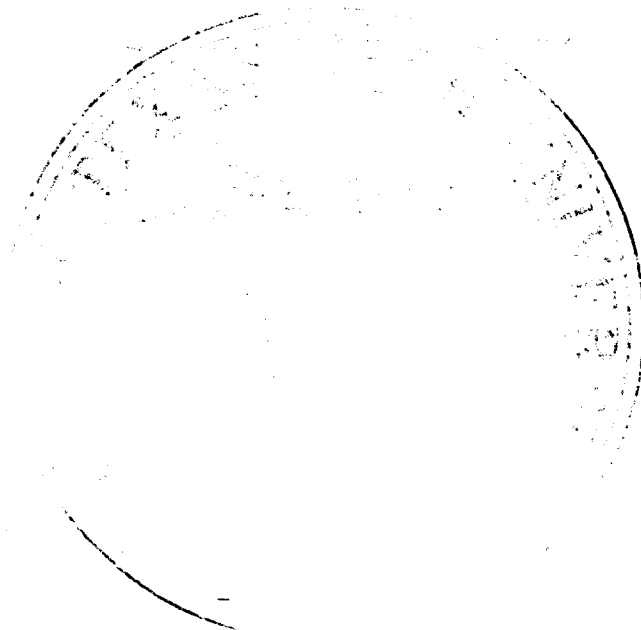


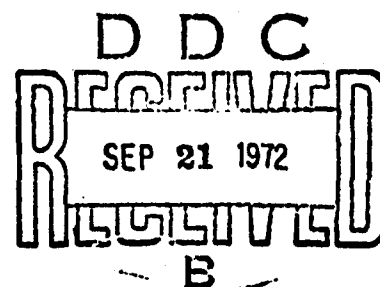
EFFECTS OF CYCLICAL TEMPERATURE ON VIGILANCE PERFORMANCE

By

J.D. RAMSEY, C.G. HALCOMB AND M. KASSOUNY



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Effects of Cyclical Temperature on Vigilance Performance

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Vigilance performance has been shown to be enhanced by numerous types of environmental changes. This study evaluates the effects of a cyclically changing temperature on monitoring behavior and physiological responses of man. Vigilance performance was not enhanced by the use of variable temperature conditions of this study. Rather, the variable temperature in conjunction with a heavy food intake was shown to adversely affect both heart rate and vigilance task performance measures.

INTRODUCTION

Monitoring behavior can be influenced by the introduction of environmental changes during a performance session. Typical environmental changes include the introduction of rest pauses, (Colquhoun, 1959; Solandi and Partridge, 1946; Saldanhan, 1955; McCormack, 1958; Mackworth, 1948), random changes in noise level (Kirk and Hecht, 1963), changes in ambient lighting (Halcomb and Kirk, 1965), and presentation of knowledge of results (Hardestly, Trumbo, and Bevin, 1963). Since environmental change seems to result in improvement of vigilance performance during a normal watch, one would expect that the introduction of cyclical changes in ambient temperature might also result in a similar improvement. The purpose of this study was to test hypothesis.

Previous investigations concerning the effects of ambient temperature on vigilance performance have yielded inconsistent results. Mackworth (1948), testing subjects under ambient temperatures of 70°, 79°, 87.5°, and 97°F, reported superior performance at 79°. Marked decrements were observed for the other temperature conditions. Pepler (1953) found better performance at 67° and 92°F than at 82°. In a subsequent study, the same author (Pepler, 1958) reported fewer misses at 82°F than at 67° or 92°. Bursill (1958) found that

high ambient temperature resulted in a greater vigilance decrement than did lower temperatures. Bell (1964) using both a visual and auditory vigilance task varied the temperature from 85° to 145° F and found no significant differences due to temperature. Poulton, Hitchings, and Brooke (1965), comparing performance in Arctic and temperate climates, reported quicker reaction times in a cold environment.

The above studies yield inconsistent results with respect to the effect of temperature on the performance of a monitoring task. However, all of the studies have one characteristic in common--they all investigated the effects of a constant temperature on vigilance and/or complex monitoring performance. Since the results of previous studies suggest that a variable environmental condition may enhance vigilance performance the present study attempted to assess the effect of variable temperatures upon such performance.

METHOD

Experimental Variables

Temperature and humidity were controlled by means of an environmental chamber. Relative humidity was maintained at 55%, \pm 5% during each experimental session. The variable temperature was cyclically varied with a mean of 23.3° C and excursions of \pm 3° C on a ten minute cycle. The constant temperature was maintained at the mean of the variable temperature condition (23.3° C). These temperature and humidity ranges were selected since they were within the capability limits of

most heating and air conditioning systems, thus making it feasible to utilize the results of this research in practical settings.

Two levels of dietary intake were also considered as important parameters of this study. Earlier research at Texas Tech (Kassouny, Halcomb, and McFarland, 1970) indicated that the quantity of diet had a significant effect on the performance of some vigilance tasks. Superior performance was obtained from those subjects who had a noon meal supplying 7% of the average daily caloric requirements as compared to subjects whose noon meal contained 20% to 50% of the average daily caloric requirements. As significant differences in performance were obtained between diets supplying 50% (1570 calories, 66 grams protein) and 7% (220 calories, 10 grams protein) of average daily caloric requirements, these two levels of dietary intake were utilized in the present investigation to determine the interactive effects of temperature and diet on vigilance performance.

Subjects

Ten male subjects, ages 18 to 22, performed 100 minute vigilance watches during each experimental session. These subjects were screened on the basis of health questionnaires, meal patterns, and anthropometric characteristics to provide a homogeneous group of subjects and to allow for assessment of the dietary effects.

Procedure

The subjects were given a task trial session on the Friday prior to the week in which the experimental sessions were conducted. They then performed the vigilance watch from 1:00 to 3:30 p.m. on Monday through Thursday of the following week. Each subject was supplied the appropriate dietary intake levels at noon each day, and at 1:00 p.m. the watch session was initiated. This provided a uniform interval between the meal ingestion and the beginning of the watch period. Two subjects were run simultaneously at separate stations in the environmental chamber. Each subject was required to wear a set of earphones which presented white noise at 85 decibel intensity. On the initial trial session, each subject read a set of instructions that contained basic information, operational rules and safety information. This was done to instruct and to standardize the degree of motivation elicited by the instructions. After reading the instruction sheet, each subject was allowed a two-minute practice period during which they were shown several signals and given practice in pushing the signal button. Verbal instructions were presented via the head phones during this practice period. On subsequent experimental sessions, the written material was not reread. However the two-minute practice period was conducted at the beginning of each session. This served to reorient the subject prior to each session and to check the equipment for proper functioning.

The vigilance task consisted of a cathode ray tube (CRT) display on which the subject monitored a point of light that moved randomly from the center of the screen. At selected times, the signal deflected an extra 1.2 cm in either an upward or downward direction, and this was defined as a signal to which the subjects responded by pressing a button held in their preferred hand. The CRT was driven by means of a magnetic stereo tape recorder, one channel supplying the signal for the CRT and the other channel supplying instructions and subsequently white noise through the head sets worn at all sessions. The signals occurred with a mean frequency of one each 2.5 minutes. The intersignal intervals were selected pseudo-randomly with no intervals being shorter than .5 minutes or longer than five minutes, such that four signals occurred during each ten minute period. The magnetic tape program used for driving the CRT was of sufficient length to allow the experimental sessions to be started at different points on the tape and thus eliminate any possibilities that the subject would learn the pattern of signal occurrence.

The physiological indices which served as independent variables in this investigation were heart rate and body temperature. Surface electrodes were used to obtain the heart response and a surface thermister was attached under the subjects arm to obtain an estimate of the subjects body temperature. This thermister, which is smaller in diameter than a dime, was housed in a styrofoam pad fastened to the subject by means

of an adhesive collar. An elastic bandage was then used to cover the entire thermister and insure that it remained in contact with the subject. Subjects were instructed to keep the left arm under which the thermister was located in their lap or on the table to minimize the flow of ambient air under the arm. In pilot studies conducted prior to this investigation, this estimate of body temperature was found to correlate very highly with rectal temperature. This method of temperature monitoring was selected since it was considerably more comfortable for the subject than was the rectal probe.

RESULTS

The mean performance for ten subjects is pictured in Figure 1. There appears to be two definite types of performers, i.e., high performers (detectors) who consistently perform above ninety percent accuracy on this vigilance task, and moderate performers (nondetectors) whose performance level is such a low level and with such high variability that his performance was considered atypical, and his data were deleted from all subsequent data analysis.

Insert Fig. 1 about here

A significant ($P=.95$) temperature-diet interaction effect on performance was observed in this experimental data. Neither diet nor temperature however, was statistically significant as a main effect. Under conditions of constant temperature,

performance after the light diet was superior to the performance after the heavy diet as depicted in Figure 2. This finding substantiates the one reported earlier by Kassouny, Halcomb and McFarland (1969). However, when the variable temperature was included, the influence of the light or heavy diet disappeared. Apparently the variable temperature interferes with performance to the point that it dominates any influence normally attributable to diet differences. This is somewhat contradictory to the original hypothesis which proposed that a variable temperature would tend to enhance performance of a vigilance task.

Insert Fig. 2 about here

Each of the experimental subjects performed the task on four subsequent days during a single week. The vigilance performance was also analyzed over this sequence of four days on watch to determine if any appreciable learning effect was encountered. This factor was not significant. This and all other statistical tests in this study utilized a significance level of $P = .95$.

Heart rate was monitored during each experimental session in order to evaluate if this physiological parameter related to performance level or cognizance of a signal. If substantial physiological response to a signal occurred, this should be detectable as a differential between heart rate before and

after signal presentation. Accordingly, the heart rate during five seconds immediately after the signal was compared to the five seconds before, and also the ten seconds after the signal was compared with the ten seconds before. None of the five-second interval differences were significant. However, the temperature-diet interaction again showed significance when the heart rate ten seconds before the signal was compared to ten seconds after the signal. This is pictured in Figure 3. For the constant temperature no heart rate difference was observed. That is, the heart rate ten seconds after the presentation of the signal was not different from the ten seconds before. The combination of variable temperature and heavy diet resulted in an increase in heart rate after the stimulus presentation. The positive difference in Figure 3 indicates a heart rate increase after a stimulus. A possible explanation of this phenomenon is that homeostasis, or maintenance of a regulated internal environment, is more difficult under variable temperature conditions. Thus the additive effects of a heavy diet and variable temperature resulted in a significant differential between heart rates before and after the signal.

Insert Fig. 3 about here

Heart rate was sampled randomly throughout the work session in twenty-second periods, and with a between sample mean interval of 2.5 minutes. These samples were used as estimates

of the minute heart rate during the watch session. Figure 4 indicates that heart rate for the heavy diet was higher than for the light diet. This probably reflects the metabolic stresses of digestion and assimilation after the heavier meal.

Insert Fig. 4 about here

The effects of temperature-diet interaction on the physiological parameter of heart rate are shown in Figure 5. As with constant temperature, the heart rate is less with the light meal than with the heavy meal. Under conditions of variable temperature, however, the autonomic nervous system is apparently under more stress. This resulted in a higher heart rate for the heavy diet than was anticipated when observing the light diet-variable temperature condition.

Insert Fig. 5 about here

The heart rate as a function of time on watch is depicted in Figure 6 where the mean heart rate during each of five successive twenty minute periods is plotted. The almost linear negative slope of this relationship is no doubt a result of the time after ingestion of the meal coupled with the inactivity of sitting for prolonged periods. Here the diet-period interaction was not significant, i.e., for both the heavy and light

diet the heart rate decreases were comparable and thus plotted as parallel over the time period.

Insert Fig. 6 about here

CONCLUSIONS

Performance of a vigilance task was not enhanced by the use of variable temperature conditions. Rather, variable temperature appeared to negate any performance improvement observed during a light diet-constant temperature condition. (See Fig. 3).

The physiological response, as indicated by heart rate, followed the same pattern. Variable temperatures appeared to interfere with autonomic regulation of heart rate that was observed when temperature was constant.

Homeostatic regulation requires the heart rate to continuously compensate for change in external temperature and digestive activity. The variable temperature appears to place stress on autonomic controls and thus adversely affects both heart rate and vigilance task performance measures.

Thus the use of a cyclically varying variable temperature as a means of enhancing vigilance performance is not indicated. The authors would suggest further research, however, to determine if a randomly varied temperature, rather than the cyclical temperature of this study, would yield results more consistent with those found with other types of environmental change.

ACKNOWLEDGMENTS

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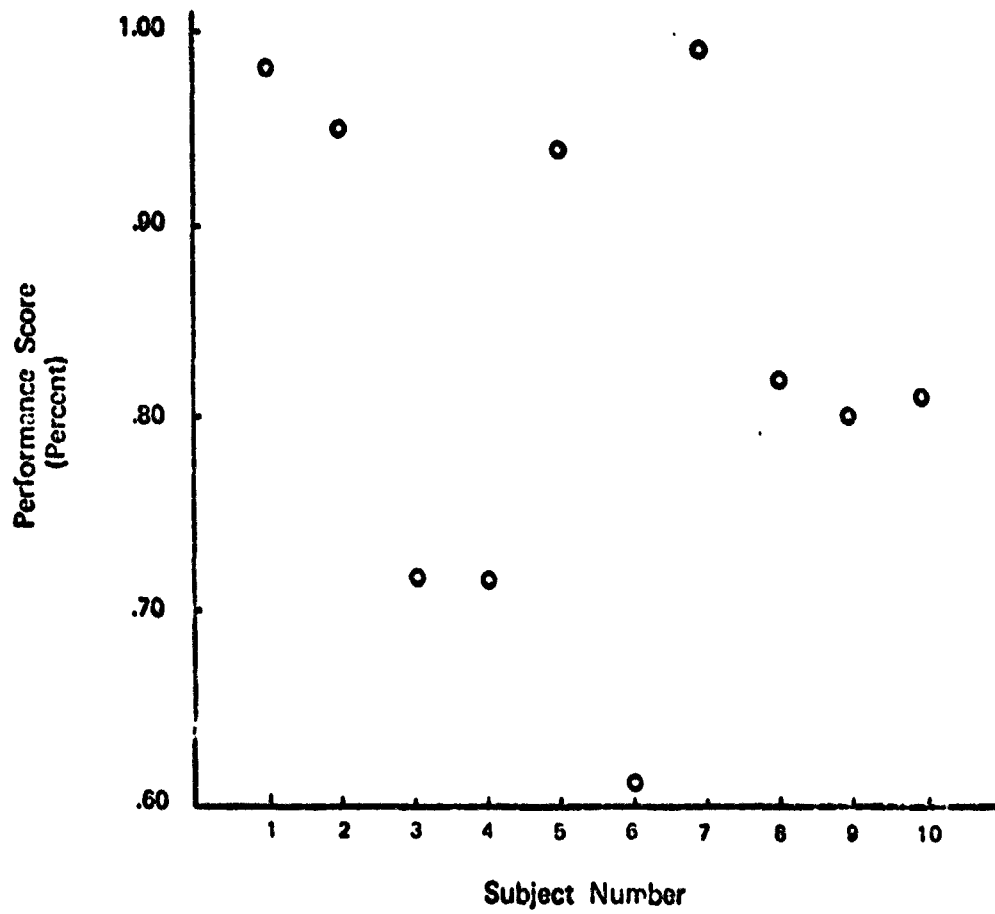


Figure 1 - Performance Scores for Subjects

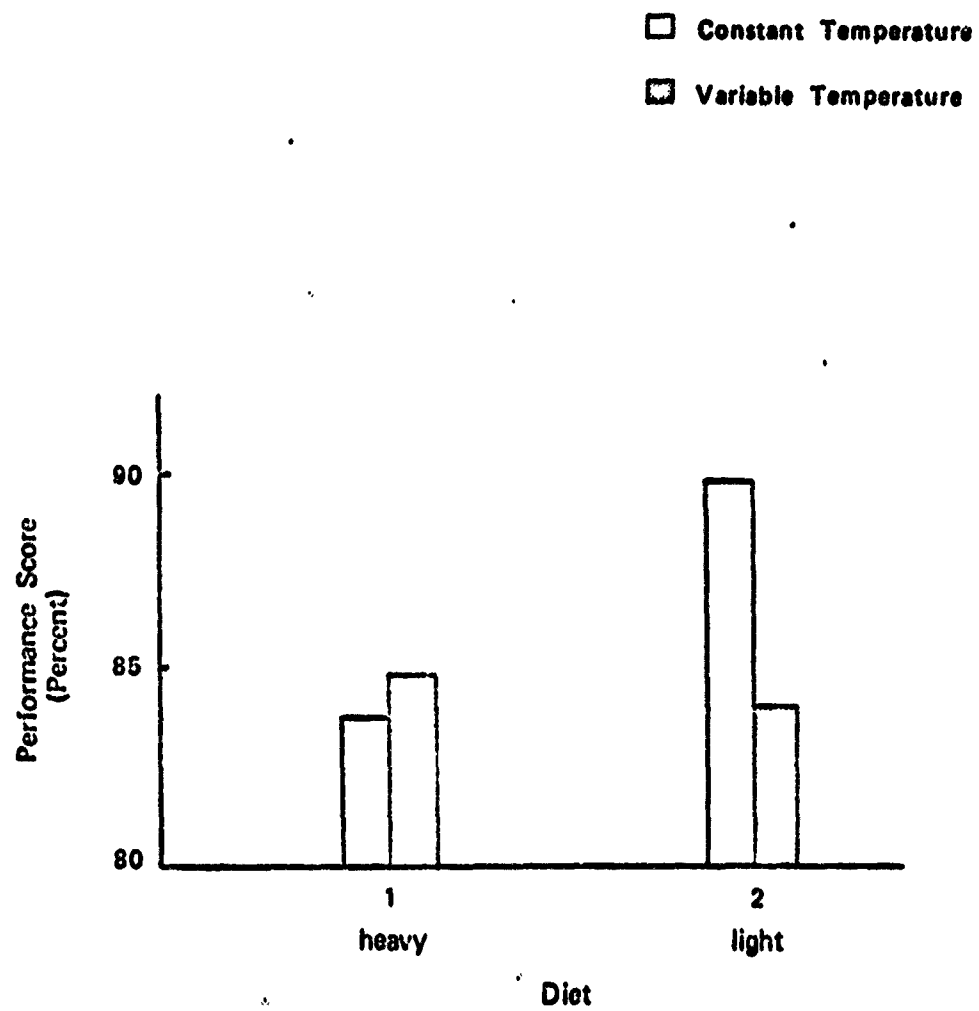


Figure 2 - Performance Scores for Temperature-Diet Interaction

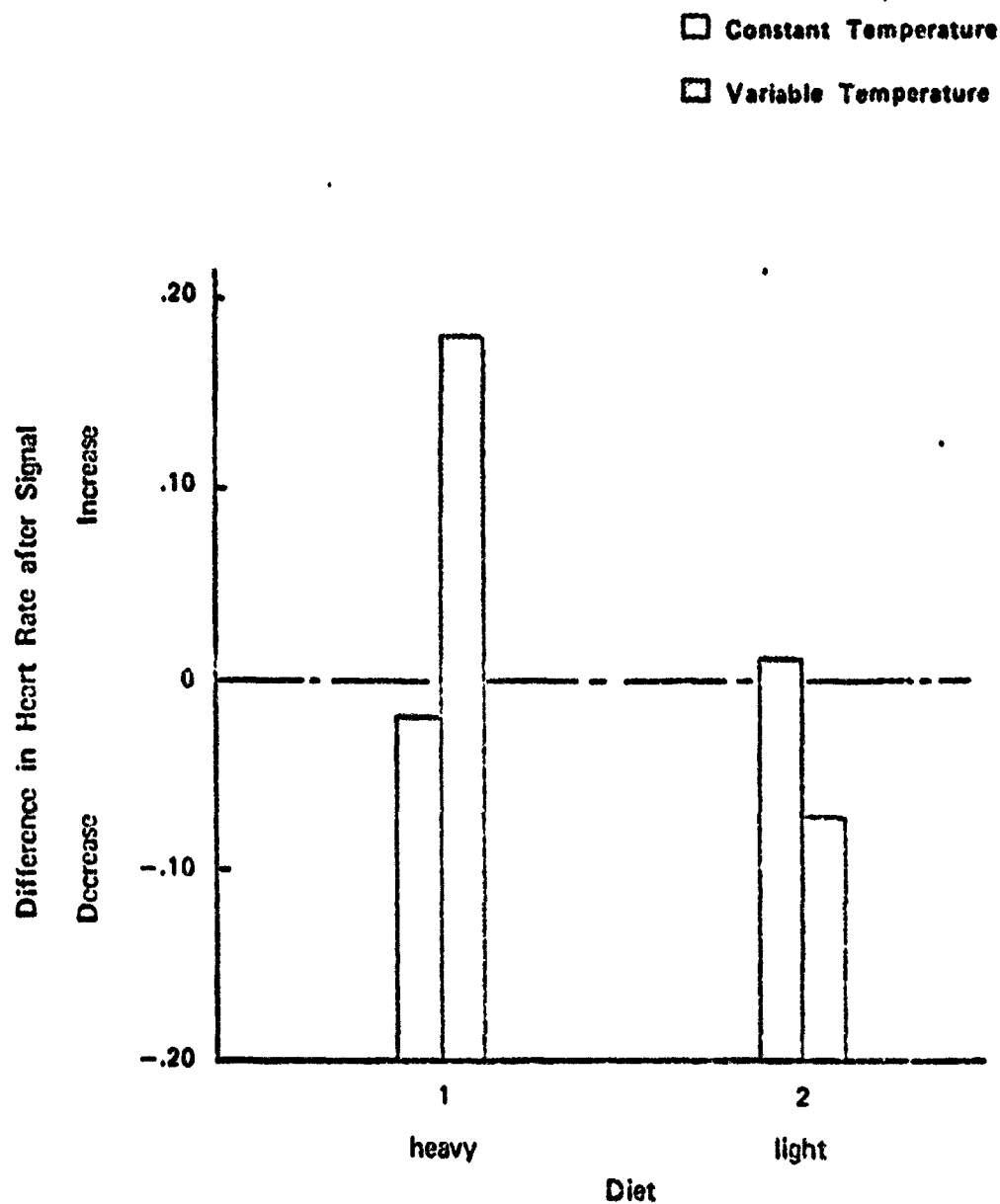


Figure 3 - Heart Rate Differential
For Temperature-Diet Interaction
(Ten seconds before minus ten seconds after)

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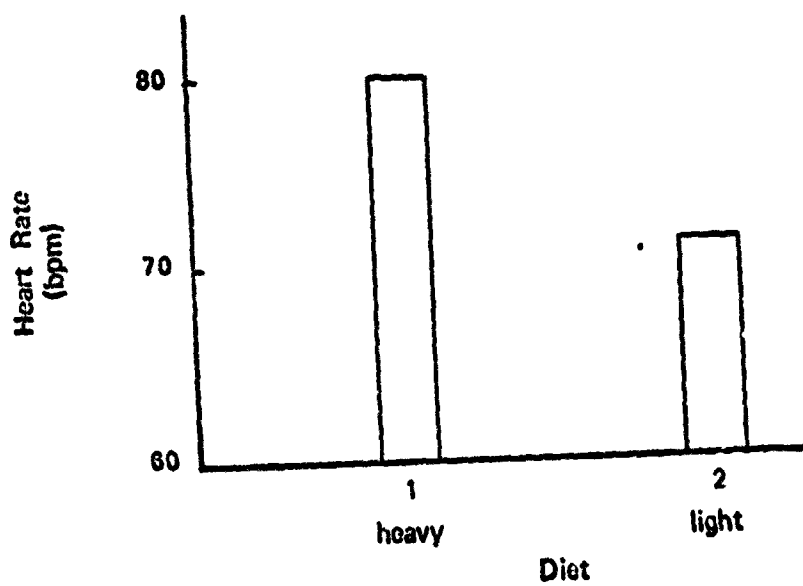


Figure 4 - Heart Rate for Diet

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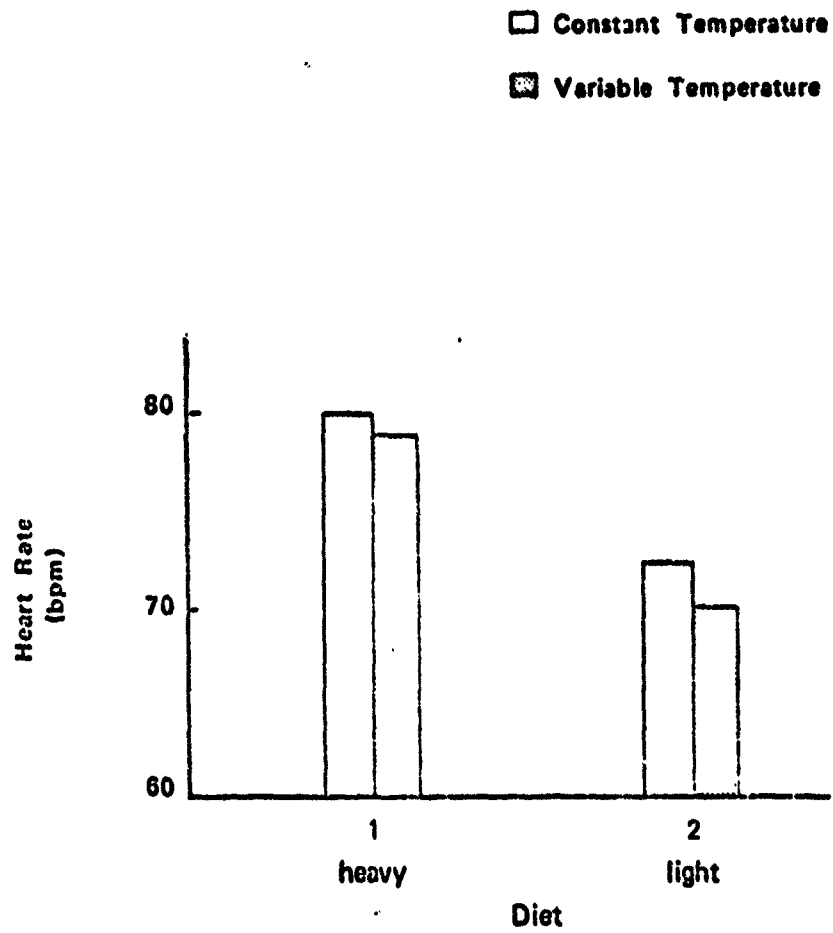


Figure 5 - Heart Rate for Temperature-Diet Interaction

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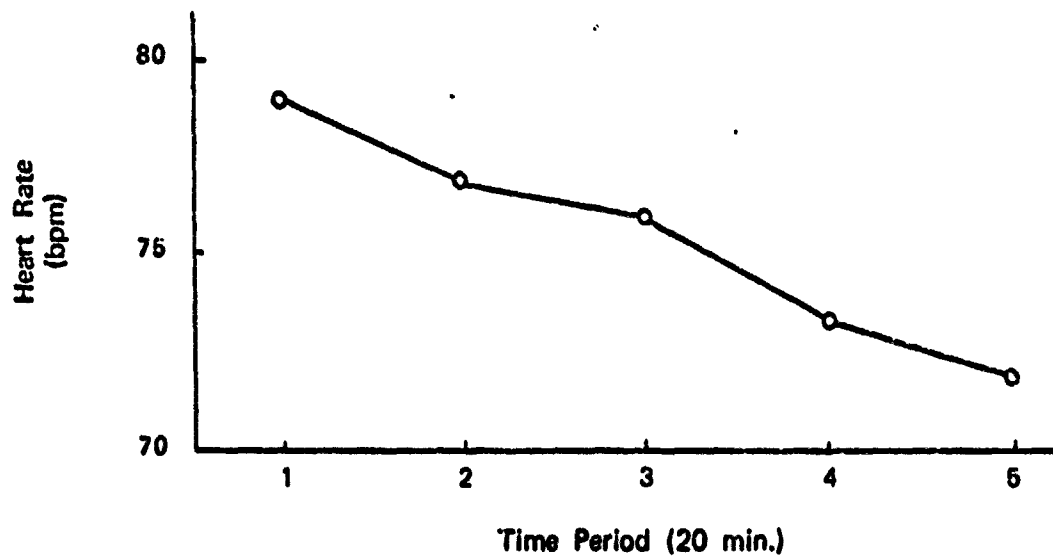


Figure 6 - Heart Rate for Time Period

BIOGRAPHY

JERRY D. RAMSEY (Effects of Cyclical Temperature on Vigilance Performance) is an Associate Professor of industrial engineering at Texas Tech University. He received his B.S. in industrial engineering at Texas A & M University in 1955; his M.S. from the same institution in 1960; and his Ph.D. from Texas Tech in 1967. His primary research and teaching interest is in the area of biotechnology and human performance. He has previous teaching experience at Texas A & M University and the University of New Mexico, as well as teaching industrial short courses in statistics, quality control and value engineering. His industrial experience includes employment or consulting with Sandia Corporation, Collins Radio Company, Square D Company, and others. He holds membership in a number of professional and honorary societies.

CHARLES G. HALCONE (Effects of Cyclical Temperature on Vigilance Performance) is a professor of psychology at Texas Tech University and is director of programs in experimental psychology. He also serves as coordinator for the engineering psychology program within the department. He received the Ph.D. degree from Baylor University in 1964. He is currently interested in the application of real-time computer technology to the measurement of human performance. He is a member of the American Psychological Association and the Human Factors Society.

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MARGARET E. KASSOUNY (Effects of Cyclical Temperature on Vigilance Performance) is an Associate Professor of food and nutrition at Texas Tech University. She received her B.S. in 1957 and M.S. in 1961 from Ohio State University and her Ph.D. in 1970 from Cornell University. Her special teaching and research interests are in the areas of nutrition, metabolism and disease. She holds membership in American Home Economics Association and American Public Health Association.

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Figure 2. Performance scores for temperature-diet interaction

Figure 3. Heart rate differential for temperature-diet interaction.

Figure 4. Heart rate for diet

Figure 5. Heart Rate for temperature-diet interaction

Figure 6. Heart rate for time period

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