported higher skin temperature at the onset of sweating in women. For equal sweat rates (per unit of body surface area), the women's skin temperatures were about 1°C (1.8°F) higher than men's. On the other hand, the rectal temperatures were nearly equal in both sexes. The study by Hertig et al. (1963) also reports higher skin temperatures for females than males.

The above two studies contradict the findings of Wienman (1967) and Morimoto et al. (1967). They reported no significant sex differences in their studies of skin temperatures.

Sweat Rate

Maintaining the water balance in the body is important. Males are known to increase their sweat rates as the environmental temperature increases. The sweat rates of women are generally believed to be lower than that of men. But opposite results have also been reported by Matsui (1955).

The studies by Hertig et al. (1963), Wyndham et al. (1965), Weinman et al. (1967), and Mormoto et al. (1967) all report that women sweat less than men. The difference was most pronounced under hot moist conditions. Both Hertig et al. (1963) and Wyndham et al. (1965) reported that rates of sweating increased with acclimatization. This agrees with the pattern shown by men. Weinman et al. (1967), reported that females sweat less than males when exposed to hot environments. In his investigation, the total body sweat rates were distinctly lower in females than males, the difference being present during the entire experiment.

Morimoto et al. (1967) conducted two series of experiments. Series I consisted of six exposures at temperatures varying from 36°C/22°C to 49°C/32°C dry bulb/wet bulb temperatures. Series II consisted of six exposures at temperatures varying from 33°C/31°C to 38°C dry bulb/wet bulb temperatures. In Series I, performed under a relative humidity of 30%, no significant difference was found between

the sweat rates of men and women. On the contrary, under the hot-moist conditions (Series II), the higher values of sweat rates found in men were significantly different from those of women starting with the third exposure. Morimoto et al. (1967) concludes women are able to increase their sweat rate as the environmental temperature increases, but that the rate of increase per unit increment of heat stress is less among men. Accordingly, the sex differences in sweat rates become more obvious under high heat stresses.

Haslag and Hertzman (1965) have conducted a study on temperature regulation in young women working in hot conditions and have studied the possible effects of menstrual cycle on physiological indicators. At any given level of sweating, oral temperatures were higher during the post-ovulatory period of the menstrual cycle. The rates of weight loss and averages of the regional sweating were not affected by the phase of the menstrual cycle in which the heat exposure occurred. There was no significant difference in the production of heat during the different phases of menstrual cycle.

Measurement of Environmental Conditions

The commonly used measurements and indices of the thermal environment are briefly explained in this section.

Dry Bulb Temperature. Air temperature, or dry bulb temperature, is obtained by measuring with a simple

mercury-in-glass thermometer or by using a thermistor (thermal sensing device). The thermometer or the thermister used should be shielded from any radiant heat source.

Wet Bulb Temperature. Wet bulb temperature is a function of the humidity of the environment and is measured by an aspirated wet-wick thermometer or sling psychrometer. Relative humidity is determined by measuring wet bulb temperature, dry bulb temperature, and then using this information to read humidity from a psychrometric chart.

Air Velocity. This is normally measured by using a rotating vane anemometer or hot wire anemometer.

Globe Temperature. Globe temperature is obtained from a hollow copper sphere painted black on the outside and containing a mercury-in-glass thermometer.

Reddy (1974) summarized the development, uses, and the deficiencies of the thermal indices: Effective Temperature, Corrected Effective Temperature, and Wet Bulb Temperature. These thermal indices are briefly explained below.

Effective Temperature. Effective temperature (ET) was developed by Houghten and Yaglou in 1923. Their experiments were conducted under dynamic conditions, where subjects walked between rooms with different air temperature and humidity combinations. The conditions in the second room were adjusted until the reaction of the subjects indicated identical comfort sensations. These results were

plotted on a psychrometric chart. Main deficiencies in the ET scale were: (1) it did not account for radiant heat in environments where long wave radiation was a factor; (2) ET tended to overemphasize the effect of relative humidity at lower temperatures, and placed less emphasis on the effect of air velocity at higher temperature and humidities; (3) there was no allowance for differences in clothing and metabolic rates.

Corrected Effective Temperature. To overcome the above deficiencies in the ET, a corrected effective temperature scale (CET) was developed by Vernon and Warner (1932). The CET scale compensated for the radiant temperature, but this was good only at low air velocities. The CET scale has the same drawbacks as the ET scale at high air velocities.

Wet Bulb Globe Temperature. Wet bulb globe temperature (WBGT) was developed by Yaglou and Minard (1957) as an empirical approximation of ET. WBGT is determined from several temperature measurements. It combines the effects of dry bulb, natural wet bulb, and globe temperatures and incorporates indirectly the effect of air velocity on the above measurements.

WBGT is calculated according to the following equation:

$$WBGT = 0.7\ t_{nwb} + 0.3\ (t_g - t_a)\ k + t_a$$

where

t_a = air temperature, °F

t_g = globe temperature, °F

t_{nwb} = natural wet bulb temperature, °F

k = constant depending on clothing, race, etc.

For outdoor use, k = 0.67 and the equation is

$$WBGT = 0.7\ t_{nwb} + 0.2\ t_g + 0.1\ t_a\ .$$

For indoor use, k = 1 and the equation is

$$WBGT = 0.7\ t_{nwb} + 0.3\ t_g\ .$$

The WBGT index is currently used in thermal environment research by NIOSH, ACGIH, U.S. Military and many others (National Institute for Occupational Safety and Health, 1972; Ramsey, 1975). The Occupational Safety and Health Standards Advisory Committee on heat stress has proposed the following threshold WBGT values for work in hot environments (Ramsey et al., 1975).

For light work loads (below 200 kcal per hour/800 BTU per hour), at low air velocities (up to 1.52 mps/300 fpm), the suggested threshold WBGT value is 85°F (30°C); at high air velocities (above 1.52 mps/300 fpm) the suggested threshold WBGT value is 90°F (32.2°C). For moderate work loads (200-300 kcal per hour/801-1200 BTU per hour), at low air velocities (up to 1.52 mps/300 fpm), the suggested threshold WBGT value is 82°F (27.8°C); at high air

velocities (above 1.52 mps/300 fpm), the suggested threshold WBGT value is 85°F (30.6°C). For heavy work loads (above 300 kcal per hour/1200 BTU per hour), at low air velocities (up to 1.52 mps/300 fpm), the suggested threshold WBGT value is 79°F (26.1°C); at high air velocities (above 1.52 mps/300 fpm), the suggested threshold WBGT value is 84°F (28.9°C).

NIOSH (1972) has proposed the temperature-time limits (Figure 1, page 3) in WBGT units. Hence, the temperature levels used in the study herein are measured and reported in WBGT units.

In this chapter, the typical sedentary tasks used in reported research studies have been reviewed, along with the effect of variables such as time, sex, or menstrual cycle on the sedentary job performance of the females. The physiological responses of females and males to hot environments have also been presented. Finally, the commonly used measurements and indices of the thermal environment including the WBGT index were explained. The next chapter will deal with the research procedure utilized in this study.

CHAPTER II

RESEARCH PROCEDURE

The experimental variables, the statistical design of the experiment, the experimental tasks and equipment, and the experimental procedure are discussed in this chapter.

Experimental Variables

Controlled Variables

Activity Level. The subject tasks were sedentary; in other words, the subjects sat and worked at tasks which required perceptual motor performance with a minimum of physical labor. The activity level for subjects performing these sedentary tasks was about 400-500 BTU/hour (100-125 Kcal/hour).

Air Velocity. Air velocity in the environmental chamber was maintained at less than 50 feet/minute (15.3 meters/minute).

Clo Value. The clothing for all sessions and subjects used in this study consisted of minimum underwear, a cotton short sleeved shirt, cotton jeans and tennis shoes or sneakers. This clothing gave a clo value of approximately 0.6.

Relative Humidity. The relative humidity in the environmental chamber was maintained at approximately 45%.

Skill Level on Tasks. If the subjects were to undertake the study without any training, any change in performance due to temperature-time would likely be disguised and confounded by a very large learning effect. To minimize the effect of learning on the data, all subjects underwent at least two training sessions. The first training session was conducted at an ambient temperature of 74°F (23.3°C) WBGT and lasted for two hours. The second training session was conducted at an ambient temperature of 100°F (37.8°C) WBGT for the first 30 minutes and at 74°F (23.3°C) WBGT for the next 90 minutes. This procedure provided a check on the subject's heat tolerance and provided task training. The subject's heart rate and oral temperature were monitored closely to detect any unusual or adverse response to the heat.

Independent Variables

Temperature. The WBGT levels selected for this study and the corresponding dry bulb and wet bulb temperatures for a relative humidity level of approximately 45%, are given in Table 1.

The temperature-time exposure limits as proposed by NIOSH (1972) are shown in Figure 1 on page 3. The temperature-time exposure combinations chosen for this study lie on either side of the proposed temperature-time exposure limit curve as shown by circles in Figure 1, page 3.

TABLE 1

THE WBGT LEVELS SELECTED FOR THIS STUDY AND THE CORRESPONDING DRY BULB AND NATURAL WET BULB TEMPERATURES

WBGT		DBT		NWBT	
(°F)	(°C)	(°F)	(°C)	(°F)	(°C)
110	43.3	125	57.7	104	40.0
100	37.8	115	46.1	94	34.4
90	32.2	104	40.0	84	28.9
74	23.3	84	28.9	68.5	28.3

Temperature-time exposure levels were analogus to those used in a concurrent research study at Texas Tech University using male subjects. This provided an opportunity to compare the data concerning females with that of males.

Subjects. Fifteen healthy females were chosen from the student population of the University. The effect of age was minimized by using females of similar ages, i.e., 19-23 years. Since only four subjects could work in the chamber at the same time, the subjects were divided into groups of four. In order to eliminate potential performance or physiological variations due to circadian rhythm, all sessions for each group were conducted at the same time of the day throughout the study period. All the subjects were required to answer a health questionnaire, a copy of which is attached in Appendix D. The applicants who reported undue stress due to menstrual cycle, or indicated existing

or potential health problems or susceptability to illness were deleted from the student population.

Tasks. The following four tasks, explained in detail later in this chapter, were selected:

1. Reaction time task
2. Pursuit tracking task
3. Eye-hand coordination task
4. Multiplication task

These four tasks were chosen to represent commonly encountered work situations in industry. The reaction time task represents a vigilance task or an inspection task such as reading gauges or monitoring signals. Pursuit tracking task is an eye-hand coordination task requiring a motor response which is similar in nature to driving a vehicle or operating a crane. The maze tracing task is an eye-hand coordination task requiring a small motor response such as that which is necessary for assembling electronic components on assembly line or for sewing garments in a clothing factory. The multiplication task represents mental tasks similar to inventory taking and extension, scheduling or clerical work.

Time on Each Task. The subjects worked in groups of four, one subject at each work station. At the beginning of each session the subjects were given two minutes time to take up their positions. The work was divided into fifteen

minute work cycles. Each fifteen minute cycle consisted of four 2.5 minute work periods alternated with 1 minute rest periods. Each fourth rest period marked the end of fifteen minute cycle and was extended to 2 minutes. The four temperature-time combinations chosen for this study are plotted on Figure 1 on page 3. As seen from Figure 1, the exposure limit is approximately 20 minutes for a WBGT level of 110°F (43.3°C). If the subjects were exposed to the above temperature for a time longer than 20 minutes, one should expect a decrease in performance. But if the subjects were to be exposed to a certain temperature for a time less than the proposed limit, no decrease in performance would reasonably be expected. Four WBGT levels 110°F (43.3°C), 100°F (37.8°C), 90°F (32.2°C), and 74°F (23.3°C) were chosen. Since the work cycles selected were 15 minutes in length, the corresponding exposure times for the above temperatures were chosen to the nearest multiple of 15 minutes, so that these temperature-time combinations would lie on either side of the proposed standard. The number of cycles and exposure times used for each temperature-time combination under investigation are given below:

1. 110°F (43.3°C) WBGT - 2 cycles (30 minutes)
2. 100°F (37.8°C) WBGT - 6 cycles (90 minutes)
3. 90°F (32.2°C) WBGT - 8 cycles (120 minutes)
4. 74°F (23.3°C) WBGT - 8 cycles (120 minutes)

Dependent Variables

Physiological responses. An individual functions efficiently only within a very narrow body temperature range. This is due to a "core" temperature measured deep inside the body. Fluctuations in "core" temperatures exceeding about two degrees below or three degrees above the normal temperature of 98.6°F (37°C) markedly impair performance. If this five-degree range is exceeded, a health hazard exists. Metabolic processes cause the body to produce heat, and because the body can accumulate heat only to a limited extent, it must dissipate to the surroundings most of the metabolic heat being generated. Blood plays an important role in this process in that it carries heat from deep within the body to the skin where the heat can be dissipated by evaporation, convection, radiation, and conduction. Consequently, an overly-hot environment places an additional load on the cardiovascular system of an individual, which results in an increase in both heart rate and oral temperature. Hence, heart rate and oral temperature, which are good physiological indicators of thermal stress, were monitored once every fifteen minutes for all subjects throughout the study. Heart rate was monitored by using a photocell which was picked up by a Physiograph recorder and a frequency counter which gave digital output of the heart rate. The oral temperature was

monitored by a thermistor (heat sensing device). The subject first sterilized this thermistor by dipping it in alcohol, then placed it under her tongue. A YSI surface thermistor and a YSI Telethermometer were used to monitor the oral temperature.

Performance Scores. Performance of the subjects was measured at each task in terms of speed and/or accuracy. The performance for the reaction time task was measured as the difference in time between the presentation of the stimulus and the response by the subject. Pursuit tracking performance was measured as the length of time during which the subject was able to maintain contact with a target light. The time required to trace the maze along the marked path from start to finish was the measure of performance for the eye-hand coordination task. For the multiplication task the performance was measured by speed (total number of digits completed) and by percent error (percent wrong digits) during each work cycle. These tasks are described in detail below.

Experimental Tasks and Equipment

The tasks and equipment used in this study are as follows.

Reaction Time Task. This was a simple choice reaction time task. The subject sat in front of a table upon which a light was located and held a switch in her right hand

(see Figure 2). The operator outside the chamber presented light stimuli to the subject at psuedo-random intervals during each cycle. The subject responded to the signal by pressing a hand-held button as soon as she saw the signal. The reaction time of the subject was monitored to the nearest 1/100th of a second. The light stimuli were presented in the following six sequences.

TABLE 2

THE SEQUENCES FOR LIGHT STIMULI
FOR THE REACTION TIME TASK

Sequence number	Time at which stimuli was presented					
	1	2	3	4	5	6
1	0.35	0.65	1.85	2.10	2.35	-
2	0.50	0.75	1.00	1.60	2.00	2.40
3	0.25	1.15	1.75	2.10	2.35	-
4	0.40	0.75	1.15	1.90	-	-
5	0.15	0.65	0.90	1.35	1.60	2.10
6	0.40	0.65	1.50	2.00	-	-

For each cycle, one of the above sequences was chosen by rolling a die. Once a sequence was chosen, each of the four subjects received signals in the same sequence for that particular cycle. For the next cycle, another sequence was chosen by rolling the die again, and so on. In this way, the subjects did not know how many signals to expect or when to expect a signal during a given cycle.

Figure 2. Subject performing the reaction time task.

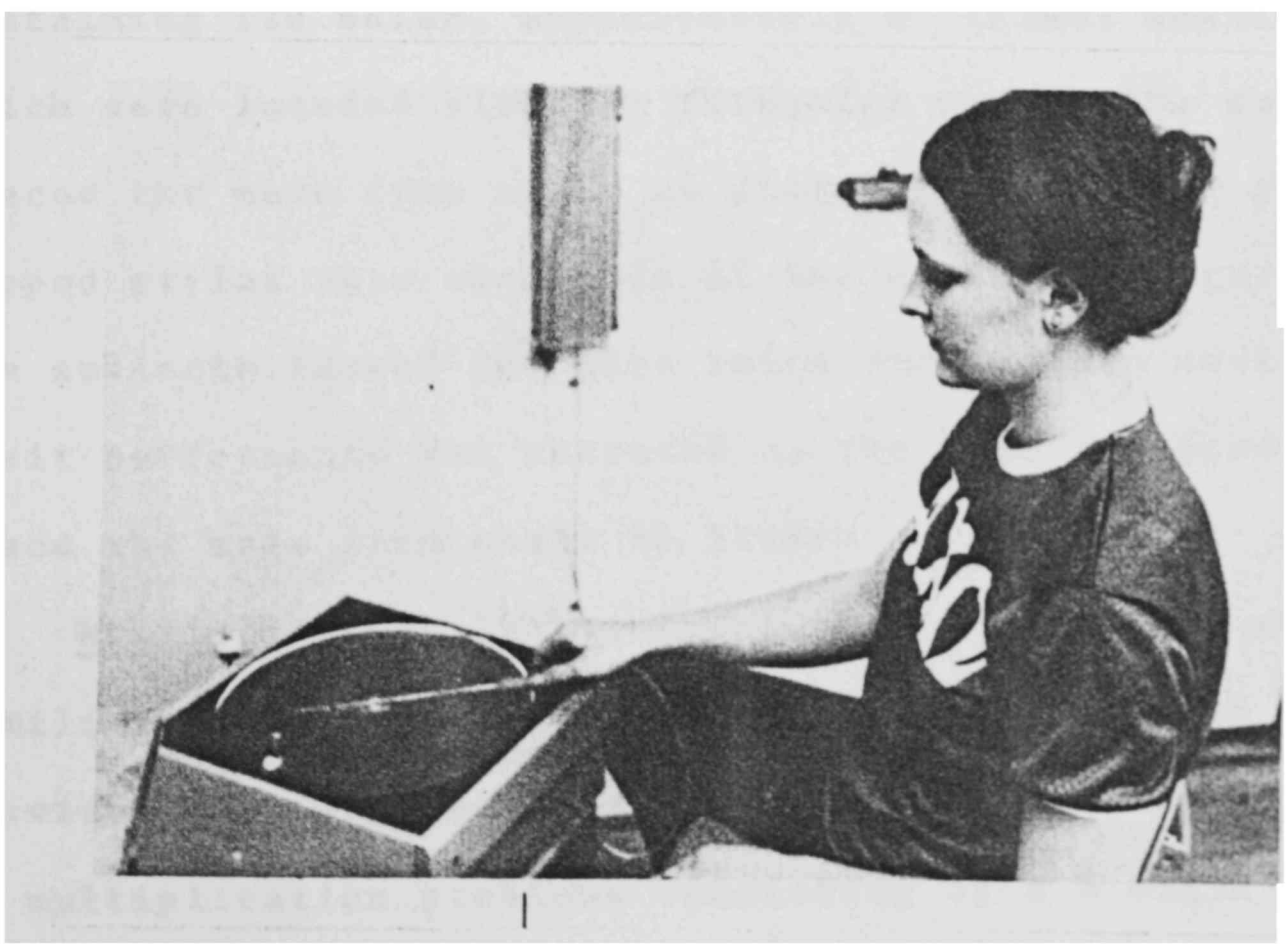


Figure 3. Subject performing the pursuit tracking task.

Pursuit Tracking Task. The pursuit rotor used in this task consisted of a rotatable disc mounted inside a box with a glass top. A circular hole drilled in the disc produced a light target which revolved when the disc was rotated. The subject held a stylus containing a photocell that initiated a timer and recorded the time the stylus was held on target (see Figure 3, page 41). The performance was measured by how long the subject was able to maintain contact with the target light as the disc rotated. The work cycle on this task consisted of alternate 20 second bouts of tracking and resting.

Eye-hand Coordination Task. This was a task requiring small motor responses. The equipment consisted of a maze containing 120 holes, approximately ½" (13mm) apart, which were located along an irregular path. The subject traced the maze from start to finish by inserting a metal tipped stylus into each hole of the maze (see Figure 4). The subjects traced the maze twice during each work cycle. Their performance was measured as the time required to trace the maze from start to finish.

Multiplication Task. This was a mental task which was familiar in some degree to each subject. Subjects were provided with printed multiplication sheets each containing 16 multiplication problems consisting of a 4 digit multiplicand and a 3 digit multiplier. In order to standardize

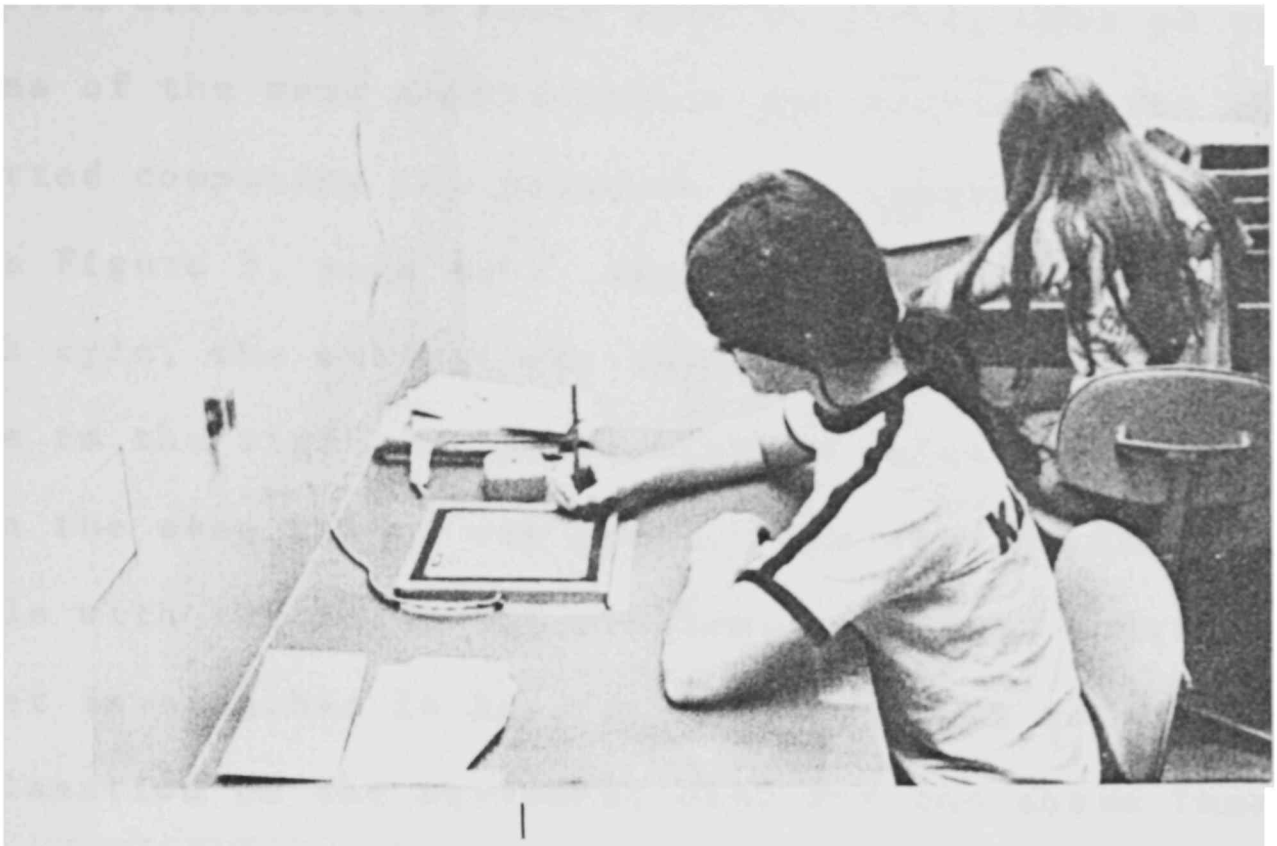


Figure 4. Subject performing the eye-hand coordination task.

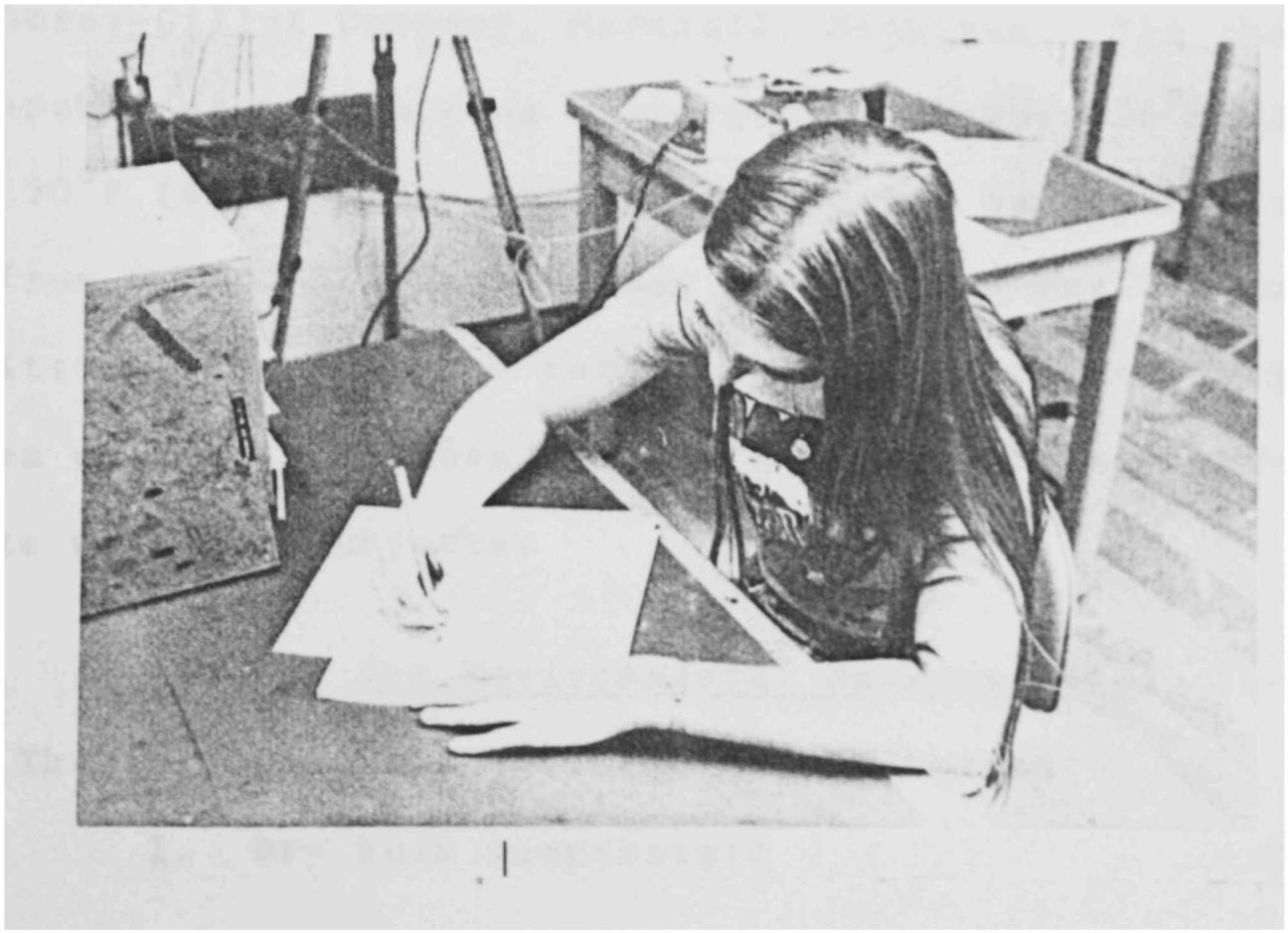


Figure 5. Subject performing the multiplication task.

problem difficulties there were no zeros, ones or repetitions of the same number within any problem. The subject started computing the products when instructed to do so (see Figure 5, page 43). After the two and one-half minute work cyle, the subject was required to put a vertical line to the right of the problem on which she was working when the stop signal was given. She started the next cycle with the following problem. A sample multiplication sheet is attached in Appendix C. For more detailed explanation on the equipment used for the above four tasks, refer Reddy (1974).

Environmental Chamber. The environmental chamber used in this study (model mumber CER 1216) was manufactured by Sherer-Gillet Company, Marshall, Michigan. The chamber is capable of maintaining temperatures between 36°F (2.2°C) and 150°F (65.6°C) dry bulb, and relative humidities ranging from 5 to 98%. The chamber has two one-way windows permitting view form the outside. An intercommunication system enabled operators outside the chamber to communicate with the subjects.

Equipment for Environmental Measurements

The following observations were recorded:

1. Dry bulb temperature

2. Natural wet bulb temperature
3. Globe temperature
4. Psychrometric dry bulb temperature
5. Psychrometric wet bulb temperature

Two sets of instruments were used to measure the dry bulb temperature, the natural wet bulb temperature, and the globe temperature. Dry bulb temperature was measured by (1) mercury-in-glass thermometer suspended in the air, and (2) probe thermistor suspended in the air and connected to the Telethermometer. The Telethermometer had a maximum range of 110°F (43.3°C). When the temperature inside the chamber was within this range, readings were taken from the Telethermometer, and when the temperature inside the chamber exceeded this range, the temperature readings were read directly from the mercury-in-glass thermometer.

Natural wet bulb temperature was recorded by (1) reading a mercury-in-glass thermometer with a 2" (5cm) cotton wick attached around the bulb and (2) a probe thermistor with a 2" (5cm) cotton wick tied around the end, the thermistor being connected to the Telethermometer. The cotton wicks from the above two instruments were immersed in distilled water contained in a plastic bottle so that at least one-half of the length of the wick was under the water level. The water level in the bottle was maintained at the same level for all the sessions. The globe temperatures

were taken from two copper globes, approximately 5½" (13.8cm) in diameter, painted black on the outside and suspended in the air. A mercury-in-glass thermometer was placed in one of the globes; the other globe contained a probe thermistor, which in turn was connected to the Tele-thermometer, as explained earlier. These two sets of measuring instruments were used depending on the temperature range inside the chamber.

Psychrometric measurements were obtained from two mercury-in-glass thermometers, one dry, the other with a 2" 5cm) cotton wick around the bulb. The cotton wick was dipped in a container filled with water. The above two thermometers were enclosed in a glass box. A small electric fan steadily blew air over the bulbs of their thermometers.

All the above instruments were placed in the same general area in the chamber. The five environmental measurements of globe, dry bulb, natural wet bulb, psychrometric dry bulb and psychrometric wet bulb temperature readings were taken once at the end of every fifteen minute cycle.

Statistical Design of the Experiment

A balanced, randomized block factorial design was used to analyze the data. Separate analyses were conducted

for the four tasks and the two physiological variables: heart rate and oral temperature.

The general mathematical model for the design is:

$$X_{ijk} = u + S_i + A_j + B_k + AB_{jk} + E_{ijk}$$

where

X_{ijk} = Dependent variable for i, j, k levels of the respective treatments.

u = Common effect

S_i = Subject effect, i = 1, 2, 3, ... 15.

A_j = Temperature effect, j = 1, 2, 3, 4.

B_k = Time effect, k = 1, 2, 3, ... 8 cycles
k = 1, 2, 3, ... 6 cycles
k = 1, 2 cycles

AB_{jk} = Temperature-time interaction effect

E_{ijk} = Error

Temperature 4 (110°F [43.3°C]) had two 15-minute cycles. Temperature 3 (100°F [37.8°C] WBGT) had six 15-minute cycles. Temperatures 2 and 1, (90°F [32.2°C] WBGT and 74°F [23.3°C] WBGT, respectively) had eight 15-minute cycles. Because of these constraints, a single analysis conducted on the entire data would produce many empty cells. For this reason, three separate analyses were necessary. The 2 temperature 8 cycle analysis, which contained the data from all of the eight cycles of two WBGT levels 74°F (23.3°C) and

90°F (32.2°C), will be referred to as the 2T-8C analysis. The expected mean squares for this analysis are given in Table 3.

TABLE 3

EXPECTED MEAN SQUARES
(2T-8C, N=15)

Source	Degrees of Freedom	Expected Mean Squares
S_i	14	$\sigma\varepsilon 2+16\sigma_A 2$
A_j	1	$\sigma\varepsilon 2+120\sigma_B 2$
B_k	7	$\sigma\varepsilon 2+30\sigma_C 2$
AB_{jk}	7	$\sigma\varepsilon 2+15\sigma_{AB} 2$
E_{ijk}	210	$\sigma\varepsilon 2$
Total	239	

The 3 temperature-6 cycle analysis, which contained the data from the first six cycles of the two WBGT levels 74°F (23.3°C) and 90°F (32.2°C), and all of the data from the six cycles of WBGT level 100°F (37.8°C), will be referred to as the 3T-6C analysis. The expected mean squares for this analysis are given in Table 4.

The 4 temperature-2 cycle analysis, which contained the data from the first two cycles of the three WBGT levels 74°F (23.3°C), 90°F (32.2°C) and 100°F (37.8°C), and all of the data from the two cycles of the WBGT level

TABLE 4

EXPECTED MEAN SQUARES
(3T-6C, N=15)

Source	Degrees of Freedom	Expected Mean Squares
S_i	14	$\sigma\varepsilon 2+18\sigma_A{}^2$
A_j	2	$\sigma\varepsilon 2+90\sigma_A{}^2$
B_k	5	$\sigma\varepsilon 2+45\sigma_B{}^2$
AB_{jk}	10	$\sigma\varepsilon 2+15\sigma_{AB}{}^2$
E_{ijk}	238	$\sigma\varepsilon 2$
Total	269	

110°F (43.3°C), will be referred to as the 4T-2C analysis. The expected mean squares for this analysis are given in Table 5.

TABLE 5

EXPECTED MEAN SQUARES
(4T-2C, N=15)

Source	Degrees of Freedom	Expected Mean Squares
S_i	14	$\sigma\varepsilon 2+8\sigma_A{}^2$
A_j	3	$\sigma\varepsilon 2+30\sigma_B{}^2$
B_k	1	$\sigma\varepsilon 2+60\sigma_B{}^2$
AB_{jk}	3	$\sigma\varepsilon 2+15\sigma_{BC}{}^2$
E_{ijk}	98	$\sigma\varepsilon 2$
Total	119	

Texas Tech Library

Experimental Procedure

A plan of the layout of task stations in the environmental chamber and the layout of the monitoring equipment is given in Figure 6.

The environmental chamber was put into operation at least one hour before the scheduled time of each session to allow for temperature stabilization. The temperatures were set at predetermined levels in accordance with the statistical experimental design. All the equipment was tested one-half hour before the start of the experiment. The sequence of exposure to different levels of temperature was balanced to minimize order effects.

The order in which groups (A, B, C and D) containing experimental subjects were exposed to different temperatures is given in Table 6. Groups A, B and C had four subjects each, and Group D had three subjects.

TABLE 6

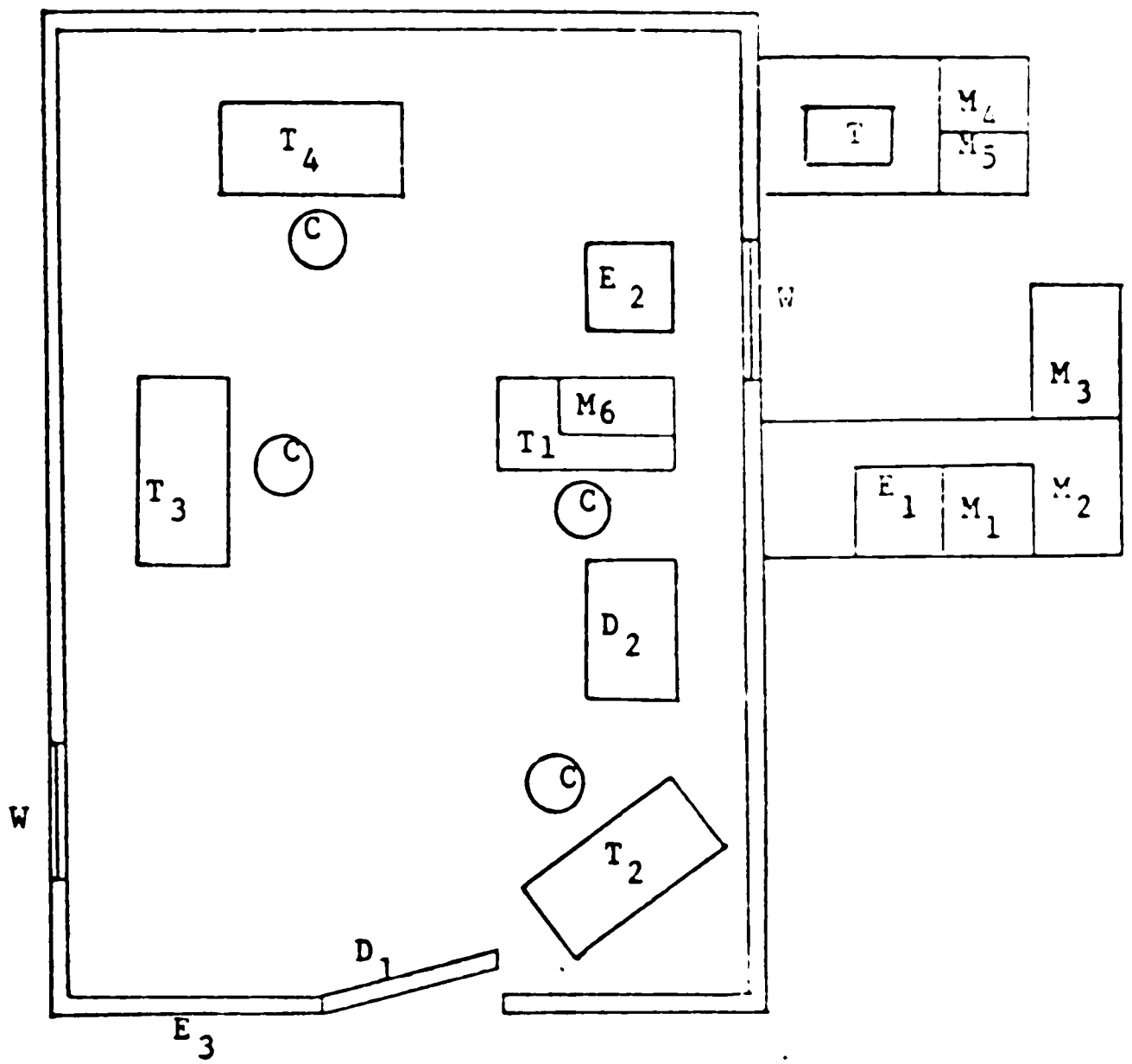
ORDER OF EXPOSURE OF GROUPS TO THE DIFFERENT WBGT LEVEL

	Session			
Group	I	II	III	IV
A	4	3	2	1
B	3	1	4	2
C	1	2	3	4
D	2	4	1	3

WBGT levels:

1 - 74°F (23.3°C) 2 - 90°F (32.2°C)

3 - 100°F (37.8°C) 4 - 110°F (43.3°C)



Monitoring Equipment:

M_1 - Reaction Timer
M_2 - Physiograph
M_3 - Digital Counter
M_4 - Pursuit Rotor
M_5 - Maze Tracing
M_6 - Photo Cell and Thermistor for Monitoring Heart Rate and Oral Temperature
E_1 - YSI meter for monitoring Oral Temperature
E_2 - Environmental Condition Measuring Equipment
E_3 - Partlow Measuring Device

Task Stations:

T_1 - Reaction Time
T_2 - Pursuit Tracking
T_3 - Maze Tracing
T_4 - Multiplication

Other:

D_1 - Door
D_2 - Drinking Water
W^2 - Windows
C - Chairs

Figure 6. Plan of the layout of the task stations in the environmental chamber and the layout of the monitoring equipment.

After the subjects of a group had arrived for their session, they were randomly assigned to work stations. A magnetic tape recorder containing instructions was started when the subjects entered the environmental chamber. The magnetic tape was prerecorded in accordance with the plans of the experiment. The subjects worked and changed stations when directed by the verbal instructions on the magnetic tape. When the session was completed, the subjects left the environmental chamber and entered a room at ambient temperature where they completed a questionnaire reporting their subjective feelings on the task-temperature-time combinations. A copy of this questionnaire is attached in Appendix E.

The results obtained in the research are presented and discussed in Chapter III.

CHAPTER III

RESULTS AND DISCUSSION

In this chapter, the results obtained and the discussion of the results are presented as follows:

1. Temperature-time effects on:
    a. Pursuit tracking task
    b. Eye-hand coordination task
    c. Reaction time task
    d. Multiplication task
2. Physiological responses
3. Session effect
4. Subjective responses
5. Environmental conditions

An analysis of variance was conducted to find the significant main effects and interactions of the variables under investigation in accordance with the model (stated on page 47). The analysis was conducted on four task scores and on the physiological variables of heart rate and oral temperature. A computer program, QAD ANOVA, provided by the Computer Center of Texas Tech University was used to analyze the data. The program also yielded the cell means and standard deviations for all of the main effects and interactions.

The design of the experiment was discussed in Chapter II. Significance levels of 1% and 5% were established as meaningful criteria (99% and 95% confidence intervals, respectively) for the evaluation of variables under investigation. The significance level of 5% was chosen for the analysis of the performance scores on four tasks, in accordance with the literature presented in Chapter I, and especially in accordance with Wing (1965), whose review served as the basis for temperature-time limits as proposed by NIOSH (1972).

Performance at 74°F (23.3°C) was considered normal, whereas performance at other temperature levels selected for this study were compared against this performance. Findings at the 1% significance level were considered as "reliable decrements" or "reliable improvements" and findings at the 5% significance level were considered as "decrements" or "improvements" in performance.

For the analyses other than the temperature-time effects on the four tasks, a significance level of 1% was established as a meaningful criteria (99% confidence) for the evaluation of the variables under investigation. The discussion of the analyses are presented as follows.

Because of certain constraints (as explained in Chapter II), three different analyses were required in order to analyze the performance on each task and the physiological

responses. The 2T-8C analysis contained the performance data during the eight 15 minute cylces of WBGT levels 1 and 2. The 3T-6C analysis consisted of the performance data during the first six 15 minute cycles of WBGT levels 1, 2 and 3. The 4T-2C analysis consisted of the performance data during the first two 15 minute cycles of all four WBGT levels. In the figures, the WBGT levels indicated below will be used to represent the corresponding WBGT levels:

WBGT level 1 - WBGT level 74°F (23.3°C)

WBGT level 2 - WBGT level 90°F (32.2°C)

WBGT level 3 - WBGT level 100°F (37.8°C)

WBGT level 4 - WBGT level 110°F (43.3°C)

As a supplement, the results of this study will be compared with the results of another investigation at Texas Tech University (Ramsey, 1975) which used male subjects and a research procedure similar to the research procedure utilized in this study. In the following discussion, the results will be referred to as "significant" when the results are found to be statistically significant for the criteria under consideration.

Temperature-Time Effects

Pursuit Tracking

The results of the ANOVA for pursuit tracking are given in Tables 9, 10 and 11 of Appendix A. The analysis showed that:

2T-8C - Temperature: significant (.01)

Time: significant (.01)

Interaction-Temp X Time: NS (.05)

3T-6C - Temperature: significant (.01)

Time: significant (.01)

Interaction-Temp X Time: NS (.05)

4T-2C - Temperature: significant (.01)

Time: significant (.01)

Interaction-Temp X Time: NS (.05)

For this task, higher scores represent higher degrees of performance since they represent the time on target. The mean scores of pursuit tracking along with the results of the Duncan's Multiple Range Test conducted on the mean scores are plotted on Figure 7.

For Figure 7, and all subsequent Figures which include a Duncan's Multiple Range analysis, the notation and format are to be interpreted as described below:

The 2T-8C notation indicates that the data shown refers to the 2 Temperature-8 Cycle analysis, and the notation 2 1 (.01) depicts that the mean scores of WBGT level 2 and level 1 are significantly different from each other at the .01 significance level. The mean scores are arranged in descending order.

The 3T-6C notation indicates that the data shown refers to the 3 Temperature-6 Cycle analysis, and the notation 3 2 1 (.01) depicts that the mean scores of WBGT levels

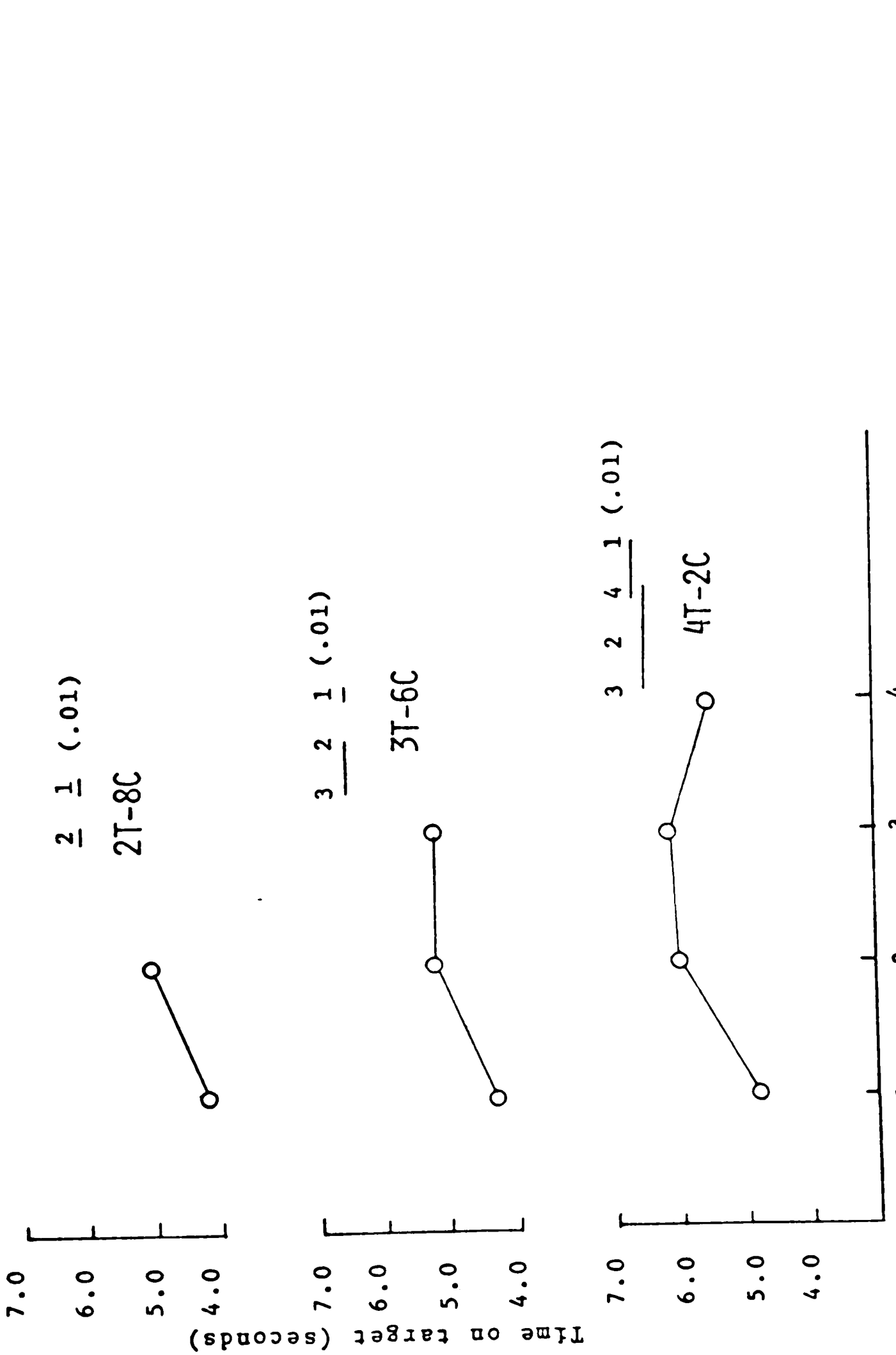


Figure 7. Pursuit tracking task, time on target vs WBGT level

3 and 2 are not significantly different from each other at .01 significance level; the mean scores of WBGT levels 3 and 2 are significantly different from the mean score of WBGT level 1 at the .01 significance level.

The 4T-2C notation indicates that the data shown refers to the 4 Temperature-2 Cycle analysis, and the notation 3 2 4 1 (.01) depicts that the mean scores of WBGT levels 3, 2, and 4 are not significantly different from each other at the .01 significance level; the mean scores of WBGT levels 4 and 1 are not significantly different from each other at the .01 significance level; the mean scores of WBGT levels 3 and 2 are significantly different from the mean score WBGT level 1 at the .01 significance level.

Effect of Temperature. Duncan's Multiple Range Test was performed on the means. As seen from Figure 7, (Page 57), performance at WBGT level 1 was lower than the performance at the other three WBGT levels. This improvement in performance at the higher WBGT levels may be explained in terms of the arousal theory, Henschel (1971). If the primary task stimulus is less than optimal, addition of another stimulus such as thermal stress, results in an optimal stimulus, and thus a higher degree of performance. If the combined stimulus of the primary task and the thermal stress exceed the optimal stimulus, a deterioration in performance can be expected. The optimal stimulus for pursuit tracking

seems to occur close to WBGT level 3. This optimum performance at WBGT level 3, however, was not significantly different from performances at WBGT levels 2 and 4. Lower performance at WBGT level 1 may be attributed to a primary task stimulus less than the optimal.

Effect of Time. Performance on the pursuit rotor decreased significantly with time. Figure 8 contains the plot of performance versus time and the results of Duncan's Multiple Range Test conducted on the mean scores. This decrease in performance is most likely attributable to fatigue caused by the thermal stress and/or loss of concentration or boredom on the task with time.

The interactions of temperature and time were not significant. The absence of interaction indicates that the decrease in performance with time for each temperature had basically the same slope or a large error variance. A plot of the interaction depicts lines which are approximately parallel, indicating that the performance decreased with time regardless of exposure to different WBGT levels under consideration.

Eye-hand Coordination Task (maze tracing)

The results of the ANOVA for the eye-hand coordination task (maze tracing) are given in Tables 12, 13 and 14 of Appendix A. The analysis showed that:

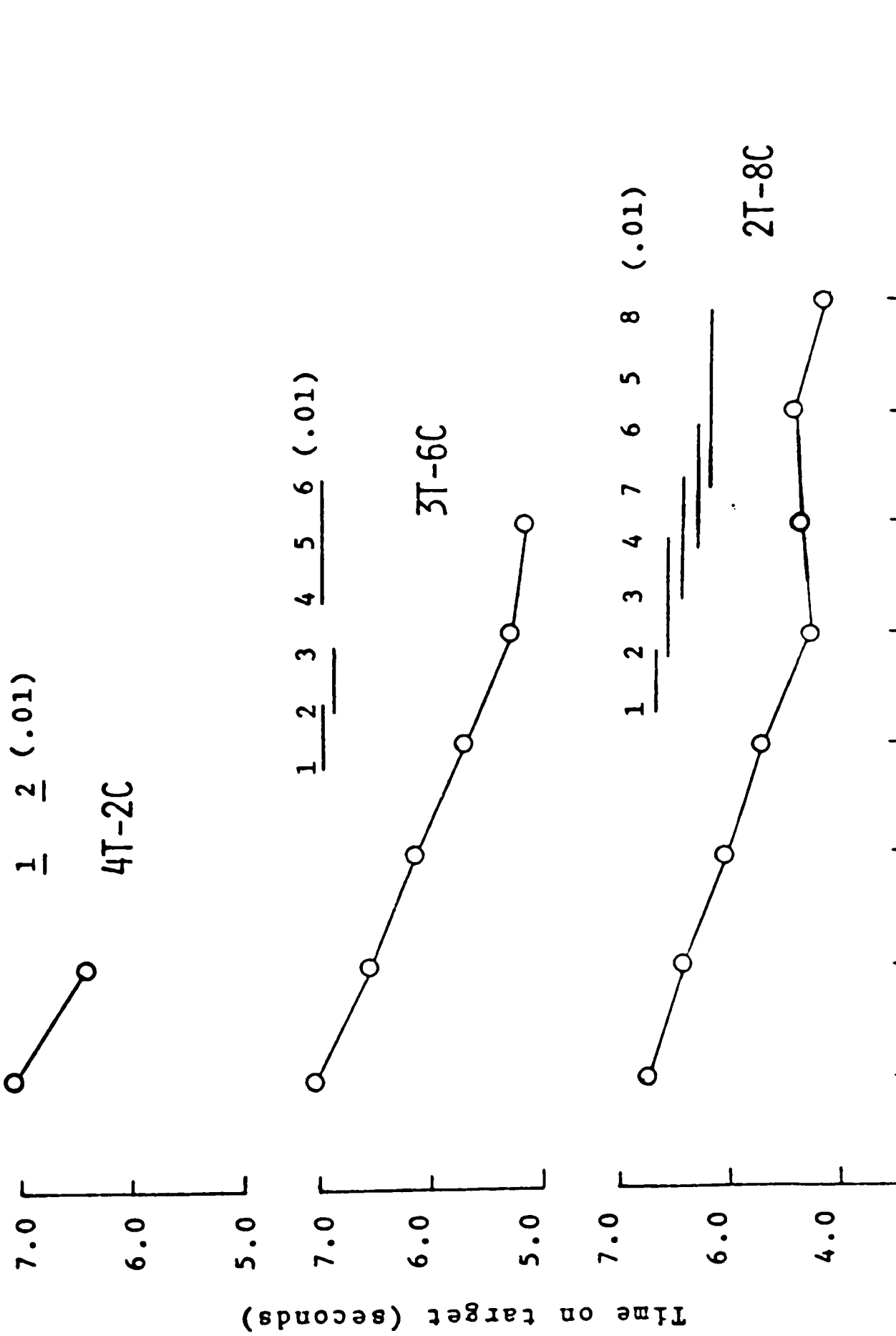


Figure 8. Pursuit tracking task, time on target vs cycle.

2T-8C - Temperature: NS (.05)

Time: significant (.01)

Interaction-Temp X Time: NS (.05)

3T-6C - Temperature: NS (.05)

Time: significant (.01)

Interaction-Temp X Time: NS (.05)

4T-2C - Temperature: NS (.05)

Time: significant (.01)

Interaction-Temp X Time: NS (.05)

For this task, the performance was measured by the time required to trace the maze along a marked path from start to finish. Hence, low scores indicate high performance.

Effect of Temperature. Effect of temperature was not significant in any of the three analyses. Performances during exposure to four WBGT levels were not statistically different from each other.

Effect of Time. The mean scores obtained in the analysis are plotted in Figure 9 along with the results of Duncan's Multiple Range Test conducted on the mean scores. Figure 9 clearly indicates that subjects performed poorly during the first cycle. They improved their performance with more repetitions of the task, but only performance during cycle one was significantly lower than the other cycles. In other words, the subjects performed poorly during the first cycle of each session and improved their performance as they repeated the tracing.

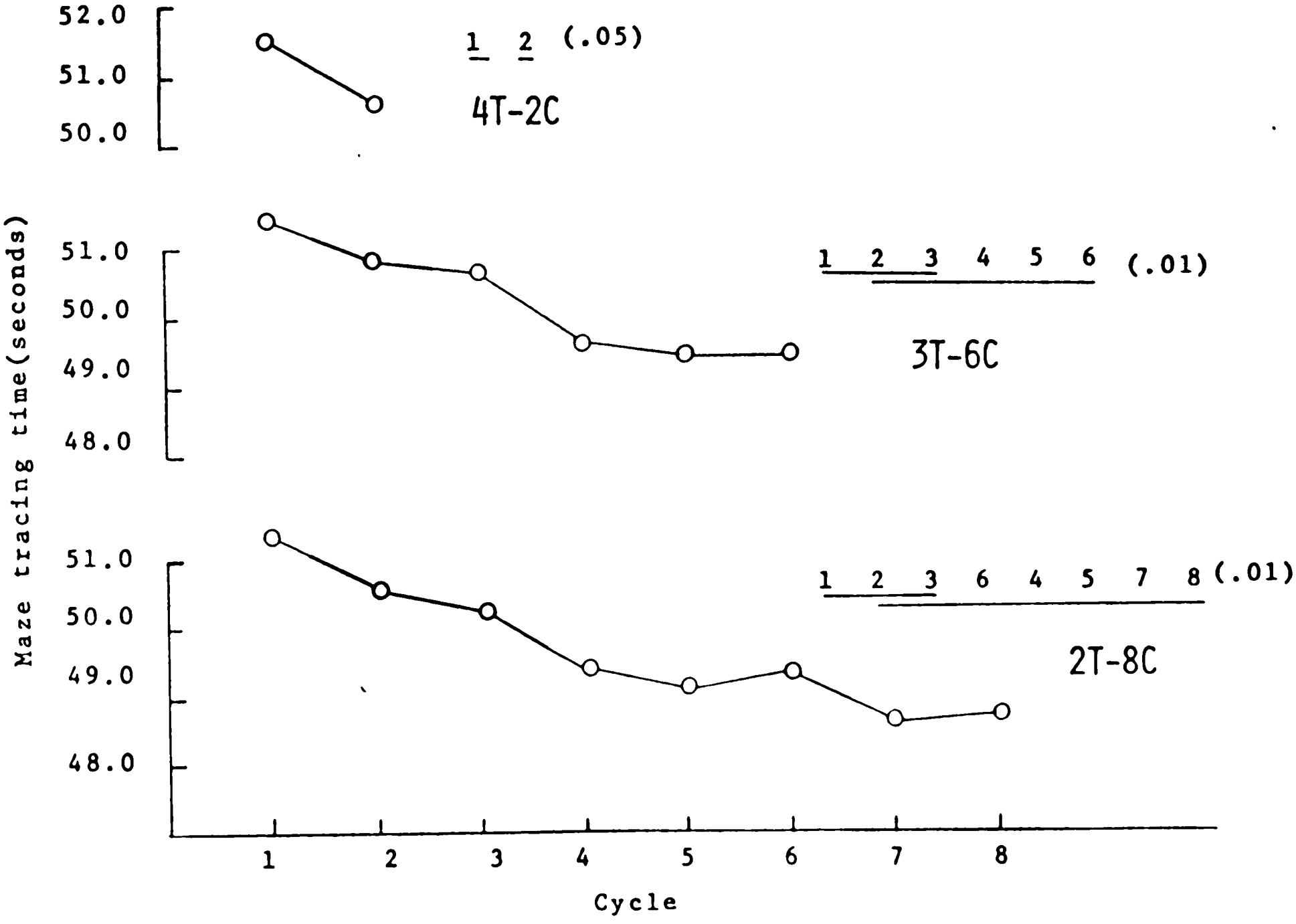


Figure 9. Eye-hand coordination task, tracing time vs cycle.

Interactions of temperature and time were not statistically significant.

Reaction Time Task

The results of the ANOVA for the reaction time task are given in Tables 15, 16, and 17 of Appendix A. The analysis showed that:

2T-8C - Temperature: NS (.05)
Time: significant (.01)
Interaction-Temp X Time: NS (.05)

3T-6C - Temperature: NS (.05)
Time: significant (.01)
Interaction-Temp X Time: NS (.05)

4T-2C - Temperature: NS (.05)
Time: NS (.05)
Interaction-Temp X Time: NS (.05)

For this task, performance was measured in terms of the difference in time between the presentation of the stimulus and the response of the subject to the stimulus. Hence, high values denote a low degree of performance. Duncan's Multiple Range Test was conducted on the significant means.

Effect on Temperature. The effect of temperature was not significant in any of the three analyses. The exposure to different WBGT levels did not effect subjects' performance.

Effect of Time. Mean scores of the analyses are plotted on Figure 10 along with the results of Duncan's Multiple Range Test conducted on the mean scores. Performance during the first cycle was significantly better than the performance during the fifth cycle, and the plot shows a decreasing performance with time. This depicts the acknowledged effect of time on vigilance performances (Hardesty et al. [1973], McCormack [1960], Smith et al. [1966], and Waag et al. [1973]).

Multiplication Task

The results of the ANOVA for speed of multiplication (number of digits completed) are given in Tables 18, 19 and 20 of Appendix A. The analysis showed that:

2T-8C - Temperature: NS (.05)
Time: NS (.05)
Interaction-Temp X Time: NS (.05)

3T-6C - Temperature: NS (.05)
Time: NS (.05)
Interaction-Temp X Time: NS (.05)

4T-2C - Temperature: NS (.05)
Time: significant (.05)
Interaction-Temp X Time: (.05)

For this analysis high values represent a high degree of performance, since the performance is measured in terms of the number of digits completed.

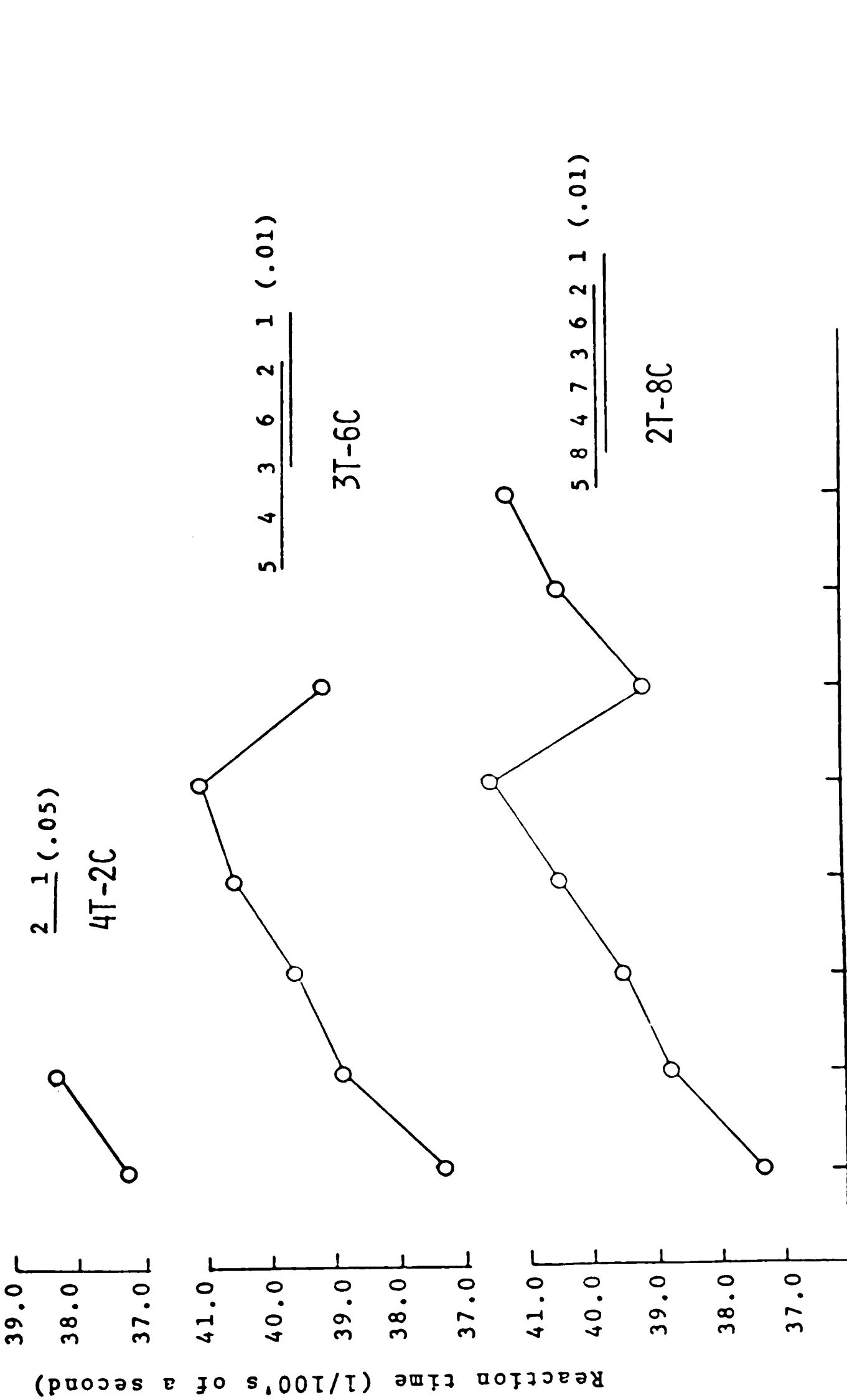


Figure 10. Reaction time task, reaction time vs cycle.

Effect of Temperature. The effect of temperature was not statistically significant in any of the three analyses. This indicates that the exposure to the different WBGT levels did not have effect on the performance of the subjects.

Effect of Time. The effect to time was statistically significant only in the 4T-2C analysis. The mean scores of the three analyses are plotted on Figure 11 along with the results of Duncan's Multiple Range Test conducted on the mean scores. The subjects' speed of multiplication dropped during the second cycle in all of the three analyses, but this drop in speed was statistically significant at the 5% level only in the 4T-2C analysis.

The results of the ANOVA for percent error are given in Tables 21, 22 and 23 of Appendix A. The ANOVA indicated a slight significance for the effect of temperature in the 3T-6C analysis. When the means were compared with Duncan's Multiple Range Test, they were not significantly different from each other. The effects of temperature or time were not significant for percent error (the percent wrong digits committed).

Physiological Responses

The heart rate and oral temperature of the subjects were monitored. Since these physiological responses were primarily monitored as a safety precatuion, only brief analyses will be made in this section.

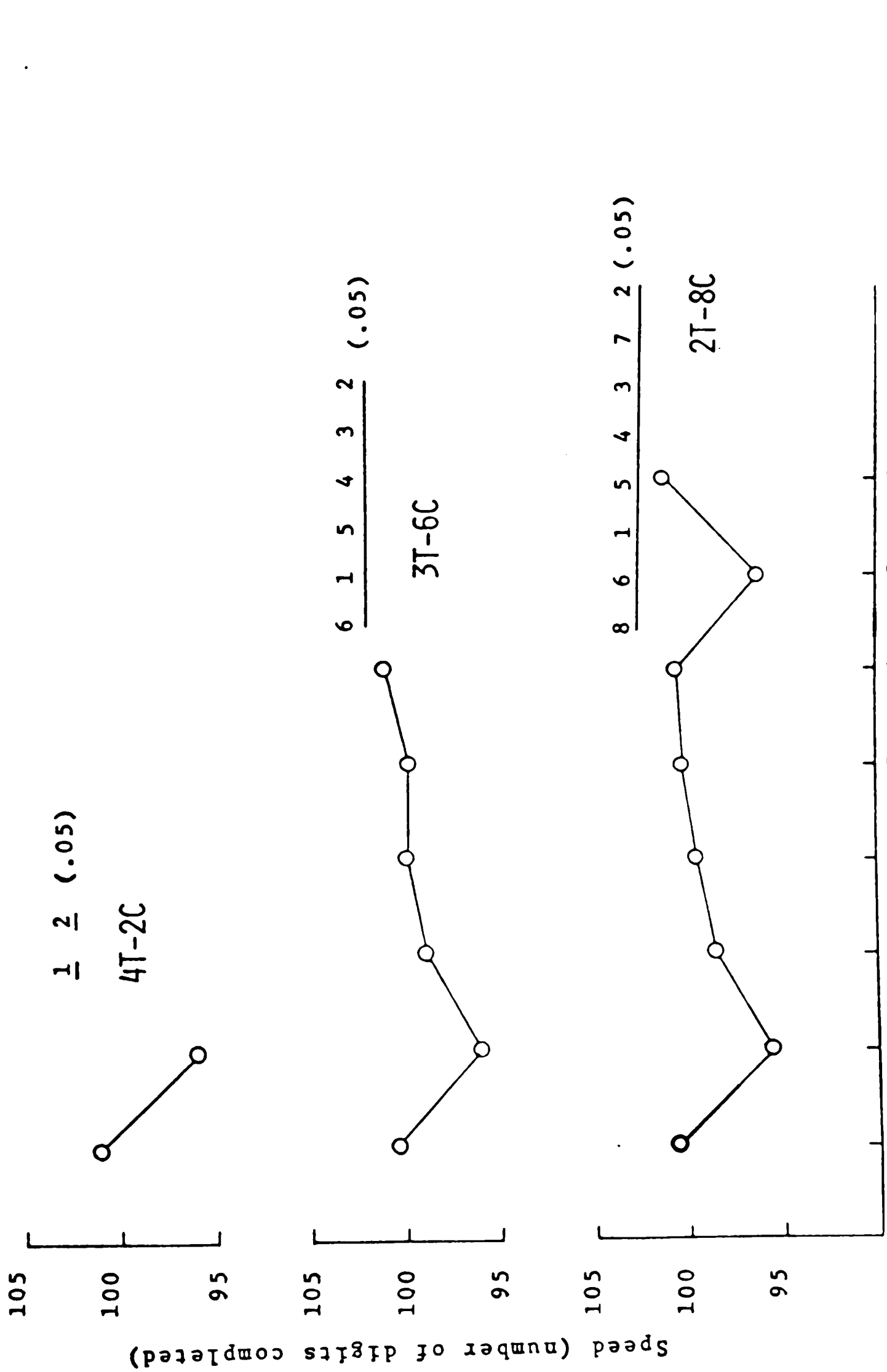


Figure 11. Multiplication task, speed vs cycle.

Heart Rate

The results of the ANOVA for heart rate are given in Tables 24, 25 and 26 of Appendix A. The analyses showed that:

2T-8C - Temperature: significant (.01)
Time: NS (.05)
Interaction-Temp X Time: NS (.01)

3T-6C - Temperature: significant (.01)
Time: significant (.01)
Interaction-Temp X Time: NS (.01)

4T-2C - Temperature: significant (.01)
Time: significant (.01)
Interaction-Temp X Time: NS (.01)

Effect of Temperature. The mean values obtained in the analyses are plotted in Figure 12 along with the results of Duncan's Multiple Range Test conducted on the mean values. Results indicated that heart rate increased with the increase in ambient temperatures. In the 4T-2C analysis, heart rates during first 30 minutes of exposure to WBGT levels 2 and 1 were not significantly different from each other and the mean heart rates during exposure to WBGT levels 2 and 3 were not significantly different from each other. In the other two analyses (3T-6C and 2T-8C) heart rates during the first 30 minutes of exposure to WBGT levels 1, 2 and 3 were significantly different from each other. Substantially higher heart rate readings during the exposure to WBGT level 4 were responsible for these differences.

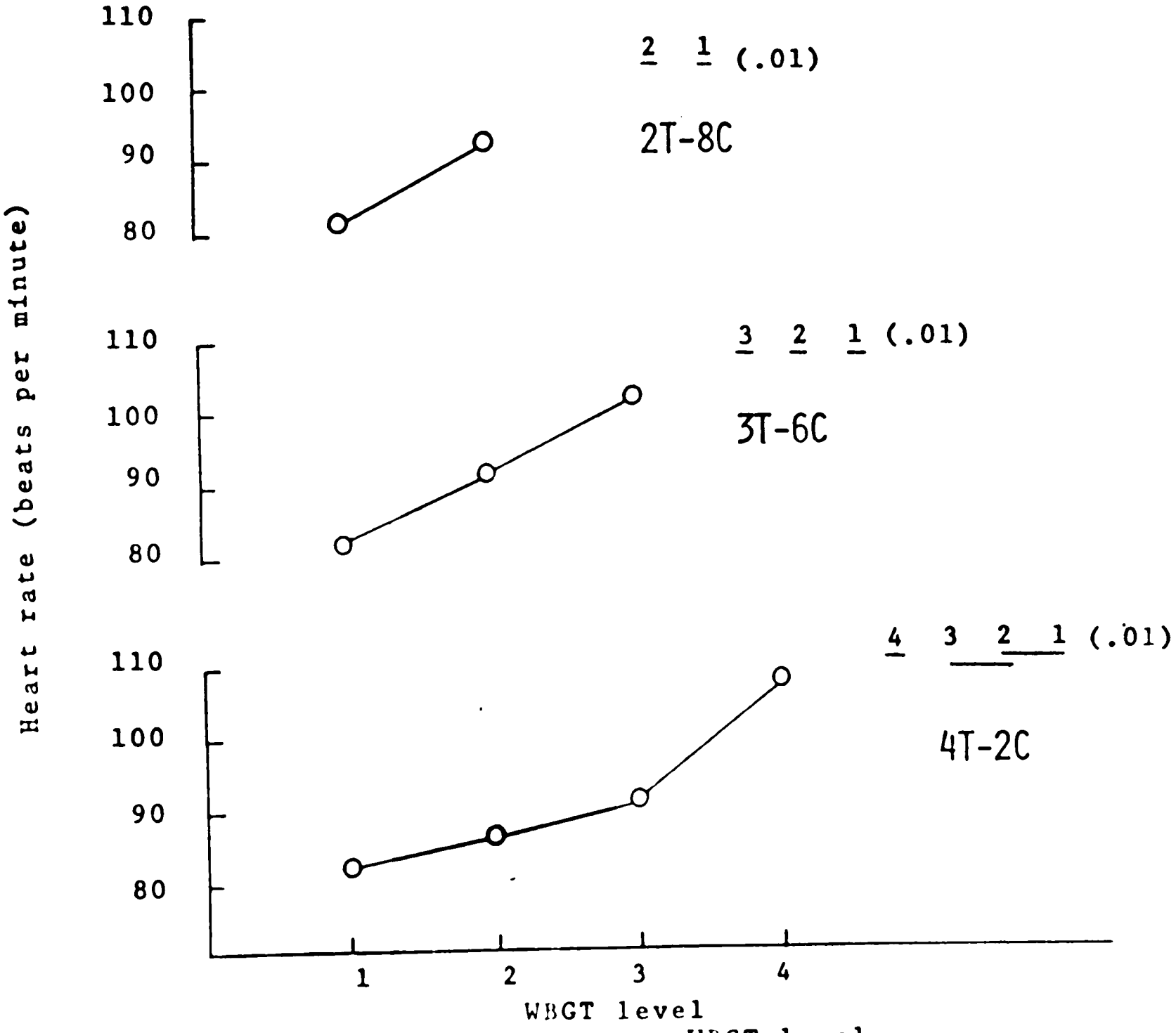


Figure 12. Heart rate vs WBGT level.

Effect of Time. The effect of time on heart rates was significant in the 4T-2C, 3T-6C analyses, but was not significant in the 2T-8C analysis. As seen from Figure 13 and Duncan's Multiple Range Test, when the subjects were exposed to the hot environment of the chamber, heart rates increased initially and reached a steady state. In the 2T-8C analysis, heart rates increased slightly, but were not statistically significant. However the other two analyses indicated that heart rates increased more rapidly with time as the environmental temperature increased.

Interaction of Temperature and Time. Interaction of temperature and time was significant in the 3T-6C and 4T-2C analyses. The means obtained in the analyses are plotted in Figure 14 which shows that heart rates during the exposure to WBGT levels 3 and 4 increased faster than during exposure to WBGT levels 1 and 2. In other words, interaction of temperature and time was more pronounced during the exposure to high temperatures.

Oral Temperature

The results of the ANOVA for oral temperature are given in Tables 27, 28, and 29 of Appendix A. The analysis showed that:

2T-8C - Temperature: significant (.01)

Time: significant (.01)

Interaction-Temp X Time: NS (.01)

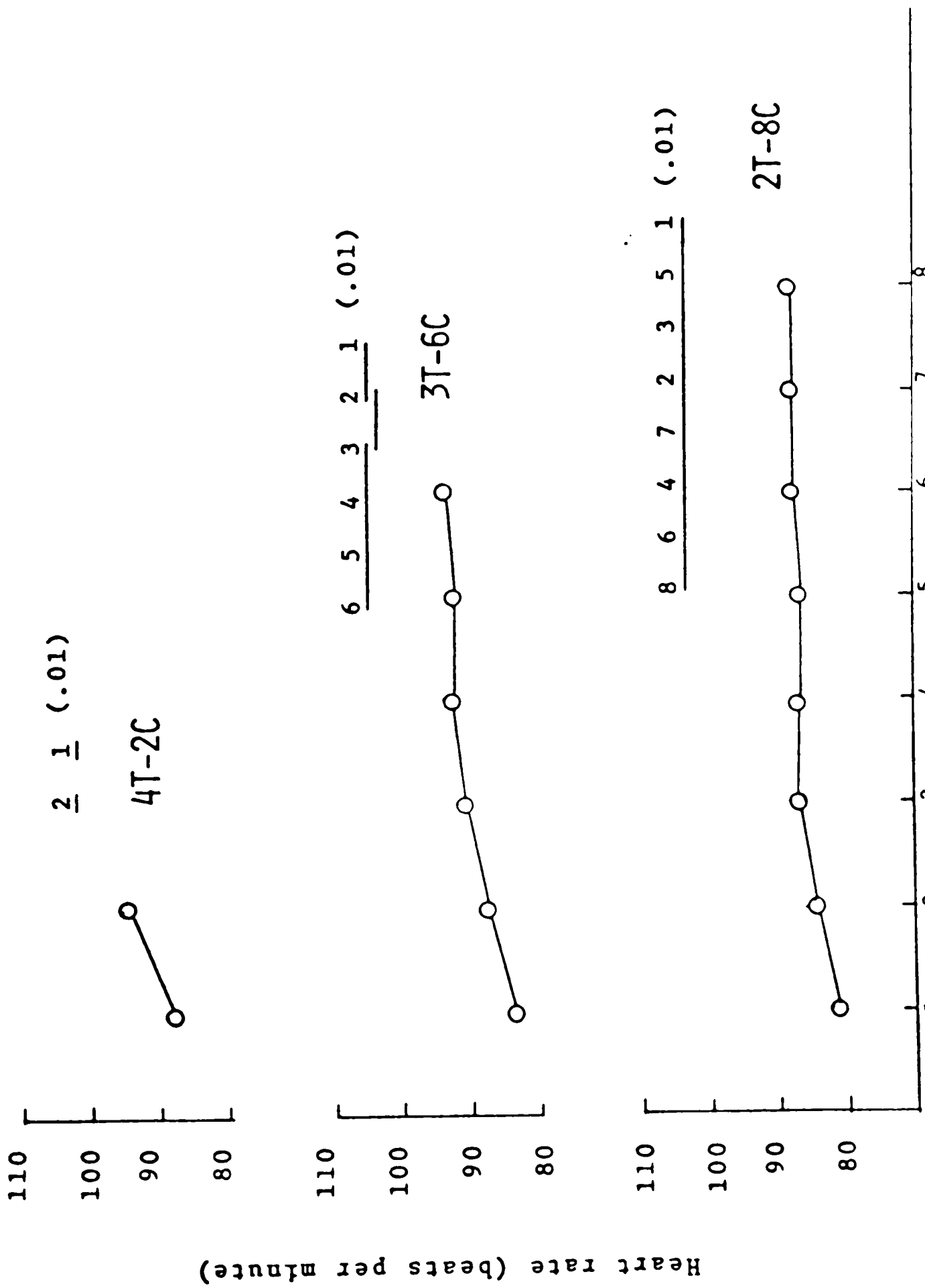


Figure 13. Heart rate vs cycle.

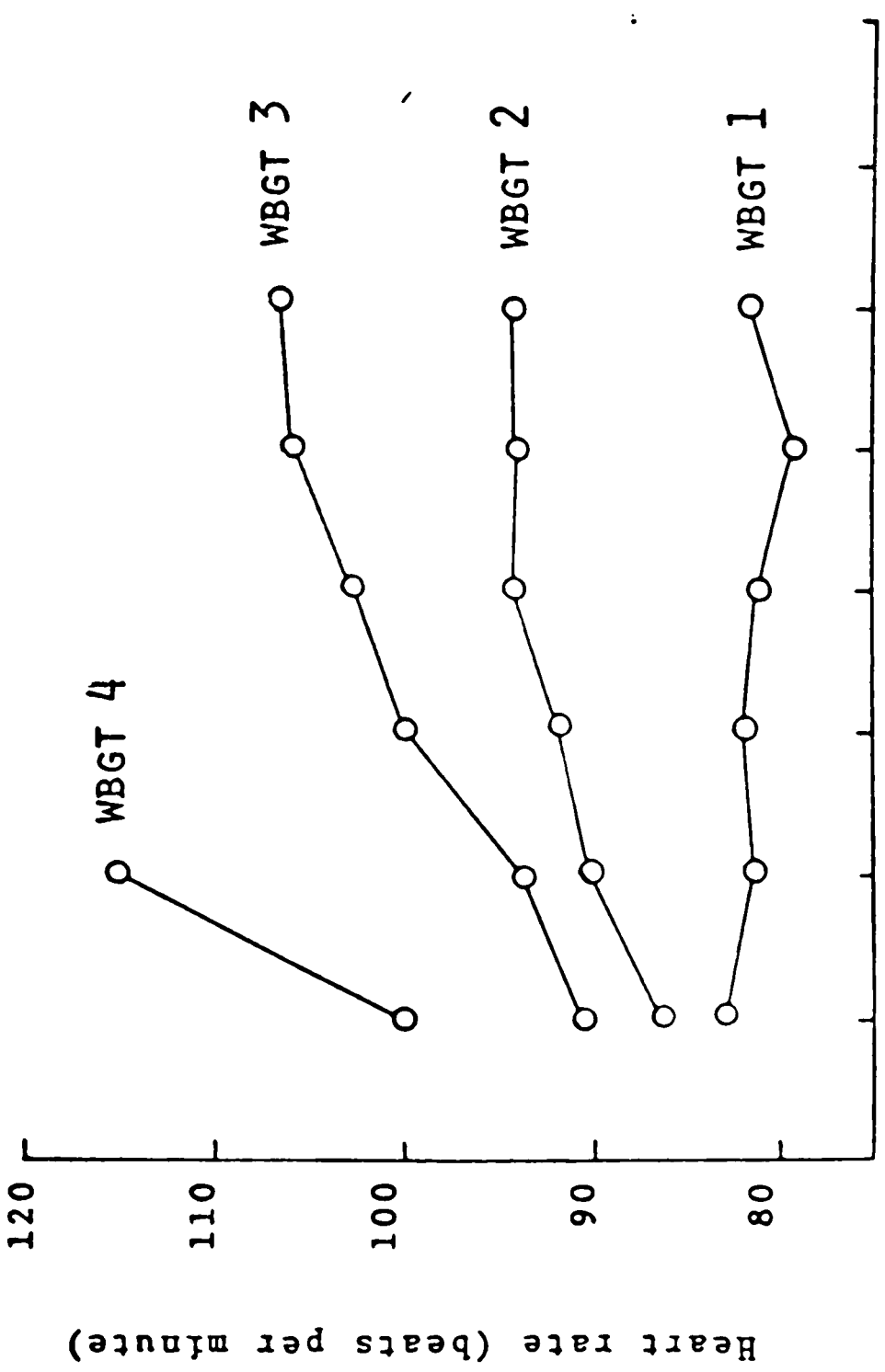


Figure 14. Heart rate, f
temperature.

3T-6C - Temperature: significant (.01)

Time: significant (.01)

Interaction-Temp X Time:

significant (.01)

4T-2C - Temperature: significant (.01)

Time: significant (.01)

Interaction-Temp X Time:

significant (.01)

Effect of Temperature. The mean values of oral temperatures obtained from the analyses are plotted on Figure 15 along with the results of Duncan's Multiple Range Test conducted on the mean values. Oral temperature increased significantly with temperature, as anticipated. Duncan's Multiple Range Test revealed that the mean oral temperatures were significantly different from each other at each level of environmental temperature.

Effect of Time. The mean oral temperatures obtained in the analyses are plotted in Figure 16 along with the results of Duncan's Multiple Range Test conducted on the mean values. Oral temperatures of the subjects increased significantly for the first 15 minutes and then attained a steady state. As seen from Figure 16, Duncan's Multiple Range Test shows that oral temperatures during cycle one were significantly different from those of the other cycles.

Interaction of Temperature and Time. Interactions of temperature and time are plotted on Figure 17. At WBGT

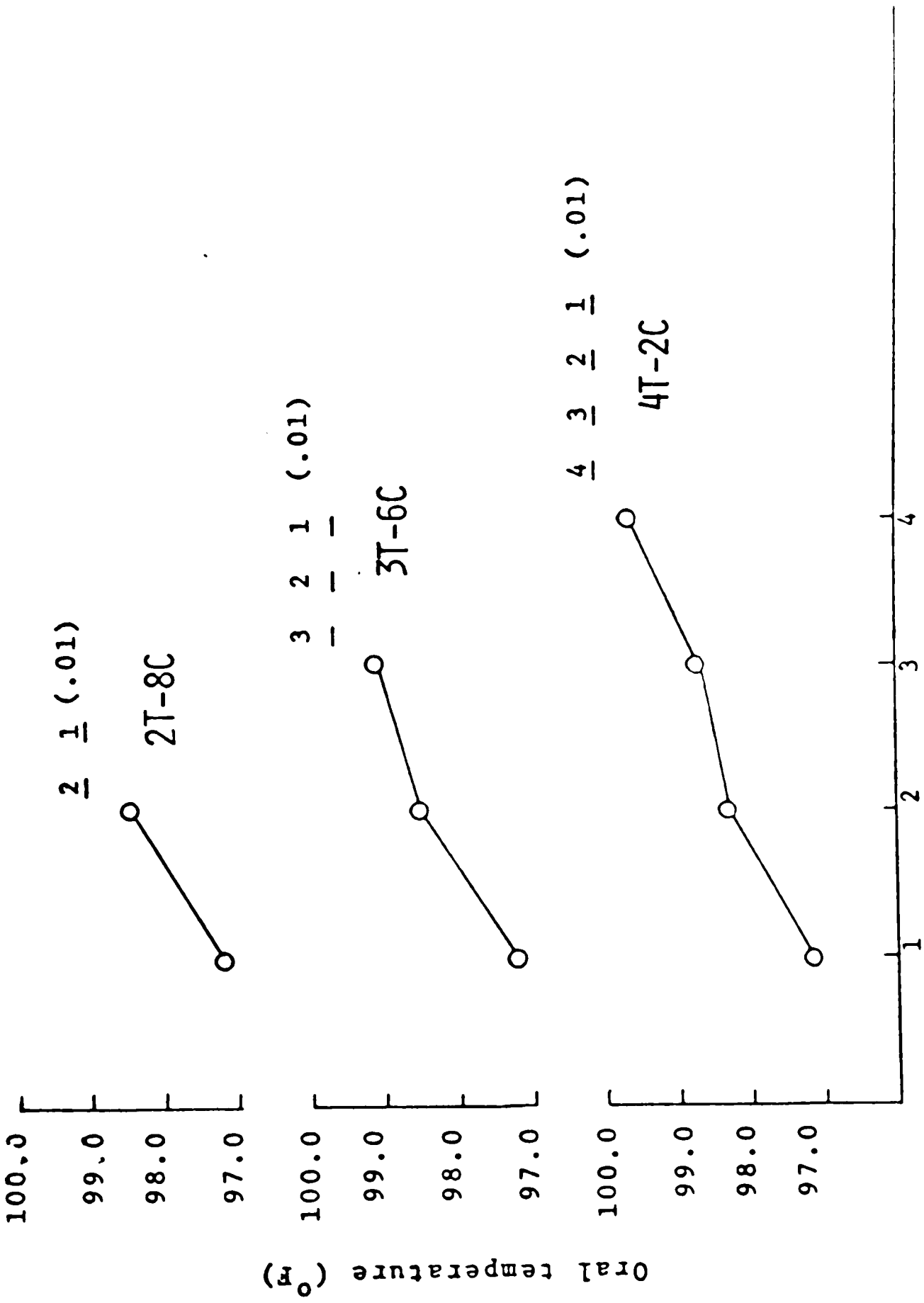


Figure 15. Oral temperature vs WBGT level.

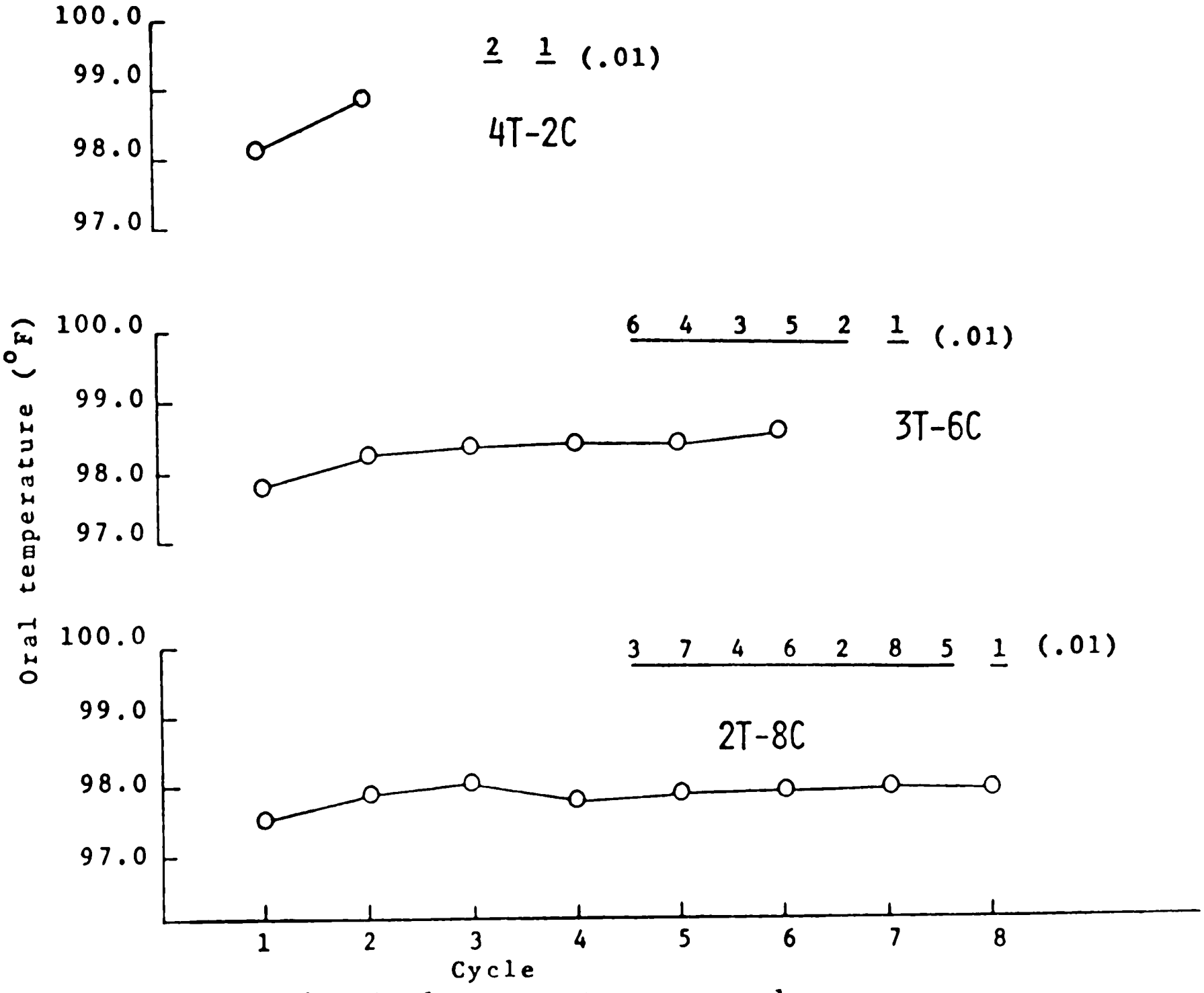


Figure 16. Oral temperature vs cycle.

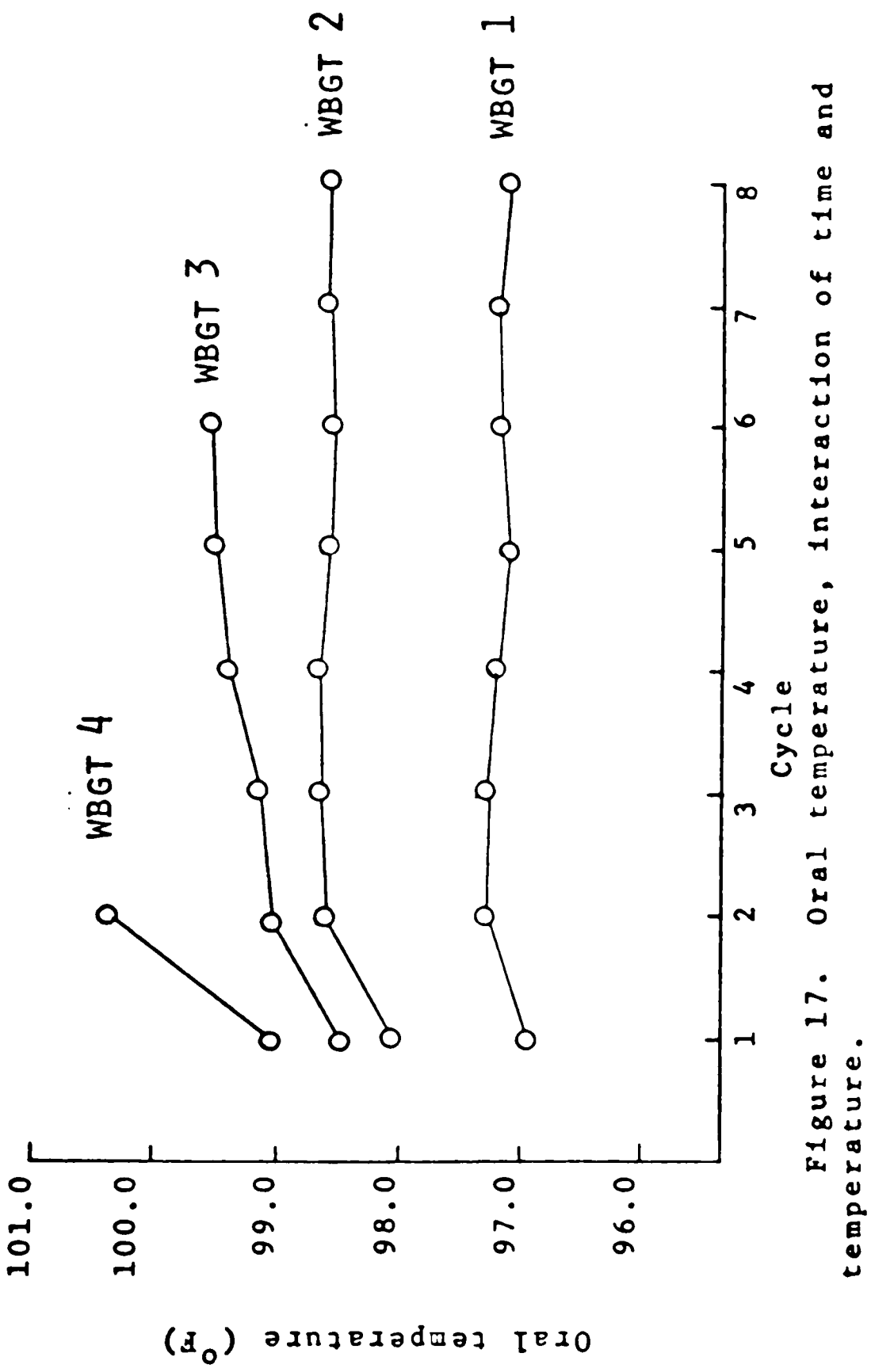


Figure 17. Oral temperature, interaction of time and temperature.

levels 1 and 2, there was no significant interaction between the temperature and time. But when the subjects were exposed to WBGT levels 3 and 4, the interaction of temperature and time on oral temperatures became statistically significant.

Session Effect

An analysis of variance for session effect was conducted on the four task scores (reaction time, pursuit tracking, eye-hand coordination, and multiplication). The results of the ANOVA for session effect are given in Tables 30 thru 34 of Appendix A. The results showed that:

Reaction time - NS (.01)

Pursuit tracking - significant (.01)

Eye-hand coordination - significant (.01)

Speed of multiplication - significant (.01)

Percent error in multiplication - NS (.01)

The data used in the above analyses used the performance scores from only the first two fifteen minute cycles of each session. This was done since the different sessions had different exposure times and it was not possible to utilize all the data in the analysis. Such a comprehensive analysis would have many empty cells.

The mean scores of these analyses along with the results of the Duncan's Multiple Range Test conducted on the mean scores are plotted on Figure 18.

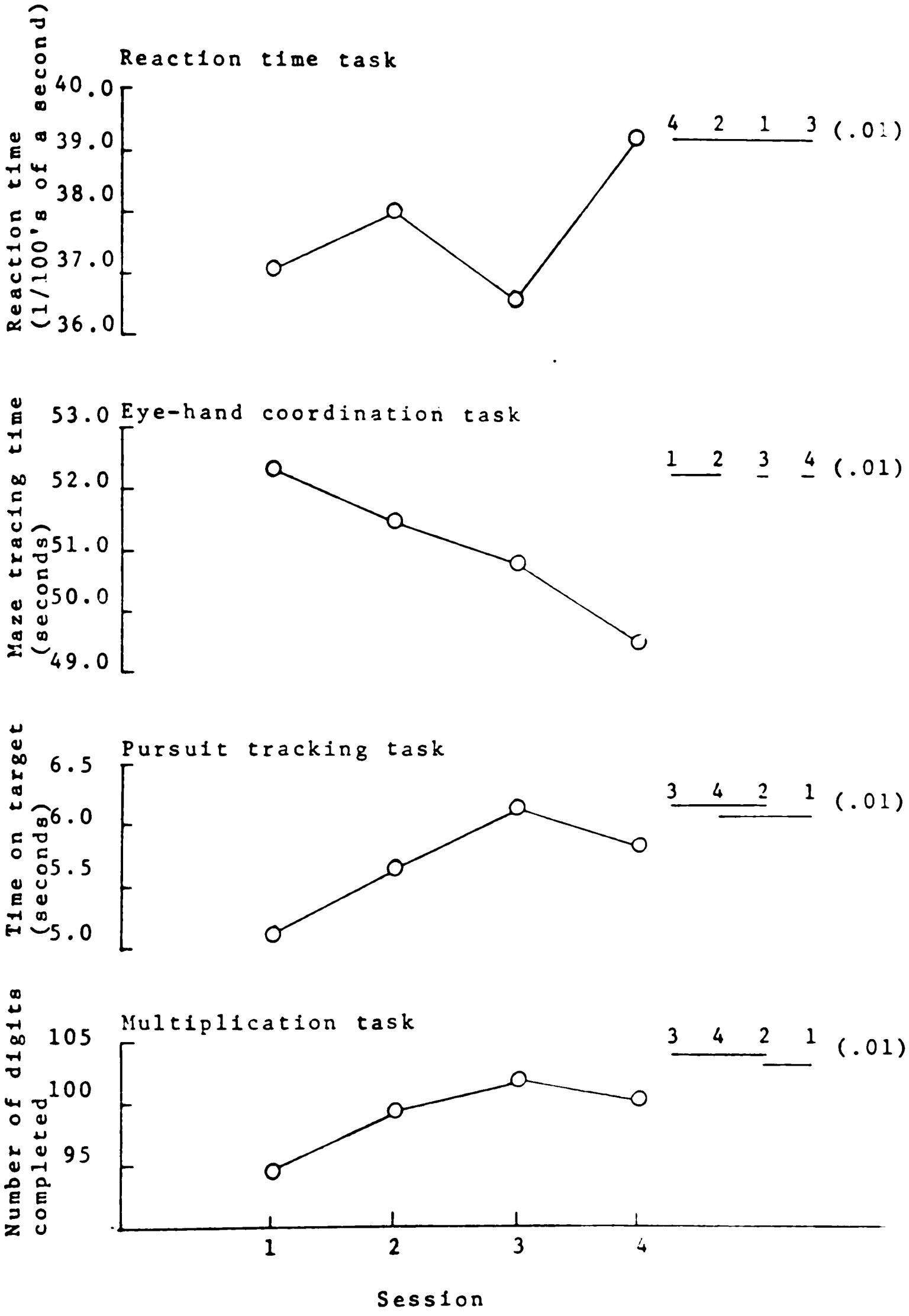


Figure 18. Session effect, performance on tasks vs session.

Reaction time task performance showed no significant session effect. No significant session effect was expected because of the simplicity of the task.

Eye-hand coordination task (maze tracing) performance improved significantly with each session.

For the pursuit tracking task, performance during session 1 was significantly lower than the performance during session 3. Performances during sessions 2, 3, and 4 were not significantly different from each other; performance during session 2, 4 and 1 were not significantly different from each other.

For the multiplication task, speed of multiplication during session 1 was significantly lower than the speed of multiplication during sessions 3 and 4. Speed of multiplication for sessions 2, 3, and 4 were not significantly different from each other; speed of multiplication during sessions 2 and 1 were not significantly different from each other. There was no significant session effect for percent error (percent wrong digits).

The results of the above analyses indicate that probably more than two training sessions are necessary to complete the learning of the tasks. A third training session would likely improve the skill level on the tasks.

Since the sequence of exposure for each group to different temperatures was balanced (Table 6, page 50), the session effects should not influence the results in

that each temperature is represented equally within each session.

Subjective Responses

Subjective responses were collected at the completion of each session. A copy of the questionnaire is attached in Appendix E. Answers to the questions were transformed into numbers (as indicated in column one of Table 7). A significance level of 1% was established as a meaningful criteria (99% confidence) to evaluate the results of the analysis. Results of the analyses are tabulated in Table 7, page 81.

Question 1 concerned the week of subject's menstrual cycle during the experimental sessions. The numbers indicated below were assigned to the corresponding weeks in order to perform an analysis of variance:

1 - Pre-flow week

2 - Flow week

3 - Post-flow week

4 - Other week

The mean values obtained for the four WBGT levels were:

WBGT level 1 - 3.0

WBGT level 2 - 2.6

WBGT level 3 - 2.7

WBGT level 4 - 2.6

TABLE 7

SUBJECTIVE RESPONSES

QUESTION		TEMPERATURES					SIGNI-FICANCE
		74	90	100	110	AVG.	
1. Week of the menstrual cycle 1 - Pre-flow week 2 - Flow week 3 - Post-flow week 4 - Other week		3.0	2.6	2.7	2.6	2.7	NS (0.01)
2. Temperature level felt 1 - cold 2 - cool 3 - slightly cool 4 - neutral 5 - slightly warm 6 - warm 7 - hot 8 - very hot 9 - extremely hot		3.3	6.1	7.4	8.1	6.2	.01
3. Heat effect on performance 1 - none 2 - minor 3 - major 4 - severe	CYCLE						
	First	1.1	1.3	1.6	1.6	1.4	NS (.01)
	Middle	1.0	1.7	1.8	2.0	1.7	.01
	Last	1.0	1.9	2.2	2.0	1.8	.01
	Average	1.0	1.6	1.6	1.9	1.6	.01

TABLE 7-continued

QUESTION	CYCLE	TEMPERATURE					SIGNI-FICANCE
		74	90	100	110	AVG.	
4. Heat effect on physiological responses 1 - none 2 - minor 3 - major 4 - severe	First	1.1	1.5	1.5	1.7	1.5	.01
	Middle	1.0	1.9	1.9	2.1	1.7	.01
	Last	1.0	2.0	2.3	2.1	1.9	.01
	Average	1.0	1.8	1.9	1.9	1.7	.01

QUESTION	TASK	TEMPERATURE					SIGNI-FICANCE LEVEL
		74	90	100	110	AVG.	
5. Feel drowsy 1 - Yes 0 - No	Reaction time	.53	.87	.73	.26	.60	.01
	Pursuit tracking	.27	.53	.40	.27	.37	NS (.01)
	Maze trace	.13	.13	.20	.07	.13	NS (.01)
	Multiplication	.07	.13	.13	.07	.10	NS (.01)
	Average	.25	.40	.40	.13	.30	NS (.01)
6. Get bored 1 - Yes 0 - No	Reaction time	.87	.93	.93	.60	.83	NS (.01)
	Pursuit tracking	.67	.67	.80	.20	.59	.01
	Maze trace	.33	.27	.20	.07	.22	NS (.01)
	Multiplication	.20	.13	.00	.07	.10	NS (.01)
	Average	.51	.50	.48	.24	.43	.01

TABLE 7-continued

QUESTION	TASK	TEMPERATURES 74	90	100	110	AVG.	SIGNI-FICANCE
7. Feel Fatigued 1 - Yes 0 - No	Reaction time	.07	.13	.13	.00	.08	NS (.01)
	Pursuit tracking	.13	.20	.07	.20	.15	NS (.01)
	Maze trace	.13	.33	.13	.13	.18	NS (.01)
	Multiplication	.07	.13	.20	.06	.13	NS (.01)
	Average	.10	.20	.13	.10	.14	NS (.01)
8. Performance improved during today's session 1 - Yes 0 - No	Reaction time	.27	.13	.13	.13	.17	NS (.01)
	Pursuit tracking	.40	.20	.13	.20	.23	NS (.01)
	Maze trace	.27	.27	.27	.20	.25	NS (.01)
	Multiplication	.40	.33	.33	.13	.30	NS (.01)
	Average	.33	.23	.21	.17	.24	NS (.01)
9. Performance improved over yester-day's session 1 - Yes 0 - No	Reaction time	.33	.27	.13	.13	.22	NS (.01)
	Pursuit tracking	.40	.47	.13	.20	.30	NS (.01)
	Maze trace	.27	.47	.20	.13	.27	NS (.01)
	Multiplication	.60	.53		.13	.38	NS (.01)
	Average	.40	.43	.18	.15	.29	NS (.01)

TABLE 7-continued

QUESTION	TASK	TEMPERATURE					SIGNI-FICANCE
		74	90	100	110	AVG.	
10. Compare performance with other subjects 1 - poor 2 - below average 3 - average 4 - above average 5 - excellent	Reactiontime	3.1	2.9	3.0	2.8	3.0	NS (.01)
	Pursuit tracking	2.9	2.8	3.2	3.1	3.0	NS (.01)
	Maze trace	2.5	2.6	2.7	2.6	2.6	NS (.01)
	Multiplication	2.3	2.6	2.6	2.6	2.5	NS (.01)
	Average	2.7	2.7	2.9	2.8	2.8	NS (.01)
11. How well did you like the task 1 - highly liked 2 - slightly liked 3 - indifferent 4 - slightly disliked 5 - highly disliked	Reactiontime	3.5	3.3	3.4	2.8	3.3	NS (.01)
	Pursuit tracking	3.7	3.5	3.5	3.6	3.6	NS (.01)
	Maze trace	2.4	2.3	2.2	2.1	2.3	NS (.01)
	Multiplication	2.1	2.0	1.9	1.9	2.0	NS (.01)
	Average	2.9	2.8	2.8	2.6	2.8	NS (.01)

The above mean values were not significantly different from each other. Hence the results obtained in this investigation are not confounded by the effect of menstrual cycle on performance.

Question 2 concerned the feelings of the subject toward the WBGT levels to which they were exposed. Numbers were assigned to the answers (1 - cool to 9 - extremely hot) and an analysis of variance was performed on the answers. The results obtained indicated that the subject's feeling towards each WBGT level was significantly different for each level. The mean scores obtained in the analysis were:

1. For WBGT level 1 - 3.3 which lies between slightly cool and neutral.
2. For WBGT level 2 - 6.1 which lies between warm and hot
3. For WBGT level 3 - 7.4 which lies between hot and very hot
4. For WBGT level 4 - 8.1 which lies between hot and extremely hot

Question 3 concerned the effect of heat on the subject's performance. The overall mean obtained in the analysis was 1.6 and this lies between none and minor effects.

Questions 5 thru 11 were task specific. These questions concerned the subject's feeling on the four different

tasks. Answers were collected in the yes/no (1/0) form for questions 5 thru 9. For questions 10 and 11 the numbers used for different answers are listed in column 1 of Table 7 on page 84.

Since the subjects were working in hot environmental conditions, it would be interesting to know their feelings of fatigue (question 7). Overall mean obtained in the analysis was 0.13, i.e., only 13% of the subjects reported that they experienced fatigue.

For question 11, numbers were assigned to the answers (1 - highly liked to 5 - highly disliked). The following responses were received:

1. Reaction time task - overall mean = 3.3 which lies between indifferent and slightly disliked
2. Pursuit tracking task - overall mean = 3.6 which lies between indifferent and slightly disliked
3. Eye-hand coordination task - overall mean = 2.3 which lies between slightly liked and indifferent
4. Multiplication task - overall mean = 2.0 which is slightly liked

From the answers it is clear that the subjects liked the multiplication task better than any other task and the pursuit tracking task was favored the least.

Environmental Conditions

Environmental measurements of globe temperature, natural dry bulb temperature, natural wet bulb temperature, psychrometric dry bulb temperature, and psychrometric wet bulb temperature were monitored using the equipment and procedure as explained in Chapter II. An analysis of variance was conducted on each measurement using a computer program ANOVAR, provided by the Computer Center at Texas Tech University. A significance level of .01 was established as a meaningful criteria (99% confidence).

Results obtained are tabulated in Table 8 along with the expected values of the environmental measurements of globe, dry bulb and wet bulb temperatures. Expected values of psychrometric dry and wet bulb temperatures are not listed because their expected values are approximate only.

At the high temperature, WBGT level 4, all temperatures between groups (sessions) and within each group (cycles) were not statistically significant. For the other WBGT levels 1, 2 and 3 there are some specific combinations which showed statistically significant differences between groups, but in no instance was the cycle effect statistically different.

TABLE 8

ENVIRONMENTAL MEASUREMENTS

WBGT LEVEL Measured/ Expected		GLOBE Measured/ Expected	NATURAL DRY BULB Measured/ Expected	NATURAL WET BULB Measured/ Expected	PSYCHROMETRIC DRY BULB Measured	PSYCHROMETRIC WET BULB Measured
109.9/110°F 43.27/43.3°C WBGT	Groups	124.63/125°F 51.46/51.67°C NS	124.62/125°F 51.45/51.67°C NS	103.58/104°F 39.77/40.0°C NS	128.5°F 53.6°C NS	96.1°F 35.6°C **
	Cycles	NS	NS	NS	NS	NS
102.5/100°F 39.2/37.7°C WBGT	Groups	114.17/115°F 45.65/46.11°C **	114.3/115°F 45.72/46.11°C **	97.44/94°F 36.36/34.44°C **	116.17°F 46.76°F NS	86.88°F 30.49°C **
	Cycles	NS	NS	NS	NS	NS
90.8/90°F 32.7/32.2°C WBGT	Groups	104.62/104°F 40.34/40°C NS	105.16/104°F 40.64/40°C **	84.87/84°F 29.37/28.89°C **	106.56°F 41.42°C NS	74.0°F 23.33°C **
	Cycles	NS	NS	NS	NS	NS
73.8/74°F 23.2/23.3°C WBGT	Groups	83.44/84°F 28.58/28.89°C **	83.07/84°F 28.37/28.89°C NS	69.63/68.5°F 20.91/20.28°C **	83.63°F 28.68°C **	60.41°F 15.78°C NS
	Cycles	NS	NS	NS	NS	NS

** - Significant (.01)

These results indicate that the temperature selected for a particular session or group remained very stable from one cycle to the next. Further, although in some cases, the temperature level varied enough from one session to the next to show statistical significance, the mean WBGT values for all the four groups were centered at the point desired for the investigation.

CHAPTER IV

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS FOR FUTURE RESEARCH

Summary

Over the past decades the number of women in the labor force has increased significantly. Today, one-third of the labor force of the world consists of women. Women are taking up jobs in new areas they had not previously entered.

When individuals begin to work in hot environmental conditions their ability to work decreases due to physiological stress. Many research studies have been conducted concerning people working in hot environmental conditions in an effort to establish some upper limits of exposure to heat stress levels. Most of the research, however, has been conducted on male subjects and very little research has been conducted with female subjects.

The purpose of this research was to study the perceptual-motor task performance of females working in hot environmental conditions in an attempt to evaluate the temperature-time limits proposed by the National Institute for Occupational Safety and Health (NIOSH). The proposed

limits (Figure 1, page 3) do not differentiate between males and females.

Performance was measured by using four different sedentary tasks at four temperature-time combinations. The tasks selected to measure the performance at these four temperature-time combinations were chosen as representative of those commonly encountered in industry. The four tasks selected were: (1) reaction time task, (2) pursuit tracking task, (3) eye-hand coordination (maze tracing) task, and (4) multiplication task.

In the reaction time task, the subject was required to press a hand held button switch in response to a light stimuli randomly presented. In the pursuit tracking task, the subject tracked a revolving light target with a stylus. In the eye-hand coordination task, the subject was required to trace a maze along a marked path with a metal stylus. In the multiplication task, the subject was required to perform standard multiplication. Performance was measured on the basis of quickness of reaction, time on target, maze tracing time, and speed and error rate of multiplication respectively.

The subjects were 15 randomly selected healthy females between the ages 12 and 23. They were divided into four groups, three groups containing four subjects each and one group containing three subjects. The subjects participated in the research after being provided pre-training

on the tasks. Physiological measures of heart rate and oral temperature were monitored as a safety precaution, as well as to determine the physiological responses of the subjects to the WBGT levels under consideration.

A randomized block factorial analysis of variance design was used to analyze the scores on each task and the two physiological variables. For all tasks and analyses performance at WBGT level 1 (74°F [23.3°C]) was considered as normal. Performances at the other WBGT levels (2-[90°F (32.2°C)], 3-[100°F (37.8°C)], and 4-[110°F (43.3°C)]) were compared with the performance at WBGT level 1 using Duncan's Multiple Range Test. Comparisons were made at the following time intervals:

1. WBGT level 1 (74°F [23.3°C]) - 15, 30, 60, 90 and 120 minutes

   (Cycles 1, 2, 4, 6, and 8)

2. WBGT level 2 (90°F [32.2°C]) - 15, 30, 60, 90 and 120 minutes

   (Cycles 1, 2, 4, 6, and 8)

3. WBGT level 3 (100°F [37.8°C]) - 15, 30, 60 and 90 minutes

   (Cycles 1, 2, 4, and 6)

4. WBGT level 4 (110°F [43.3°C]) - 15 and 30 minutes

   (Cycles 1 and 2)

Improvements or decrements in performance at 1% level (99% confidence interval) were considered to represent reliable improvements or reliable decrements, respectively, or whereas at the 5% level these were considered as partial improvements or partial decrements, respectively.

The summary of pursuit tracking task results are presented in Figure 19. As seen from Figure 19, during the first 30 minutes of exposure to the WBGT levels 2 and 3, there was an arousal effect experienced by the subjects. The subjects performed better during the first 30 minutes of exposure to WBGT levels 2 and 3 than during the exposure to WBGT level 1. There was reliable ($p<.01$) improvement in performance during the first fifteen minutes of exposure to WBGT level 2 and partial ($p<.05$) improvement in performance during the next fifteen minutes. During the exposure to WBGT level 3, only partial ($p<.05$) improvement in performance occurred during the first 30 minutes. For all other temperature-time combinations of this task there was no change ($p<.05$) in performance. The improvement in performance during the exposure to WBGT levels 2 and 3 can be interpreted as an arousal effect. Here the addition of the thermal stress of the primary task stimulus resulted in an optimal task stimulus, and hence an improvement in performance was seen. During the exposure of WBGT level 4, the combination of thermal stress and the primary task stimulus seem to exceed the optimal task stimulus, and hence no improvement in performance was found.

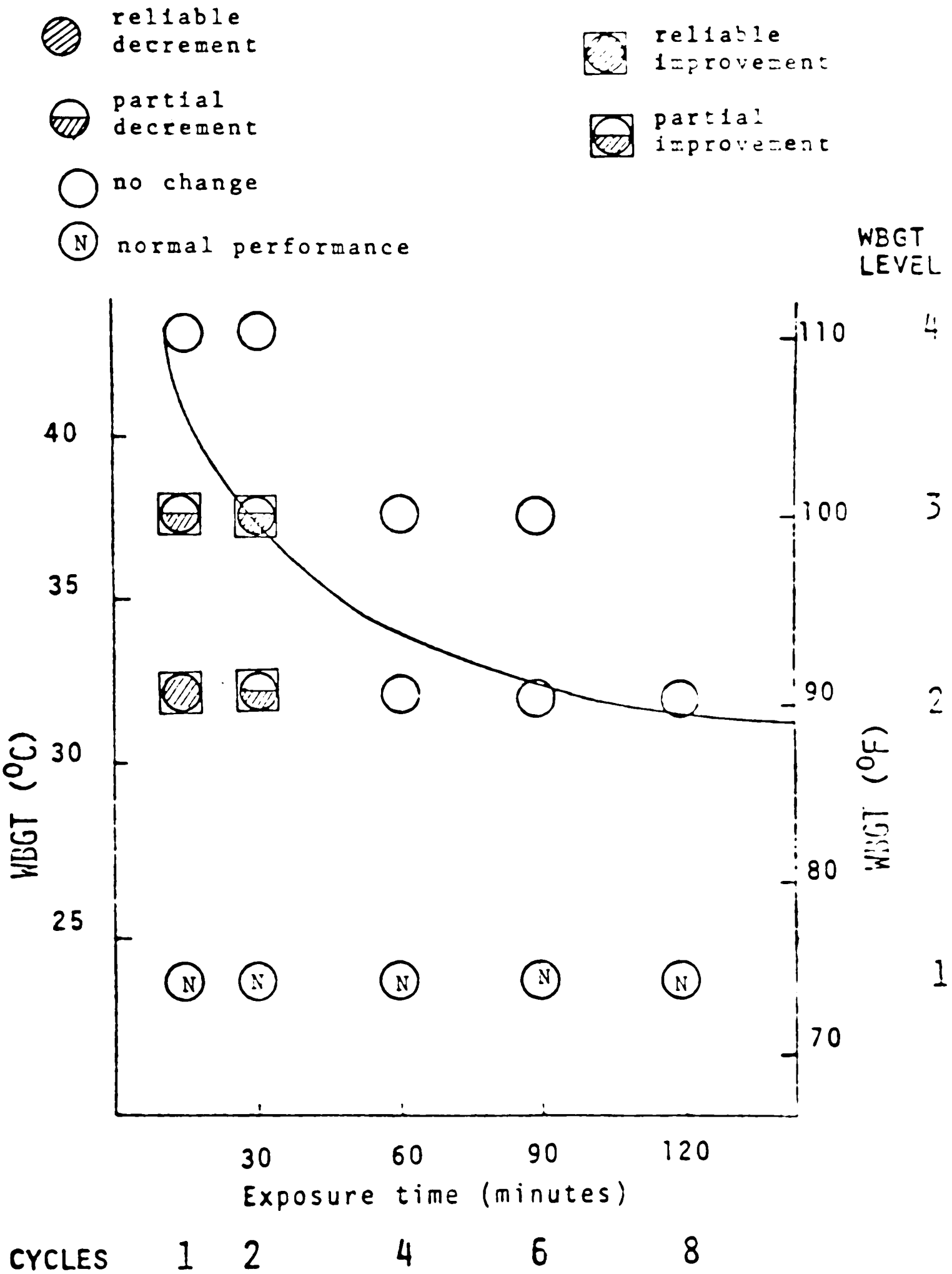


Figure 19. Summary of performance on pursuit tracking task (female).

For the eye-hand coordination task (maze tracing) there was no change ($p<.05$) in performance for all the temperature-time level combinations under consideration. The same results were obtained for reaction time, speed of multiplication, and error rate of multiplication. This indicates that females were not significantly affected by the heat on these tasks at the temperature-time combinations and the experimental conditions chosen for this study. On these tasks, addition of thermal stress to the primary task stimulus had no effect on performance.

Male-Female Differences. The results obtained in the study were compared with the results obtained in another research study (Ramsey, 1975) which utilized the same temperature-time combinations and experimental procedures but used 31 males as subjects. The results of the Ramsey study appear to be significantly different from those of this study. Males results showed increments in performance for mental tasks, decrements in performance for tasks requiring large motor responses, and less pronounced effects were obtained for eye-hand combination tasks requiring small motor responses. The male and female subjects' performance on the reaction time task, the multiplication task, and the eye-hand coordination task are plotted against WBGT levels in Figures 20, 21 and 22, respectively.

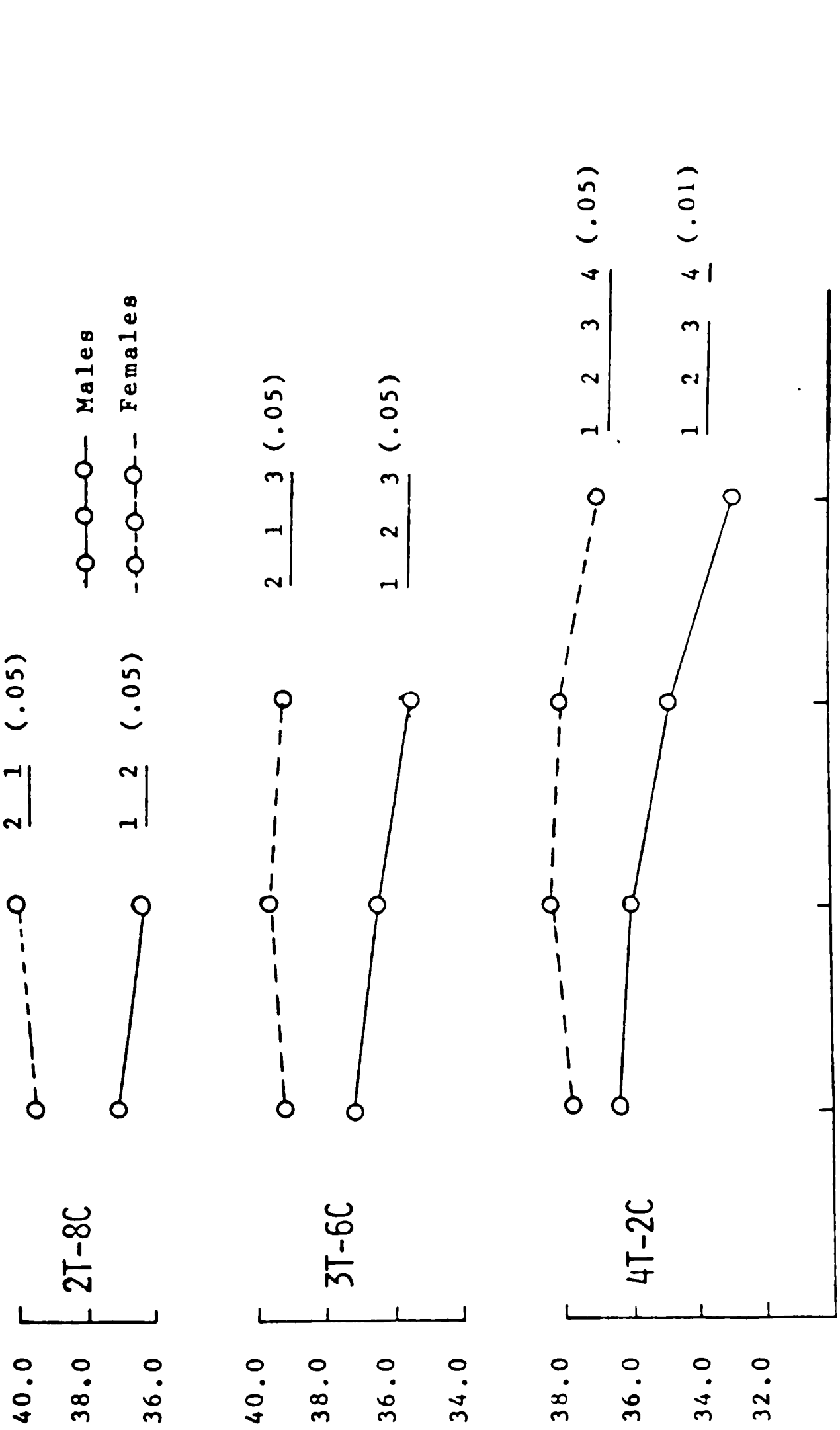


Figure 20. Reaction time task, male vs female performance.

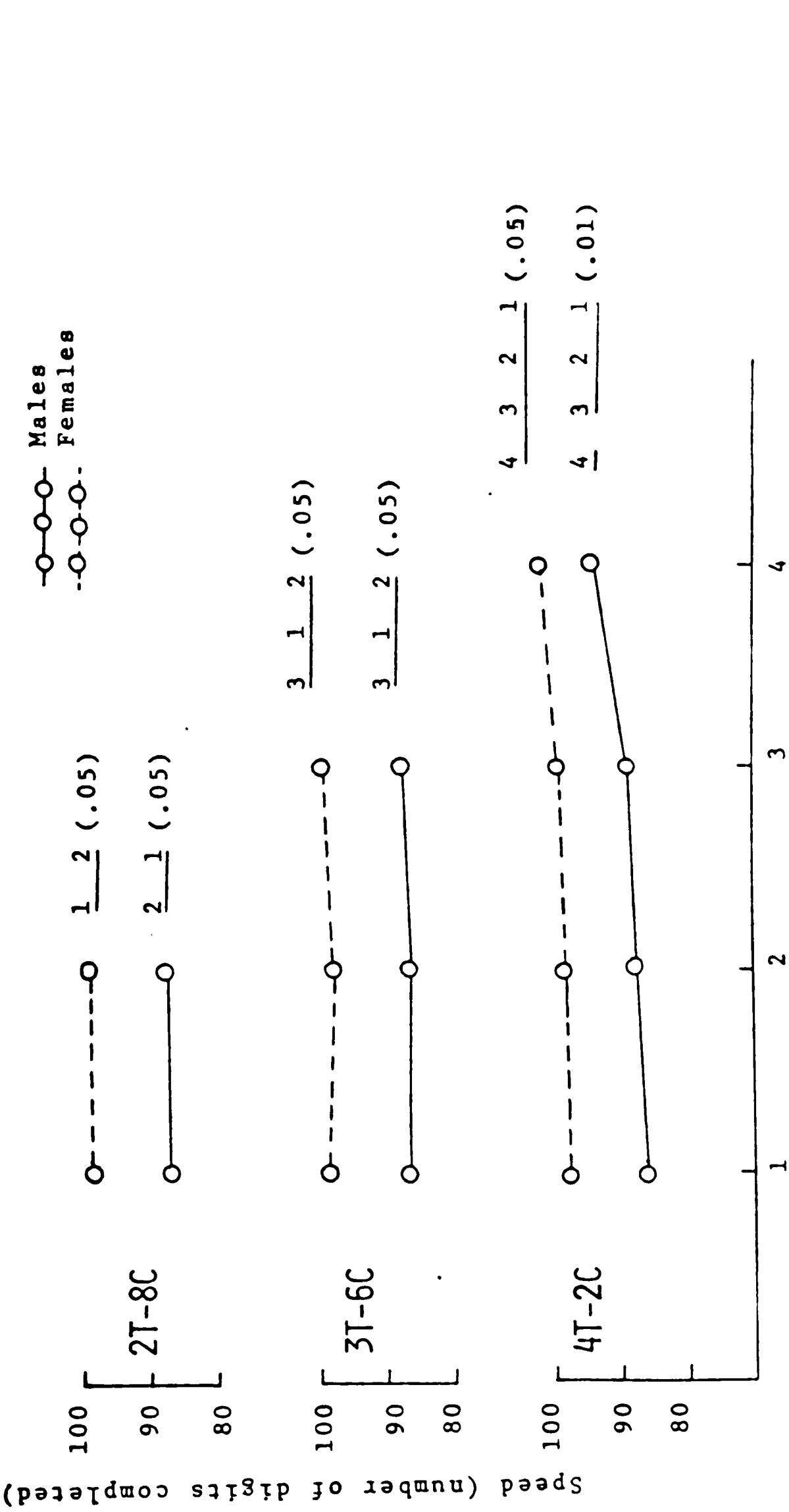


Figure 21. Multiplication speed, male vs female performance.

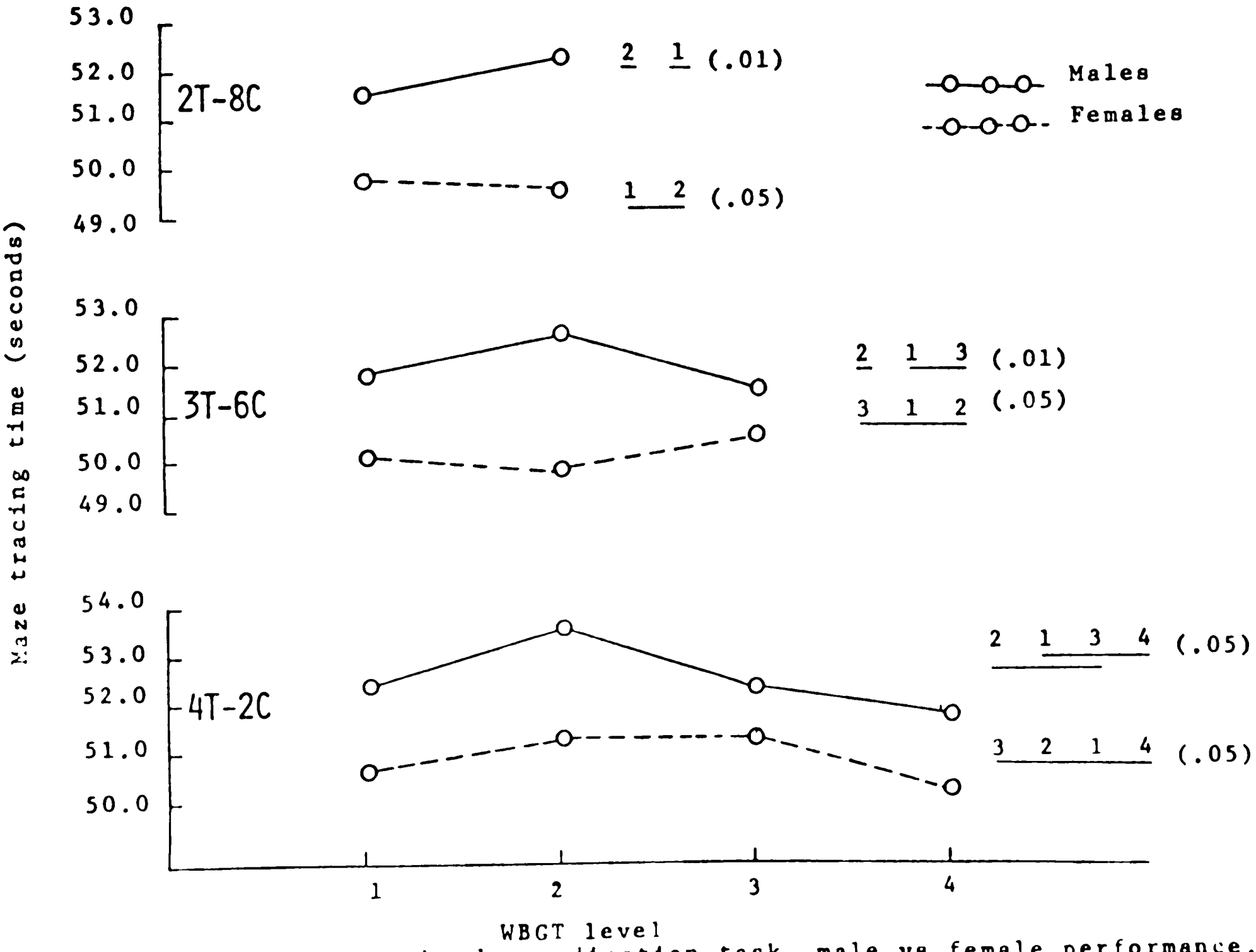


Figure 22. Eye-hand coordination task, male vs female performance.

As seen from Figures 20 thru 22 the behavior of males is strongly similar to that of females. For that reaction time task, Figure 20, in both 2T-8C and 3T-6C analyses, performances during exposure to different WBGT levels were not statistically different from each other for either females or males. In the 4T-2C analysis, females and males behaved similarly, but the performance of males during exposure to WBGT level 4 was significantly better ($p<.01$) than their performance during the exposure to the other three WBGT levels under consideration. Also for males, when exposed to WBGT level 4, the combination of thermal stress and primary task stimulus resulted in a task stimulus which improved their performance. This arousal was observed in the female data, but it was not sufficient to produce a significant improvement in performance.

As seen from Figure 21 similar results were obtained for the performance on the speed of multiplication. Here again, males were aroused when they were exposed to WBGT level 4. The combination of thermal stress and the primary task stimulus resulted in a task stimulus which improved their performance. The arousal experienced by the females as a result of the addition of the thermal stress to the primary task stimulus was not strong enough to show a significant improvement in performance although the pattern of performance is similar.

On the eye-hand coordination task (maze tracing), females and males behaved in similar manners. As seen

from Figure 22, females' performance was not significantly different during the exposure to different WBGT levels. For males, performance during the exposure to WBGT level 2 was significantly different from the performance during the exposure to the other three WBGT levels under consideration. In an attempt to explain this result the raw data was checked, and it was found that a single male subject had performed noticeably poorly during his session at WBGT level 2; it was this data which made the performance during the exposure to WBGT level 2 different from the other WBGT levels under consideration.

On visual inspection of Figures 20 thru 22, performance of males and females appears to be different from each other; however, no significant differences were found when tested by Student's t-test. Hence, when exposed to WBGT levels under consideration, female behavior was similar in performance score and pattern to that of males. For mental tasks, males were most aroused when exposed to the WBGT level 4. For tasks involving small motor responses (i.e., maze tracing) there was no significant difference in the performances of females and males. Performance patterns on the pursuit tracking task could not be compared because the equipment was modified during the time interval between the studies.

A summary of the performance of females and males on the four tasks under consideration are plotted against the proposed NIOSH limits for sedentary work in the heat

in Figures 23 thru 26. Performance during the exposure to WBGT level 1 was considered normal. As previously explained, performances during the exposure to WBGT levels 2, 3, and 4 were tested for statistical differences against the performance during exposure to WBGT level 1.

For the pursuit tracking task, Figure 23, there was a reliable ($p<.01$) decrement in performance for males at all the temperature-time combinations under consideration.

For females during the first 30 minutes of exposure to the WBGT levels 2 and 3, there was an arousal effect experienced by the subjects. For all other temperature-time combinations there was no change ($p<.05$) in performance. For males working on tasks requiring substantial motor responses, the combination of thermal stress and primary task stimulus exceed the optimal task stimulus and result in a decrement in performance when exposed to WBGT levels 2, 3 and 4. For females working on tasks requiring substantial motor responses, the combination of primary task stimulus and thermal stress approached an optimal task stimulus which caused an improvement in their performance when exposed to WBGT levels 2 and 3. During the exposure to the other temperature-time combinations under consideration, addition of the thermal stress to the primary task stimulus seems to exceed the optimal task stimulus, but not to an extent so as to cause a decrement in performance.

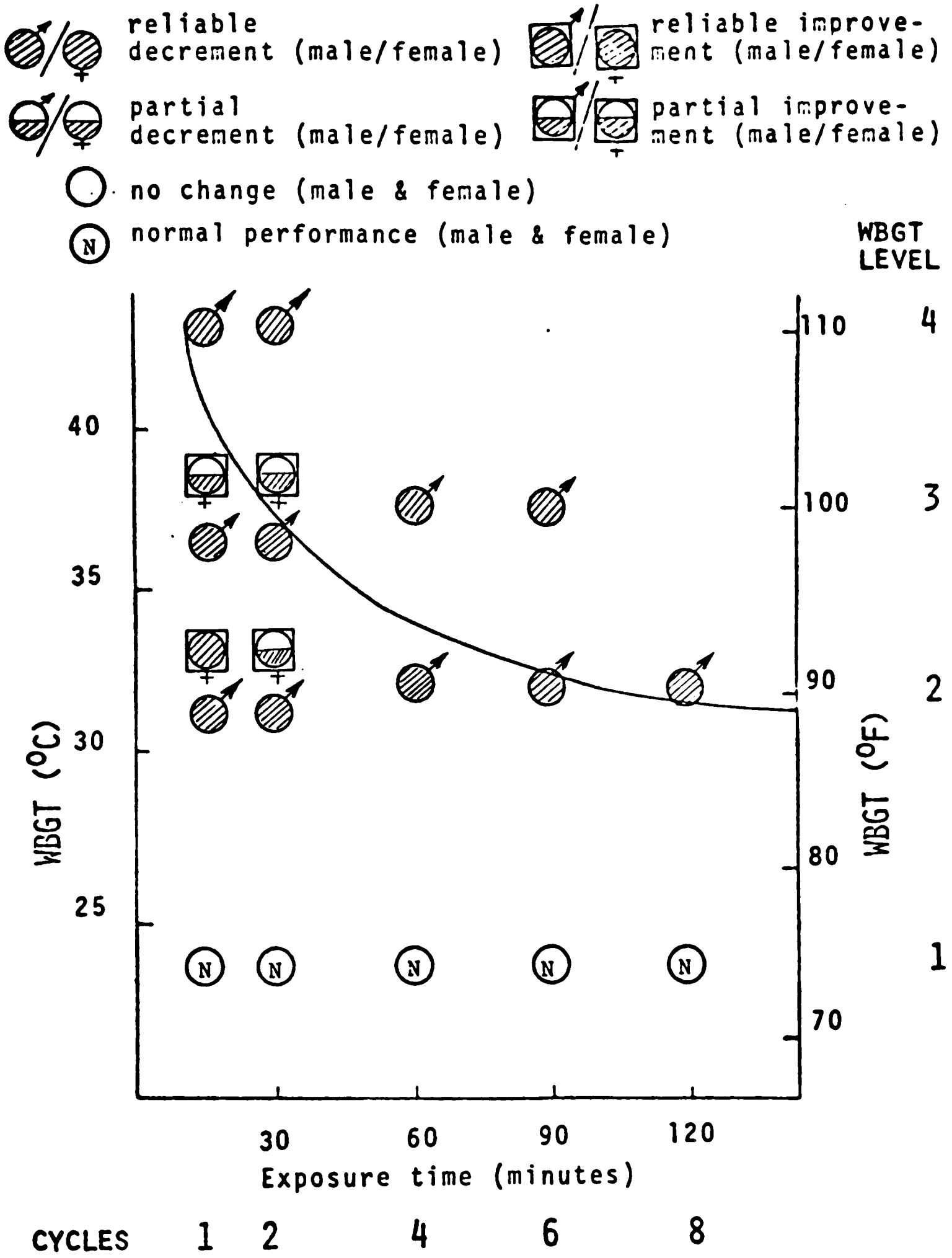


Figure 23. Summary of performance on pursuit tracking task (male vs female).

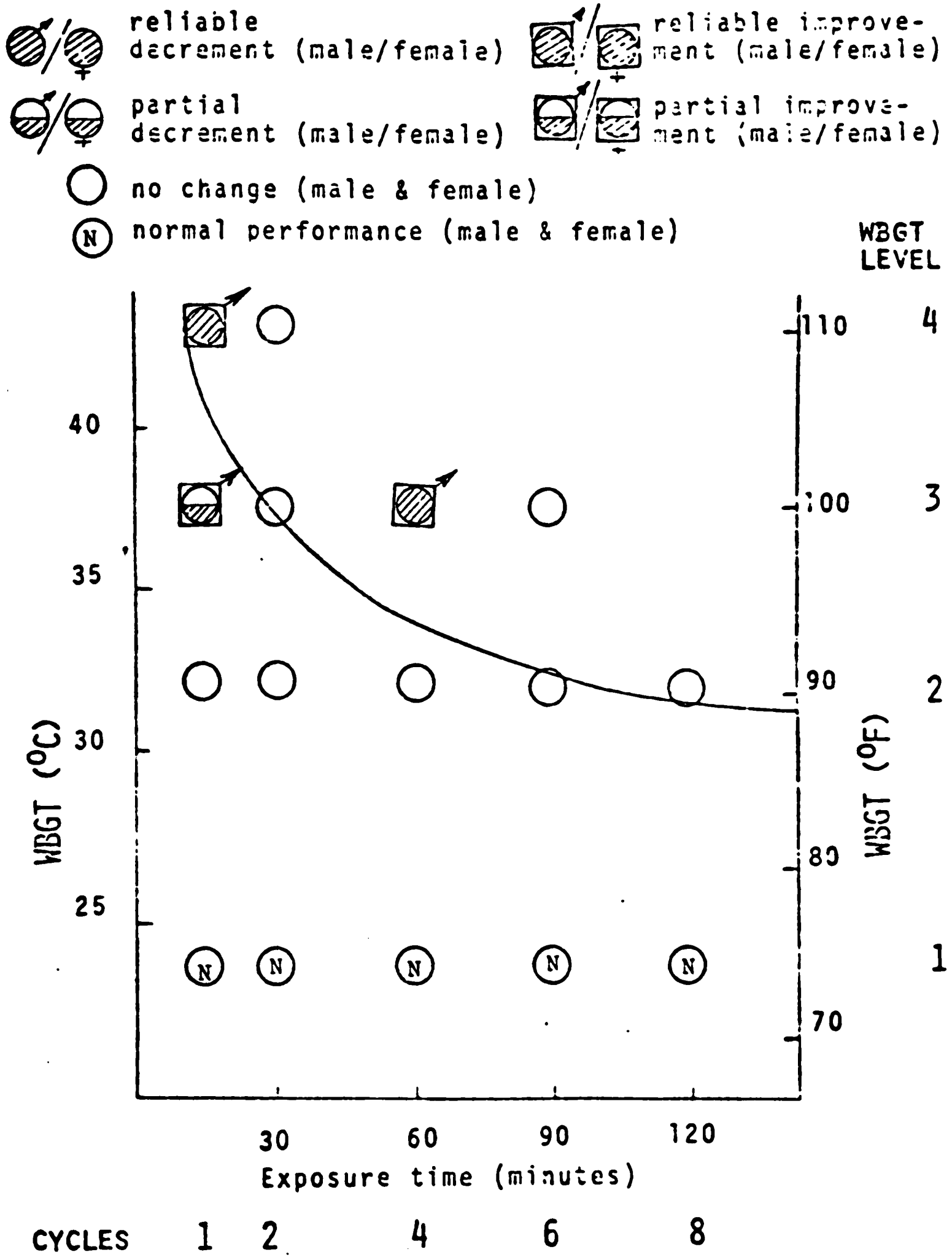


Figure 24. Summary of performance on reaction time task (male vs female).

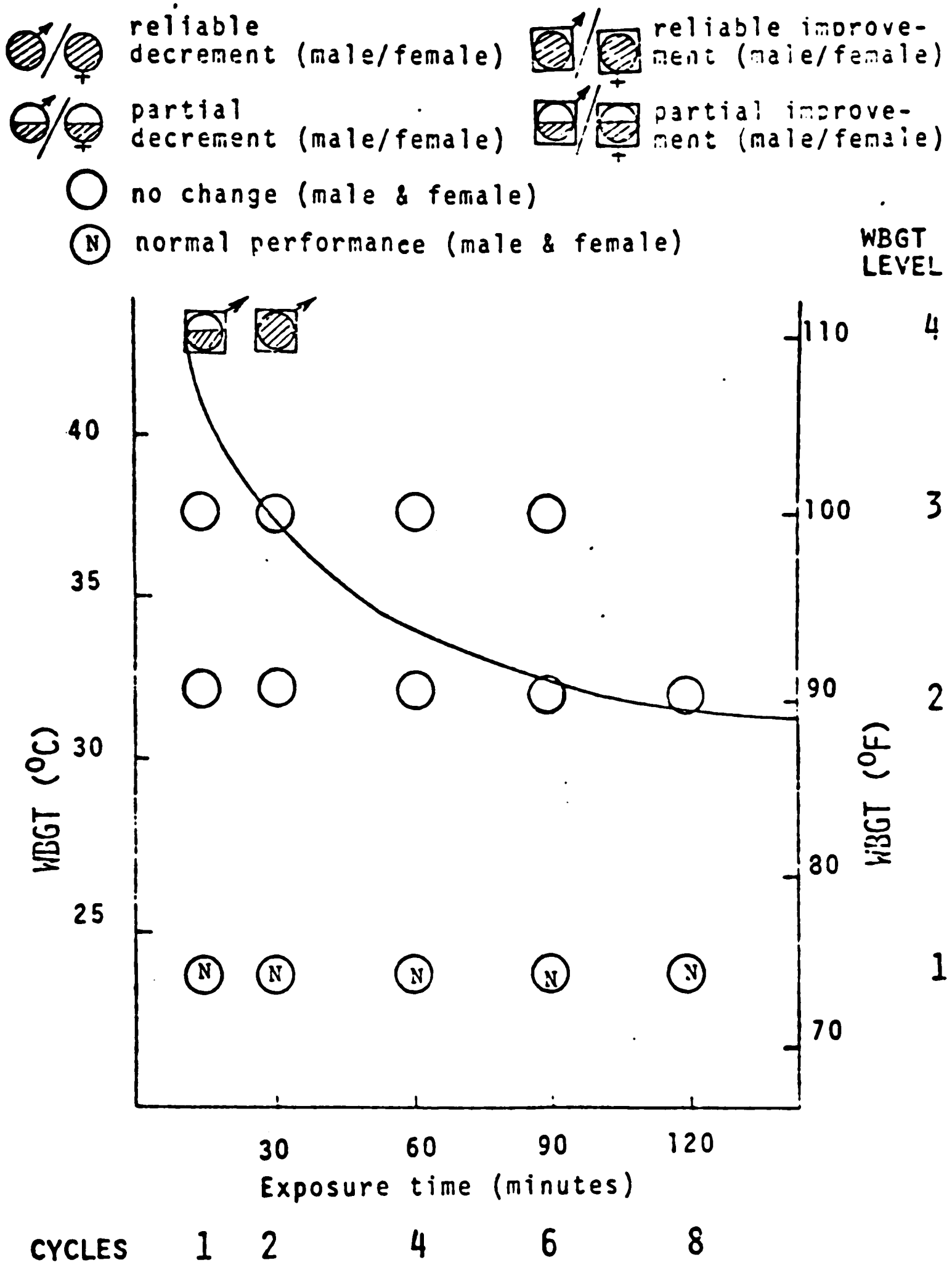


Figure 25. Summary of performance on multiplication task (male vs female).

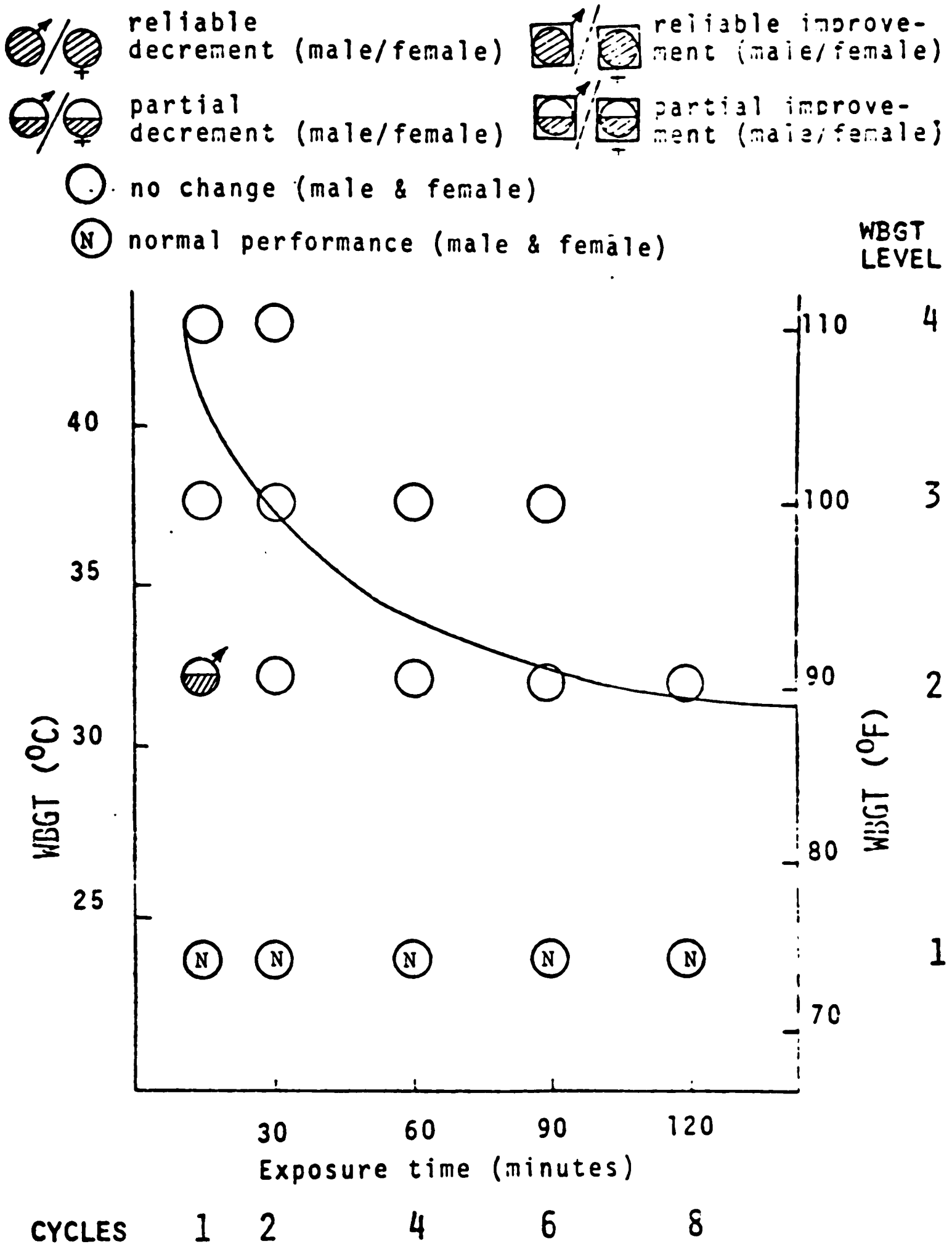


Figure 26. Summary of performance on eye-hand coordination task (male vs female).

For the reaction time task, males were aroused when exposed to the WBGT level 4 during the first fifteen minutes. As seen from Figure 24 (page 103), there was reliable increment ($p<.01$) in performance when exposed to the WBGT level 4 for the first fifteen minutes. When exposed to the WBGT level 3, there was only a partial ($p<.05$) improvement in performance during the first fifteen minutes and reliable improvement ($p<.01$) in performance during the fourth cycle. For females, there was no change ($p<.05$) in performance for all temperature-time combinations under consideration. When males were exposed to WBGT levels 3 and 4, the combination of thermal stress and primary task stimulus caused improvements in performance. For females, addition of thermal stress to the primary task stimulus had no effect on the performance.

As seen from Figure 25 (page 104), male performance showed partial ($p<.05$) improvement in the speed of multiplication during the first fifteen minutes and there was reliable improvement ($p<.01$) in performance during the next fifteen minutes when exposed to the WBGT level 4. For all other temperature-time combinations under consideration, there was no change ($p<.05$) in performance. For females, for all temperature-time combinations under consideration there was no change in performance. For males, an improvement in performance was found due to the arousal effect caused by the addition of thermal stress to the primary task

stimulus when exposed to WBGT level 4. For females, addition of thermal stress to the primary task stimulus did not cause an arousal effect when exposed to WBGT level 4.

On the eye-hand coordination task (maze tracing), Figure 26 (page 105), males experienced partial decrement ($p<.05$) in performance when exposed to WBGT level 2. For females there was no change ($p<.05$) for all temperature-time combinations under consideration. The decrement in performance of males during exposure to WBGT level 2 is similar to that indicated when working on the pursuit tracking task, where a suppressing effect was experienced by the subjects when exposed to the WBGT level 2. As seen from Figure 22 (page 98), although the performance during exposure to WBGT level 2 is significantly lower than the performance during exposure to WBGT level 1 in 2T-8C and 3T-6C analyses, when tested by using the procedure stated on page 92, only the performance during the first fifteen minutes of exposure to WBGT level 2 showed a decrement ($p<.05$). For females, the addition of thermal stress to the primary task stimulus had no effect on the performance.

Conclusions

The NIOSH criteria (Figure 1, page 3) suggests performance at temperature-time combinations above the line to show decrement. The results obtained in this study did not show decrements for temperature-time combinations above the line except those for the pursuit tracking task where different results were obtained between males and females.

For tasks requiring large motor-muscular components, males showed a decrement in performance, whereas the females experienced an arousal effect initially when exposed to WBGT levels 2 and 3. But the exposure of female to WBGT level 4 was severe enough to suppress this arousal effect.

Males experienced an arousal effect when working on mental tasks such as reaction time and multiplication, whereas females did not show any changes in performance.

These results differ significantly from much of the literature, which refers to continuous work in the heat. The investigator feels that these differences can be accounted for by the fact that the subjects did not work continuously on a single task during this study. For this investigation, subjects changed the tasks every 2.5 minutes and had a one minute rest interval between the tasks, and although this satisfies the criteria of the NIOSH proposal, it does not eliminate heat storage or fatigue accumulation effects which would be encountered with continuous work.

The conclusion can be summarized as:

1. For the temperature-time combinations under consideration, there will be minimal performance decrements when working in hot environments, if allowed to change tasks frequently, and if sufficient rest intervals are provided between the tasks.

2. For the temperature-time combinations and the experimental protocol under consideration, short work bouts in high temperatures produce an arousal effect which actually enhances performances on tasks which are mental in nature.
3. For the temperature-time combinations under consideration, the performance of females was not affected by the heat as much as that of males. They did not experience decrement in performance on pursuit tracking task, whereas males experienced a reliable decrement in performance. Males were aroused on the reaction time and multiplication tasks, whereas females did not experience as much arousal. Hence, for females working in hot environmental conditions, the changes in performance are significantly lower than the changes in performance experienced by males, although the behavior pattern of females is quite similar to that of males.

Recommendations for Future Research

Several recommendations can be made for future research studies concerning sedentary work in hot environments. In industry, commonly the same task will be assigned to a worker each day. It would be meaningful to determine performance effects if the subjects were to work on the same

tasks throughout the session instead of changing tasks regularly.

This study utilized subjects in the age group 19-23. Since workers of ages 16-60 are found in industry it would be worthwhile to conduct an investigation similar in nature to this study using subjects in different age groups. Also, research studies using female industrial subjects are recommended. Noise is a common problem in many industries. It would be worthwhile to investigate the combined effects of noise and temperature on sedentary task performance.

The present study considered clothing, activity level and relative humidity as non-variables. Research may be conducted by utilizing different levels of the above three variables. But the first two recommendations, i.e., utilizing continuous tasks and different age groups are more important.

LIST OF REFERENCES

Astrand, P. O., Human Physical Fitness with Special Reference to Sex and Age, Physiological Review, 36, (1956), 307-335.

Brouha, L., Smith, P. E., DeLanne, R., and Maxfield, M. E., Physiological Reactions of Men and Women During Muscular Activity and Recovery in Various Environments, Journal of Applied Physiology, 16, 1 (1960), 133-140.

Coules, J., and Avery, D. L., Human Performance and Basal Skin Conductance in Vigilance-type Task With and Without Knowledge of Results, Perceptual and Motor Skills, 23, (1966), 1295-1302.

Darden, E., and Shappnell, R. T., Performance by Males and Females on the Motor Tasks Under Standard and Mirror Reversal Conditions, Research Quarterly, 43, 4 (1972), 460-467.

Finkelstein, L. O., On Sensory Disorders in Decreases and on Changes of the Fields of Vision in Menstruation, Opthalmic Review, 6, (1885), 325-326.

Freischlag, J., A Comparison of the Effects of Sex, Competition, and Ability on a Perceptual Motor Task, Research Quarterly, 44, 2 (1972), 178-184.

Gagge, A. P., American Journal of Physiology, (1936), 116, 656.

Geblwiczowa, M., Reminiscence in Motor Learning, Research Institute of Physical Culture, Warsaw, Poland, (1973).

Halcomb, C. G., and Blackwell, P., Motivation and the Human Monitor: I. The Effect of Contingent Credit, Perceptual and Motor Skills, 28, (1969), 615-623.

Hardesty, D., Trumbo, D., and Beven, W., The influence of Knowledge of Results in Performance in a Monitoring Task, Perceptual and Motor Skills, 16, (1963), 629-634.

Hardy, J. D., Physiology of Temperature Regulation, Physiological Review, 41, (1961), 521-606.

Haslag, Sister Wilma Marie and Hertzman, A. B., Temperature Regulation in Young Women, Journal of Applied Physiology, 20, 6 (1965), 1283-1288.

Henschel, A., Physiology of Work Capacity and Fatigue, Simonson, E., (Editor), C. C. Thomas (Publisher), Springfield, Chapter 14, (1971).

Hertig, B. A., Belding, H. S., Kraning, K. K., Batterton, D. L., Smith, C. R., and Sargent II, F., Artificial Acclimatization of Women to Heat, Journal of Applied Physiology, 18, 2 (1963), 383-386.

Houghten, F. C., and Yaglou, C. P., Determining Limits of Equal Comfort and Determination of the Comfort Zone, ASH & VE Transactions, 29 (1923).

Kumar, P., and Mathur, C. N., Sex and Noise Distractability, Indian Journal of Applied Psychology, 6, 1 (1969), 13-14.

Lanfair, K. M., and Smith, L. A., A Review of the Effect of Menstruation Accident Involvement, Size of the Visual Field, and Color Perception, Proceedings of the Human Factors Society, 18th Annual Meeting, October, (1974).

Lorenzetti, F., The Female Sex Ryth, Psychological Bulletin, 31, (1926), 153-192.

Matsui, N., Ability to Perspire in Relation to Sexuality, Bulletin of Research Institute for Diathetic Medicine, Kumamoto University, 6:60-70, (1955).

McCormach, P. D., Performance in a Vigilance Task as a Function of Length of Inter-stimulus Interval, Canadian Journal of Psychology, 14, 4 (1960), 265-268.

Morimoto, T., Slabochova, Z., Naman, R. K., and Sargent II, F., Journal of Applied Physiology, 22, 3, (1967), 526-532.

National Institute of Occupational Safety and Health, Occupational Exposure to Hot Environments, U. S. Department of Health, Education and Welfare, Health Services and Mental Health Administration, NIOSH, 1972.

Noble, C. E., and Noble, C. S., Pursuit Tracking Skill with Separate and Combined and Auditory Feed Back, Journal of Motor Behavior, 4, 3 (1972), 195-205.

Ramsey, J. D., Heat Effects on Sedentary Job Performance, Symposium on Physiological Requirements of the Microclimate in Industry and Problems of their Technical Reaclization, Society of Occupational Medicine and Institute of Hygiene and Epidemiology, Prague, Czeckoslovokia, (1975).

Ramsey, J. D., Dayal, D., and Ghahramani, B., Heat Stress Limits for the Sedentary Worker, American Industrial Hygience Association Journal, 36, 4 (1975), 259-265.

Reddy, S. P., Sedentary Job Performance within the thermal Comfort Zone, Unpublished Thesis, Department of Industrial Engineering, Texas Tech University, (1974).

Redgroove, J. A., Menstrual Cycles, Biological Rhythms and Human Performance, Coloquhom, W. O., (Editor), Academic Press, Newyork, Chapter 6:211-240, (1971).

Smith, R. L., Luccaccini, L. F., and Epatien, M. H., Effects of Monetary Rewards and Punishments on Vigilance Performance, Journal of Applied Psychology, 51 (1967), 411-416.

Waag, W. L., Halcomb, C. G., and Tyler, D. M., Sex Differences in Monitoring Performance, Journal of Applied Psychology, 58, 2 (1973), 272-274.

Whittenberg, J. A., Ross, S., and Andrews, T. G., Sustained Efficiency as Measured by the Mackworth Clock Test, Perceptual and Motor Skills, 6, (1959), 109-116.

Wienman, K. P., Slabocholva, Z., Bernuer, M., Morimoto, T., and Sargent II, F., Journal of Applied Physiology, 22, 3 (1967), 533-538.

Wing et al. The Effects of High Ambient Temperature on Short-Term Memory, AMRL-TR-65-103, Air Force Systems Command, Wright-Patterson Air Force Base, Ohio (1965).

Wyndham, C. H., Morrison, J. F., and Williams, C. G., Heat Reactions of Male and Female Caucasians, Journal of Applied Physiology, 20, 3 (1965), 357-364.

Words and Figures, Women Power, U. S. Department of Labor, 7, 11 (1975), 25.

Yaglou, C. P., and Minard, D., Control of Heat Casualties at Military Training Center, Arch. Indus. Hlth., 16, (1957).

APPENDIX

A. ANOVA Tables

B. Cell Means and Standard Deviations of Significant Main Effects

C. Sample Multiplication Sheet

D. Health Questionnaire

E. Subjective Questionnaire

APPENDIX A

ANOVA TABLES

TABLE 9

TEMPERATURE-TIME EFFECTS
ANALYSIS OF VARIANCE FOR
PURSUIT TRACKING TASK: 2T-8C ANALYSIS

Source	DF	Sum of Squares	F max	F ratio	Proba-bility
Subjects	10	169.04	1.92	28.00	0.0000
Temperature	1	29.05	1.04	48.11	0.0000
Time	7	59.63	1.92	14.11	0.0000
Temp X Time	7	5.37	4.03	1.27	0.2679
Error	150	90.57			
Total	175	353.66			

TABLE 10

TEMPERATURE-TIME EFFECTS
ANALYSIS OF VARIANCE FOR
PURSUIT TRACKING TASK: 3T-6C ANALYSIS

Source	DF	Sum of Squares	F max	F ratio	Proba-bility
Subjects	10	131.62	1.76	14.48	0.0000
Temperature	2	36.78	1.25	19.82	0.0000
Time	5	89.22	1.76	19.23	0.0000
Temp X Time	10	6.80	4.03	0.73	0.6941
Error	170	157.78			
Total	197	422.20			

TABLE 11

TEMPERATURE-TIME EFFECTS
ANALYSIS OF VARIANCE FOR
PURSUIT TRACKING TASK: 4T-2C ANALYSIS

Source	DF	Sum of Squares	F max	F ratio	Proba-bility
Subjects	10	80.65	1.01	9.82	0.0000
Temperature	3	24.56	1.44	9.97	0.0000
Time	1	7.46	1.01	9.09	0.0039
Temp X Time	3	0.45	2.22	0.19	0.5235
Error	70	57.48			
Total	87	170.60			

TABLE 12

TEMPERATURE-TIME EFFECTS
ANALYSIS OF VARIANCE FOR
MAZE TRACING TASK: 2T-8C ANALYSIS

Source	DF	Sum of Squares	F max	F ratio	Proba-bility
Subjects	14	3179.25	1.83	45.85	0.0000
Temperature	1	2.99	1.11	0.60	0.4460
Time	7	199.70	1.83	5.76	0.0000
Temp X Time	7	37.51	2.91	1.08	0.3760
Error	210	1040.09			
Total	239	4459.54			

TABLE 13

TEMPERATURE-TIME EFFECTS
ANALYSIS OF VARIANCE FOR
MAZE TRACING TASK: 3T-6C ANALYSIS

Source	DF	Sum of Squares	F max	F ratio	Proba-bility
Subjects	14	3988.45	1.87	45.26	0.0000
Temperature	2	17.75	1.26	1.41	0.2449
Time	5	162.34	1.87	5.16	0.0003
Temp X Time	10	41.68	2.78	0.66	0.7601
Error	238	1497.95			
Total	269	5708.17			

TABLE 14

TEMPERATURE-TIME EFFECTS
ANALYSIS OF VARIANCE FOR
MAZE TRACING TASK: 4T-2C ANALYSIS

Source	DF	Sum of Squares	F max	F ratio	Proba-bility
Subjects	14	1691.29	1.05	24.10	0.0000
Temperature	3	11.19	1.39	0.74	0.5012
Time	1	21.39	1.05	4.27	0.0390
Temp X Time	3	10.58	1.88	0.70	0.5020
Error	98	491.23			
Total		2225.68			

TABLE 15

TEMPERATURE-TIME EFFECTS
ANALYSIS OF VARIANCE FOR
REACTION TIME TASK: 2T-8C ANALYSIS

Source	DF	Sum of Squares	F max	F ratio	Proba-bility
Subjects	14	8981.86	3.07	30.53	0.0000
Temperature	1	19.27	1.80	0.92	0.3577
Time	7	414.62	3.07	2.82	0.0081
Temp X Time	7	62.06	6.98	0.42	0.8880
Error	210	4412.80			
Total	239	13890.61			

TABLE 16

TEMPERATURE-TIME EFFECTS
ANALYSIS OF VARIANCE FOR
REACTION TIME TASK: 3T-6C ANALYSIS

Source	DF	Sum of Squares	F max	F ratio	Proba-bility
Subjects	14	7467.63	3.04	29.28	0.0000
Temperature	2	15.55	1.95	0.40	0.5227
Time	5	383.06	3.04	4.21	0.0014
Temp X Time	10	75.02	5.98	0.41	0.9401
Error	238	4336.39			
Total	269	12276.65			

TABLE 17

TEMPERATURE-TIME EFFECTS
ANALYSIS OF VARIANCE FOR
REACTION TIME TASK: 4T-2C ANALYSIS

Source	DF	Sum of Squares	F max	F ratio	Proba-bility
Subjects	14	2212.06	1.24	11.94	0.0000
Temperature	3	45.94	1.77	1.19	0.3191
Time	1	45.13	1.24	3.62	0.0568
Temp X Time	3	33.98	4.06	0.89	0.4982
Error	98	1243.93			
Total	119	3491.04			

TABLE 18

TEMPERATURE-TIME EFFECTS
ANALYSIS OF VARIANCE FOR
MULTIPLICATION TASK: 2T-8C ANLYSIS

Source	DF	Sum of Squares	F max	F ratio	Proba-bility
Subjects	14	138592.56	1.75	130.39	0.0000
Temperature	1	40.02	1.25	0.53	0.5759
Time	7	875.58	1.75	1.65	0.1231
Temp X Time	7	314.52	2.35	0.59	0.7639
Error	210	15943.13			
Total	239	155765.81			

TABLE 19

TEMPERATURE-TIME EFFECTS
ANALYSIS OF VARIANCE FOR
MULTIPLICATION TASK: 3T-6C ANALYSIS

Source	DF	Sum of Squares	F max	F ratio	Proba-bility
Subjects	14	158397.50	1.25	135.97	0.0000
Temperature	2	152.27	1.31	0.92	0.4881
Time	5	749.66	1.25	1.80	0.1123
Temp X Time	10	364.93	2.33	0.44	0.9265
Error	238	19803.52			
Total	269	179467.88			

TABLE 20

TEMPERATURE-TIME EFFECTS
ANALYSIS OF VARIANCE FOR
MULTIPLICATION TASK: 4T-2C ANALYSIS

Source	DF	Sum of Squares	F max	F ratio	Proba-bility
Subjects	14	73828.56	1.07	63.27	0.0000
Temperature	3	229.49	1.35	0.92	0.4977
Time	1	559.01	1.62	6.71	0.0107
Temp X Time	3	14.96	1.62	0.06	0.5631
Error	98	8167.91			
Total	119	82799.93			

TABLE 21

TEMPERATURE-TIME EFFECTS
ANALYSIS OF VARIANCE FOR
MULTIPLICATION TASK(PERCENT ERROR): 2T-8C ANALYSIS

Source	DF	Sum of Squares	F max	F ratio	Proba-bility
Subjects	14	0.1206	5.72	4.56	0.0000
Temperature	1	0.0040	2.01	2.49	0.1119
Time	7	0.0105	5.72	0.94	0.4798
Temp X Time	7	0.0127	14.16	1.13	0.3440
Error	210	0.3379			
Total	239	0.4677			

TABLE 22

TEMPERATURE-TIME EFFECTS
ANALYSIS OF VARIANCE FOR
MULTIPLICATION TASK(PERCENT ERROR): 3T-6C ANALYSIS

Source	DF	Sum of Squares	F max	F ratio	Proba-bility
Subjects	14	0.0950	4.73	4.32	0.0000
Temperature	2	0.0097	2.83	3.09	0.0460
Time	5	0.0062	4.73	0.79	0.5612
Temp X Time	10	0.0120	18.69	0.76	0.6676
Error	238	0.3742			
Total	269				

TABLE 23

TEMPERATURE-TIME EFFECTS
ANALYSIS OF VARIANCE FOR
MULTIPLICATION TASK(PERCENT ERROR): 4T-2C ANALYSIS

Source	DF	Sum of Squares	F max	F ratio	Proba-bility
Subjects	14	0.0627	2.35	1.84	0.0000
Temperature	3	0.0082	3.53	1.13	0.3399
Time	1	0.0013	2.35	0.51	0.4822
Temp X Time	3	0.0035	10.46	0.48	0.5077
Error	98	0.2383			
Total	119				

TABLE 24

TEMPERATURE-TIME EFFECTS
ANALYSIS OF VARIANCE FOR
HEART RATE: 2T-8C ANALYSIS

Source	DF	Sum of Squares	F max	F ratio	Proba-bility
Subjects	14	29094.62	1.36	62.7	0.0000
Temperature	1	7172.27	1.43	216.3	0.0000
Time	7	397.90	1.36	1.7	0.1064
Temp X Time	7	769.67	1.93	3.0	0.0047
Error	210	6961.45			
Total	239	44335.91			

TABLE 25

TEMPERATURE-TIME EFFECTS
ANALYSIS OF VARIANCE FOR
HEART RATE: 3T-6C ANALYSIS

Source	DF	Sum of Squares	F max	F ratio	Proba-bility
Subjects	14	22734.87	1.76	36.8	0.0000
Temperature	2	15190.56	1.66	172.31	0.0000
Time	5	2472.50	1.76	1.76	0.0000
Temp X Time	10	2360.43	3.56	11.23	0.0000
Error	238	10490.66			
Total	269	53249.02			

TABLE 26

TEMPERATURE-TIME EFFECTS
ANALYSIS OF VARIANCE FOR
HEART RATE: 4T-2C ANALYSIS

Source	DF	Sum of Squares	F max	F ratio	Proba-bility
Subjects	14	11345.74	1.59	13.74	0.0000
Temperature	3	106-9.11	3.02	60.19	0.0000
Time	1	866.72	1.59	14.70	0.0005
Temp X Time	3	1174.99	2.83	6.64	0.0006
Error	98	5779.59			
Total	119	29816.15			

TABLE 27

TEMPERATURE-TIME EFFECTS
ANALYSIS OF VARIANCE FOR
ORAL TEMPERATURE: 2T-8C ANALYSIS

Source	DF	Sum of Squares	F max	F ratio	Proba-bility
Subjects	14	46.90	1.70	21.82	0.0000
Temperature	1	114.06	1.77	745.15	0.0000
Time	7	5.77	1.70	5.38	0.0001
Temp X Time	7	1.32	4.11	1.23	0.2485
Error	210	32.14			
Total	239	200.19			

TABLE 28

TEMPERATURE-TIME EFFECTS
ANALYSIS OF VARIANCE FOR
ORAL TEMPERATURE: 3T-6C ANALYSIS

Source	DF	Sum of Squares	F max	F ratio	Proba-bility
Subjects	14	36.49	1.82	16.47	0.0000
Temperature	2	188.32	1.63	594.66	0.0000
Time	5	14.13	1.82	17.85	0.0000
Temp X Time	10	4.68	4.63	2.95	0.0019
Error	238	37.67			
Total	269	281.29			

TABLE 29

TEMPERATURE-TIME EFFECTS
ANALYSIS OF VARIANCE FOR
ORAL TEMPERATURE: 4T-2C ANALYSIS

Source	DF	Sum of Squares	F max	F ratio	Proba-bility
Subjects	14	13.10	1.50	4.1	0.0007
Temperature	3	105.10	2.61	152.8	0.0000
Time	1	15.81	1.50	68.9	0.0000
Temp X Time	3	5.35	3.99	7.8	0.0002
Error	98	22.46			
Total	119	161.82			

TABLE 30

SESSION EFFECTS
ANALYSIS OF VARIANCE FOR
PURSUIT TRACKING TASK: 4S-2C ANALYSIS

Source	DF	Sum of Squares	F max	F ratio	Proba-bility
Subjects	10	80.65	1.01	8.84	0.0000
Session	3	17.16	1.81	6.27	0.0011
Time	1	7.46	1.01	8.18	0.0057
Session X Time	3	1.49	3.02	0.54	0.5060
Error	70	63.85			
Total	87	170.61			

TABLE 31

SESSION EFFECTS
ANALYSIS OF VARIANCE FOR
MAZE TRACING TASK: 4S-2C ANALYSIS

Source	DF	Sum of Squares	F max	F ratio	Proba-bility
Subjects	14	1691.29	1.04	31.00	0.0000
Session	3	130.09	1.43	11.13	0.0000
Time	1	21.39	1.05	5.49	0.0199
Session X Time	3	1.03	1.62	0.09	0.5449
Error	98	381.88			
Total	119	2225.68			

TABLE 32

SESSION EFFECTS
ANALYSIS OF VARIANCE FOR
REACTION TIME TASK: 4S-2T ANALYSIS

Source	DF	Sum of	F max	F ratio	Proba-bility
Subjects	14	2122.06	1.24	12.75	0.0000
Session	3	123.24	1.32	3.46	0.0191
Time	1	45.94	1.24	3.87	0.0482
Session X Time	3	35.01	4.06	0.98	0.4965
Error	98	1164.79			
Total	119	3491.04			

TABLE 33

SESSION EFFECTS
ANALYSIS OF VARIANCE FOR
MULTIPLICATION(SPEED): 4S-2C ANALYSIS

Source	DF	Sum of Squares	F max	F ratio	Proba-bility
Subjects	14	73828.0	1.07	74.71	0.0000
Session	3	1407.0	1.11	6.64	0.0006
Time	1	559.0	1.07	7.92	0.0060
Session X Time	3	87.6	1.43	0.41	0.5099
Error	98	6917.6			
Total	119	82799.9			

TABLE 34

SESSION EFFECTS
ANALYSIS OF VARIANCE FOR
MULTIPLICATION(PERCENT ERROR): 4S-2C ANALYSIS

Source	DF	Sum of Squares	F max	F ratio	Proba-bility
Subjects	14	0.0627	2.35	1.88	0.0369
Session	3	0.0082	5.33	1.15	0.3321
Time	1	0.0013	2.35	0.53	0.4772
Session X Time	3	0.0089	13.32	1.25	0.2960
Error	98	0.2330			
Total	119	0.3141			

APPENDIX B

SIGNIFICANT MAIN EFFECTS

TABLE 35

CELL MEANS AND STANDARD DEVIATIONS FOR PURSUIT TRACKING TASK: 2T-8C ANALYSIS

WBGT level	Mean	Standard Deviation
74°F	4.34	1.35
90°F	5.12	1.38

TABLE 36

CELL MEANS AND STANDARD DEVIATIONS FOR PURSUIT TRACKING TASK: 3T-6C ANALYSIS

WBGT level	Mean	Standard Deviation
74°F	4.39	1.45
90°F	5.37	1.31
100°F	5.21	1.46

TABLE 37

CELL MEANS AND STANDARD DEVIATION FOR PURSUIT TRACKING TASK: 4T-2C ANALYSIS

WBGT level	Mean	Standard Deviation
74°F	4.94	1.43
90°F	6.19	1.22
100°F	6.27	1.42
110°F	5.65	1.19

TABLE 38

CELL MEANS AND STANDARD DEVIATIONS FOR HEART RATE: 2T-8C ANALYSIS

WBGT level	Mean	Standard Deviation
74°F	81.83	11.33
90°F	92.77	13.56

TABLE 39

CELL MEANS AND STANDARD DEVIATIONS FOR HEART RATE: 3T-6C ANALYSIS

WBGT level	Mean	Standard Deviation
74°F	81.92	11.31
90°F	92.06	13.67
100°F	100.26	10.62

TABLE 40

CELL MEANS AND STANDARD DEVIATIONS FOR HEART RATE: 4T-2C ANALYSIS

WBGT level	Mean	Standard Deviation
74°F	82.30	11.73
90°F	88.35	13.52
100°F	91.70	9.20
110°F	107.77	15.99

TABLE 41

CELL MEANS AND STANDARD DEVIATIONS FOR ORAL TEMPERATURE: 2T-8C ANALYSIS

WBGT level	Mean	Standard Deviation
74°F	97.22	0.68
90°F	98.60	0.51

TABLE 42

CELL MEANS AND STANDARD DEVIATIONS FOR ORAL TEMPERATURE: 3T-6C ANALYSIS

WBGT level	Mean	Standard Deviation
74°F	97.22	0.66
90°F	98.56	0.52
100°F	99.23	0.59

TABLE 43

CELL MEANS AND STANDARD DEVIATIONS FOR ORAL TEMPERATURE: 4T-4C ANALYSIS

WBGT level	Mean	Standard Deviation
74°F	97.15	0.63
90°F	98.32	0.58
100°F	98.79	0.60
110°F	99.75	0.93

TABLE 44

CELL MEANS AND STANDARD DEVIATIONS FOR PURSUIT TRACKING TASK: 2T-8C ANALYSIS

Cycle	Mean	Standard Deviation
1	5.79	1.38
2	5.35	1.53
3	5.03	1.44
4	4.68	1.33
5	4.19	1.31
6	4.26	1.20
7	4.40	1.25
8	4.01	1.10

TABLE 45

CELL MEANS AND STANDARD DEVIATIONS FOR MAZE TRACING TASK: 2T-8C ANALYSIS

Cycle	Mean	Standard Deviation
1	51.41	4.22
2	50.58	4.51
3	50.27	5.18
4	49.43	3.93
5	49.15	4.11
6	49.40	4.48
7	48.64	3.82
8	48.66	3.89

TABLE 46

CELL MEANS AND STANDARD DEVIATIONS FOR REACTION TIME TASK: 2T-8C ANALYSIS

Cycle	Mean	Standard Deviation
1	37.41	5.32
2	38.87	6.30
3	39.53	8.06
4	40.55	6.81
5	41.66	9.32
6	39.20	6.50
7	40.53	8.74
8	41.32	8.94

TABLE 47

CELL MEANS AND STANDARD DEVIATIONS FOR ORAL TEMPERATURE: 2T-8C ANALYSIS

Cycle	Mean	Standard Deviation
1	97.52	0.83
2	97.95	0.81
3	98.05	0.86
4	97.98	0.93
5	97.89	1.05
6	97.97	0.85
7	97.99	0.97
8	97.93	1.00

TABLE 48

CELL MEANS AND STANDARD DEVIATIONS FOR PURSUIT TRACKING TASK: 3T-6C ANALYSIS

Cycle	Mean	Standard Deviation
1	6.06	1.45
2	5.53	1.47
3	5.14	1.34
4	4.77	1.28
5	4.29	1.23
6	4.16	1.10

TABLE 49

CELL MEANS AND STANDARD DEVIATIONS FOR MAZE TRACING TASK: 3T-6C ANALYSIS

Cycle	Mean	Standard Deviation
1	51.42	4.67
2	50.85	4.45
3	50.62	5.56
4	49.60	4.06
5	49.46	4.39
6	49.41	4.43

TABLE 50

CELL MEANS AND STANDARD DEVIATIONS FOR REACTION TIME TASK: 3T-6C ANALYSIS

Cycle	Mean	Standard Deviation
1	37.39	4.94
2	38.97	6.12
3	39.70	7.54
4	40.57	6.46
5	41.07	8.62
6	39.11	5.96

TABLE 51

CELL MEANS AND STANDARD DEVIATIONS FOR HEART RATE: 3T-6C ANALYSIS

Cycle	Mean	Standard Deviation
1	86.46	11.90
2	88.44	12.42
3	91.60	12.89
4	93.26	14.58
5	93.69	15.79
6	95.01	15.17

TABLE 52

CELL MEANS AND STANDARD DEVIATIONS FOR ORAL TEMPERATURE: 3T-6C ANALYSIS

Cycle	Mean	Standard Deviation
1	97.84	0.89
2	98.33	0.88
3	98.46	0.94
4	98.46	1.05
5	98.43	1.18
6	98.50	1.06

TABLE 53

CELL MEANS AND STANDARD DEVIATIONS FOR PURSUIT TRACKING TASK: 4T-2C ANALYSIS

Cycle	Mean	Standard Deviation
1	6.05	1.37
2	5.47	1.38

TABLE 54

CELL MEANS AND STANDARD DEVIATIONS FOR MAZE TRACING TASK: 4T-2C ANALYSIS

Cycle	Mean	Standard Deviation
1	51.52	4.27
2	50.67	4.47

TABLE 55

CELL MEANS AND STANDARD DEVIATIONS FOR MULTIPLICATION TASK(SPEED):4T-2C ANALYSIS

Cycle	Mean	Standard Deviation
1	102.00	26.87
2	97.68	25.93

TABLE 56

CELL MEANS AND STANDARD DEVIATIONS FOR HEART RATE: 4T-2C ANALYSIS

Cycle	Mean	Standard Deviation
1	81.83	11.34
2	92.77	13.56

TABLE 57

CELL MEANS AND STANDARD DEVIATIONS FOR PURSUIT TRACKING SCORE: SESSION EFFECTS

Session	Mean	Standard Deviation
1	5.14	1.29
2	5.69	1.29
3	6.38	1.60
4	5.84	1.19

TABLE 58

CELL MEANS AND STANDARD DEVIATIONS FOR MAZE TRACING SCORE: SESSION EFFECTS

Session	Mean	Standard Deviation
1	52.42	4.60
2	51.51	4.55
3	50.89	3.94
4	49.55	3.85

TABLE 59

CELL MEANS AND STANDARD DEVIATIONS FOR MULTIPLICATION(SPEED): SESSION EFFECTS

Session	Mean	Standard Deviation
1	94.77	27.09
2	98.93	26.48
3	103.93	26.61
4	101.73	25.77

APPENDIX C

SAMPLE MULTIPLICATION SHEET

Run code number_____ Name_____ Date_____

Temp Time

5326	4678	8265	4273
652	479	284	483
2594	3526	3789	8635
872	273	837	593
5389	8234	9247	5346
473	358	732	829
2574	2435	4582	2438
385	347	295	392

APPENDIX D

HEALTH QUESTIONNAIRE

NAME_____ DATE_____

Date of Birth_____

1. Weight and Height

   Current weight (nude)_____lbs.
   (with clothes and shoes)_____lbs.

   Current height_____ft_____in.

2. Right or Left Handed_____

3. Health Information

   Do you regularly take medication_____
   If yes, list_____

   Are you susceptible to:

Colds	_____yes	____no
tonsilitis	_____yes	____no
headaches	_____yes	____no
allergies	_____yes	____no
digestive up sets	_____yes	____no
constipation	____yes	____no
sleeplessness	____yes	____no
fatigue	____yes	____no
dizzines	____yes	____no
Undue emotional stress due to menstrual cycle	_____yes	____no

   If yes or some other, explain_____

4. Do you know any potential problems with your:

hearing	____yes	___no
vision	____yes	___no
sensitivity to heat	____yes	___no
sensitivity to confinement	____yes	___no
breathing or respiratory system	____yes	___no
heart or blood pressure	____yes	___no
stomach or digestive system	____yes	___no
bladder or kidney	____yes	___no

   If yes or some other, explain_____

I have accurately answered the questions on page 1 to the best of my knowledge. I hereby give consent for my participation in the study entitled "Temperature - Time Effects on Sedentary Job Performance." I have had the purpose and risks of participation explained to me by the investigator responsible for conducting the studies, and I understand these risks. The risks as explained to me are as follows:

> The environmental temperatures used in this study can potentially strain the cardiovascular, respiratory and thermal regulatory systems. This may result in symptoms such as headache, nausea, dizziness, fatigue, weakness, or in severe case, heat stroke. The probability of serious heat disorders however, is very minimal.

I understand that I may discontinue this study at any time I choose. If I have any questions at any time concerning the procedures which relate to subject risks in the study, the responsible investigator offers to answer them.

Subject signature_____

Signature of responsible investigator_____

Signature of witness_____

Date_____

APPENDIX E

SUBJECTIVE QUESTIONNAIRE

Name_____ Subject#_____ Date_____

Code I.D.#_____

Temp-Time Effects on Performance

Subject Comments

1. Indicate the week of your menstrual cycle in which this session falls.

   1. pre-flow week 2. flow week 3. post flow week 4. other week

2. I felt the temperature level this session was:

Cold	Cool	Slightly Cool	Neutral	Slightly Warm	Warm	Hot	Very Hot	Extremely Hot

3. The heat affected my performance response during each cycle as indicated:

Cycle	1	2	3	4	5	6	7	8
	none	none	none	none	none	none	none	none
	minor	minor	minor	minor	minor	minor	minor	minor
	major	major	major	major	major	major	major	major
	severe	severe	severe	severe	severe	severe	severe	severe

4. The heat affected my physiological response during each cycle as indicated:

Cycle	1	2	3	4	5	6	7	8
	none	none	none	none	none	none	none	none
	minor	minor	minor	minor	minor	minor	minor	minor
	major	major	major	major	major	major	major	major
	severe	severe	severe	severe	severe	severe	severe	severe

FOR EACH TASK:	Reaction time task - 1	Pursuit rotor task - 2	Maze trace task - 3	Multiplication cation task - 4
5. Did you get drowsy				
drowsy?	yes - no	yes - no	yes - no	yes - no
6. Did you get bored?	yes - no	yes - no	yes - no	yes - no
7. Did you get fatigued?	yes - no	yes - no	yes - no	yes - no
8. Did your performance improve over your previous session?	yes - no	yes - no	yes - no	yes - no

FOR EACH TASK:	Reaction time task task - 1	Pursuit rotor task - 2	Maze trace task - 3	Multipli-cation task - 4
10. How would your performance compare with other subjects on this task?	execellent above avg. below avg. poor	execellent above avg. below avg. poor	execellent above avg. below avg. poor	excellent above avg. below avg. poor
11. How well do you like this type task?	highly liked slightly liked indifferent slightly disliked highly disliked	highly liked slightly liked indifferent slightly disliked highly disliked	highly liked slightly liked indifferent slightly disliked highly disliked	highly liked slightly liked indifferent slightly disliked highly disliked