THE DISCERNIBILITY OF THE EFFECTS OF VARYING LEVELS OF ILLUMINATION ON INDIVIDUALS

by

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CHAPTER I

INTRODUCTION AND PURPOSE

Remarkable changes have taken place in residential and industrial lighting since the invention of the electric light bulb. Interior designers, illumination engineers, ophthalmologists, and psychologists, each professional group with a different aim, have had a part in the changes.

The interior designer's aim has been to enhance lighting through the placement of varying amounts and hues of light in order to obtain a desired effect.

The illumination engineer has as one of his aims to provide environmental conditions conducive to obtaining maximum efficiency for the user.

The ophthalmologist has as one of his aims to prevent harmful effects to the eye caused by inadequate quantity or quality of light.

The psychologist has sought to determine the emotional reactions of persons to varying light conditions.

Different tasks require varying quantities of light, and recommendations have been made for levels of illumination as measured in foot-candles[1] according to the task. In industrial tasks, a rise in

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[1]Foot-candle(ftc.)--A unit of illumination, being the direct illumination on a surface everywhere one foot from a uniform point source of one international candle.(9:323)

production has been achieved by increasing the amounts and quality of light.

It is known that hue and quantity of light has an effect on persons performing tasks; however, instrumentation to measure the effects precisely have not been uncovered.

Humans perform less efficiently with lower levels of illumination when the task requires fine lines of discrimination. Knowing that the body reacts as a whole to any stressful condition, it was thought that some of the easily measurable physical conditions could be used to indicate reactions of humans to lighting levels.

The primary purpose of this study was to determine whether the physiological measurements - blood pressure, pulse rate, and galvanic skin response - changed significantly when humans worked under high and low levels of illumination. The accuracy and rate of a written task were to be checked as a possible indication of human performance under high and low amounts of illumination.

Specifically, the following null hypotheses were to be tested:

1. There is no statistically significant difference in the pulse rates of subjects performing the same task under test conditions providing five foot-candles and providing seventy foot-candles of illumination.

2. There is no statistically significant difference in the systolic nor in the diastolic blood pressure of subjects performing the same task under test conditions providing five foot-candles and providing seventy foot-candles of illumination.

3. There is no statistically significant difference in the galvanic skin response of subjects performing the same task under test conditions providing five foot-candles and providing seventy foot-candles of illumination.

4. There is no statistically significant difference in the accuracy nor in the rate of copying printed words and numbers by subjects under test conditions providing five foot-candles and providing seventy foot-candles of illumination.

CHAPTER II

REVIEW OF LITERATURE

Illuminating Engineering suggests that the underlying philosophy of the "best" seeing conditions have remained unchanged through the years. This philosophy is "To provide the best possible ability to see with greatest ease and comfort".(35:140) The researchers have had trouble in finding a method of measuring precisely this degree of seeing with "ease and comfort".

> The measurement of fatigue in general and eye fatigue in particular is very difficult. Much has been written and a number of investigators have studied this. Some have used speed, accuracy, or rate of working as a criterion. Even though the subjects report fatigue, there often was no decrement in any of these measures and, in fact, sometimes there was an improvement. Thus, it has been necessary to devise other, more sensitive methods or indicators for evaluating fatigue or ease of seeing.(35:141)

Fatigue generally speaking means "to tire" or "to become weary". Actually there are two types of human fatigue--one is physical and the other is mental. Stedman's Medical Dictionary states that fatigue is:

> That state following a period of mental or bodily activity characterized by a lessened capacity for work and reduced efficiency of accomplishment, usually accompanied by a feeling of weariness, sleepiness, or irritability....(8:568)

Stress

Mental and physical fatigue cause bodily stress. Much study has been done in the field of stress by Hans Selye, as well as other researchers who have built upon Selye's Theory of Stress and Adaptation.

In The Stress of Life, Hans Selye has defined stress as "The state manifested by a specific syndrome, which consists of all nonspecific induced changes within a biologic system".(7:54) According to Selye, a homeostatic level is maintained by the body under normal conditions; but a change takes place when forces cause the physiological equilibrium to be disturbed. The total body responds physiologically to these stressors. This Selye called "General Adaptation Syndrome".(7:3) Hennis and Ulrich in a "Study of Psychic Stress in Freshman College Women" say that:

> Stress, in its physiological meaning, is the rate of wear and tear on the body caused by agents, conditions, and situations which tend to destroy the homeostatic balance.(19:172)

Elsewhere in the article they stated that:

> Stressors may be physical, social, or psychic in nature. However, the human organism in reacting to the stressor and resolving the stress does not differentiate among the stressors. Stress appears to be stress, regardless of the nature of the stressor.(19:172)

Selye stated that, "Any one agent is more or less a stressor in proportion to the degree of its ability to produce stress, that is, nonspecific changes."(7:64)

After studying Selye's Theory of Stress and Adaptation, it was thought that physical environmental conditions such as poor lighting might act as a stressor. If so, the physiological response of the human body, along with subsequent adaptation, might be discernible by some physiological measurements.

Physiological Measurements

The physiological measurements to be used in this study included pulse rate, blood pressure, and galvanic skin response. These physiological measurements have been used as indicators of bodily response to various situations.

Pulse Rate and Blood Pressure

A variation of pulse rate may be found within one individual at different times within the same day or even when the individual is in different positions; therefore McCurdy(5) recommended that comparisions for pulse rates be made at the same time of day and in the same position each time the pulse rate of an individual is taken. Massey(36) pointed out that it is difficult to compare "normal" rates among individuals accurately unless the other variables are also considered. Changes within the same person under differing conditions are better indications of the individual bodily responses to the disturbed homeostatis than changes between two or more individuals.

Blood pressure and pulse rate, as well as other physiological measures have indicated the degree of activation in organisms. The measurement itself and interpretation of the data of some of these have been difficult. For example, experimenters have found it difficult to predict the direction of change for the heart rate under specific conditions, however Cotton, in his book Principles of Illumination, stated that:

> Whenever a person is fatigued after the performance of some task, there is a depression in the heart rate. This applies to the visual task of seeing, for example while reading, if the task is performed for a sufficient length of time. It is due to the reflex stimulation of the central nervous system as a result of the effort expended in the performance of the visual task. In one set of experiments one hour's reading produced a depression of 10% when the illumination was one lumen/ft^2, but of only 1% when it was 100 lumen/ft.^{2}(2:82)

Luckiesh and Moss found that the heart rate decreased progressively as the duration of the task increased. The decrease in the heart rate was found to be greater under one foot-candle than it was under one hundred foot-candles. Since there was a relatively large depression in heart rate observed under the lower intensity of illumination, but not under the higher, Luckiesh and Moss(24) indicated that the sensory processes were abnormally taxed under the low level of illumination.

In this study there was a correlation between nervous muscular tension and per cent of heart rate decrement. Both the decrement in the heart rate and the nervous tension of the muscles decreased when the foot-candles increased. The article stated:

> Superficially one might suppose that the greater decrement in heart-rate under the lower level of illumination was due to a natural psychological association between dim illumination and relaxation or the onset of sleep. The validity of this supposition is doubtful for several reasons.(1) It is not supported by the introspective reports of the subjects.(2) The experimental results show that the subjects read nearly as rapidly under the lower level of illumination as under the higher although it was in no sense a "speed test". The observed difference in the rate of reading is to be expected due to the lower visibility of the printed matter under the lower level of illumination.(3) Measurement of nervous muscular tension developed as a result of reading shows that tenseness is decisively greater under one foot-candle than under 100 foot-candles. It appears that the established fact definitely rules out relaxation as an explanation of heart-rate decrement.(24:135)

Studies have shown increases in either pulse rate, blood pressure or both with activation of the body. Engel(16) found an increase in both systolic and diastolic blood pressures and an increase in heart rate, but a decrease in finger pulse volume as a result of cold-pressor stimulation;stimulation has also produced a decrease in the pulse rate. Stimuli from sound has caused an increase in pulse rate at the beginning, to be followed by a decrease to a subnormal level according to Davis, Buchwald, and Frankmann.(13)

Studies have shown both an increase and a decrease in pulse rate as a result of emotional stressors. Baker and Taylor(10) have found an increase in pulse rate as the result of an emotional stressor, a jumping electrical spark. Malmo and Shagass(26) in studies done on anxiety with schizophrenia patients, have found an accelerated pulse rate as the result of an emotional stressor. McCurdy and Larson(5) stated that subjects responded with accelerated or decelerated heart rate to different emotional stressors. In each case there was a change, either acceleration or deceleration, in the affected subjects.

Blood pressure also increases with "emotional" stress according to studies by Landis and Gullette.(23) They found high blood pressure present during an experiment where a variety of "emotional stimuli" were present. While experimenting with cats, Cannon(1) found that the heart rate and arterial pressure increased after fears had been induced. Valk(34) found a temporary rise of the blood pressure in normal subjects and a higher rise of the blood pressure in hypertensive subjects during periods of emotional conflict. Hickam, Cargill, and Golden(20) found a ten per cent increase in the mean arterial pressure of healthy medical students when they were exposed to a state of anxiety. Schneider and Zangari claimed that "With anxiety, tension, fear, anger, and hostility, the blood pressure is increased."(31:302) Grollman(17) found an increase in both the pulse rate and the blood pressure when he induced a psychic stressor to normal subjects.

According to Hennis and Ulrich:

> Blood pressure, systolically and diastolically, had a tendency to rise when the individual was subjected to the stressor and the rise was statistically significant at the one per cent level of confidance. The findings indicating the directional increase in blood pressure during the alarm reaction to a psychic stressor are in accord with the knowledge concerning the general adaption syndrome.(19:175-176)

Galvanic Skin Response

The galvanic skin response (GSR) has been used mainly as an indicator of the degree of mental stress of subjects who are being subjected to "truth" tests. It is one of the measurements of the "lie detector". Researchers agree that:

> A rapid objective technique to evaluate subtle changes in the intensity of affective response to stressful stimuli, a technique that would be sensitive to minor fluctuations in the human 'alertness level' would be of extreme value in research psychiatry.(32:65)

The measurement of skin resistance, called the galvanic skin response, has been known over fifty years. The mechanism of this measurement involves the passage of a very small electric current through certain parts of the body. Although an electric resistance is being measured, what the measurements signify apparently is not known. However, the galvanic skin response has been defined by Duffy as the change in resistance from "the general level of skin resistance before stimulation is applied" to "the change in resistance which occurs upon the presentation of a stimulus".(3:26) Silverman, Cohen, and Shmavonian state that:

> Rapid changes in skin resistance occur in response to external and internal stimuli. These galvanic skin responses appear to be dependent on the sympathetic nervous system as the final common path and probably represent presecretory sweat gland changes rather than the actual amount of sweating in an area.(32:65)

Recent work by Edelberg, Greiner, and Burch(14) has suggested that these shifts in skin resistance may represent permability changes in the labile membrane. Duffy(3) further explains this permability of cell membranes by saying that it causes a polarization change, and thus a change in electrical resistance. Hemphill(18) suggests that certain hormones may control the widest variation in resistance which is probably dependent on extracellular water and electrolyte balance.

Although the galvanic skin response is a convenient measure, the reliability of the data is questioned by some researchers. Others indicate that a number of variables need to be controlled when recording the galvanic skin response. The response apparently varies:

1. Inversely, with temperature.(27)
2. Inversely, with the area of the electrodes.(6)
3. With permeability changes in a labile membrane.(14)
4. With the chemical make up of the electrodes.(14)

However, researchers have said that irreversible electrodes, such as the lead plate, with a polarizing ability, do not affect the GSR amplitude significantly.

It has been known for some time that the skin resistance rises with relaxation and increases even more in sleep. Likewise the arousal and progressive excitement of an organism results in a reduction of the resistance. According to Kleitman(4), an increase in resistance occurs at a slower rate as a person becomes more relaxed. The amount of this increase is related to the depth and duration of sleep.

Individual differences were noted by Richter(30), who reported that persons whose skin resistance showed a great increase were persons who slept more soundly and were harder to awaken than those who had only a slight increase in skin resistance. Likewise Silverman, Cohen, and Shmavonian(32) found a relationship between basal skin resistance and arousal. They stated that, "Significant drops in the basal resistance occurred with emotional stimuli, such as words or the application of pain as well as the injection of various stimulant drugs.(32:68) Elsewhere they stated:

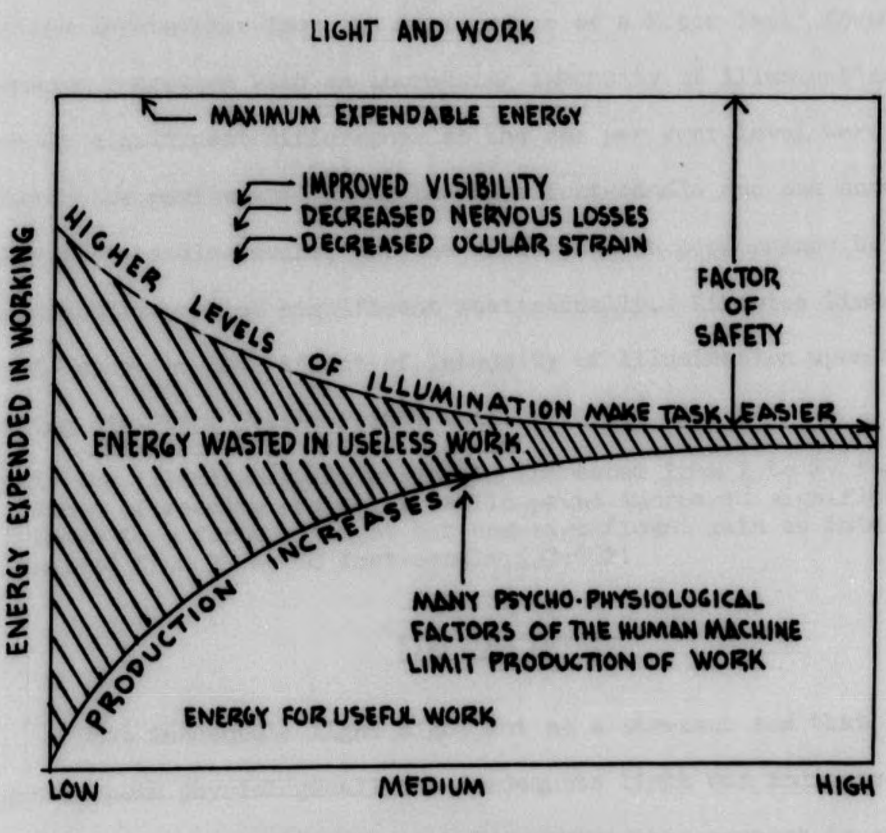
> Malmo's recent works (1959) relating the level of arousal to the shifting basal resistance appears to be a confirmation of the fact that basal skin resistance is inversely related to central nervous system arousal as expressed by amount of 'sympathetic tonus'.(32:68)

Much work has been done to find the relationship between specific emotions and physiologic changes. In an experiment, Silverman, Cohen, and Shmavonian(32) put fifteen subjects in a darkened room, one at a time, and monitored with galvanic skin responses and periodic automatic blood pressure determinations. They stated, "After baseline and control periods, during which a provoking verbal chastisement was introduced, the subjects were given (parentarally) [sic.] 5 mg. of mecholyl."(32:83) Upon examination of the data, they noted "That the amount of hormonal and vascular changes appeared related to the amount of arousal of the subject".(32:83) Among those subjects who seemed to be anxious, there was a trend toward "A direct correlation between the number of nonspecific GSR's and amount of systolic blood pressure decrease...."(32:83) Likewise there was a trend "Between G.S.R. and systolic blood pressure increase."(32:83) Elbel and Ronkin(15) found a similar association between high palmar resistance and a low pulse rate and vice versa during rest and during exercise. Silverman, Cohen, and Shmavonian, in discussing the results of their experiment pointed out that:

> It should be emphasized that the writers do not expect a clear linear relationship. This expectation could only be fulfilled in a system far simpler than that of man.(32:83)

Performance Task

Twenty-five years ago Luckiesh and Moss developed and presented with hesitancy a diagram on the relationship between light and work (fig. I) which showed that as foot-candles increased, the production also increased. In discussing this diagram, the Illuminating Engineering says that:



(24:540)

Fig. 1.--A diagram of the relationship among production of work, expenditure of human energy and levels of illumination developed by Luckiesh and Moss.

> It was an interpretation of the relationships among lighting, production of work and the expenditure of human resources. Thus, for the first time, total human effort and energy were brought into the picture. It seems strange that this new concept took so long to develop because everyone has experienced what the diagram illustrated. For example, when we increase the foot-candles to 100 or more, we may not be able to read it more rapidly, but we read it easier and for longer periods without any appreciable fatigue.(35:140)

However McCormick and Niven(29) in their study on "Effect of Varying Intensities Upon the Performance of a Motor Task" found that performance increased with an increasing intensity of illumination. Statistically significant differences at the one per cent level were found between the performance under the five foot-candle and one hundred and fifty foot-candle levels, but the difference in performance between fifty foot-candles was not significant statistically. Likewise Tinker noted in his study on the "Effect of Intensity of Illumination upon Speed of Reading Six-Point Italic Print", that:

> As the illuminating intensity is increased from 1 to 25 foot-candle, speed of reading six point italic print increased significantly. There is a further slight but non-significant gain as intensity is raised from 25 to 50 foot-candle.(33:602)

Lighting Levels

That inadequate light might act as a stressor and that the body might respond physiologically to inadequate light was indicated in an editorial in Illuminating Engineering, where this concept is expressed:

> The indirect evaluation of the effort expended in seeing which have been explored show that higher foot-candle levels provide greater ease of seeing and less expenditure of human energy.(35:142)

However it has been difficult to specify how high the foot-candle levels must be to provide "greater ease of seeing and less expenditure of energy". Blackwell, who has done an extensive amount of research in the field of lighting, has recently presented his study entitled

"Development and Use of Quantitative Method for Specification of Interior Illumination Levels on the Basis of Performance Data". In this study he reminds his readers that it is difficult to evaluate the accuracy of his recommendations for lighting by this system. He states:

> At least for the present it may have to suffice to evaluate to what extent these lighting values agree with our total experience with various visual tasks. The adequacy of low foot-candle levels for reading high contrast print certainly agrees with some evidence of the illumination needs of this task. The need for very high illumination levels for certain very difficult garment and textile tasks certainly agrees with our experience of wanting to take these tasks to the window or out-of-doors. The present data should stimulate considerable careful assessment of accumulated experience with various visual tasks.(11:343)

Those interested in lighting recognize a need for measurements and criteria in making recommendations for lighting levels. An editorial in <u>Illuminating</u> <u>Engineering</u> states:

> Considerable more work is necessary in this area. When subjective observations indicate greater ease of seeing with higher foot-candle levels, it is desirable and necessary to develop objective methods of evaluation.(35:142)

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CHAPTER III

PROCEDURE

The Test Room

The experiments were conducted in a small room in which the humidity and temperature were controlled. The furniture consisted of a day bed, a desk and a chair for the subjects, a chair and a small desk for the experimenter. The subjects' desk was covered with white matte finished cardboard to eliminate glare.

The Subjects

The subjects for this study were twenty women between the ages of twenty-seven and fifty-five, the majority of whom were teachers enrolled at The Woman's College of the University of North Carolina for the summer session of 1960. (See Table 18 for data concerning subjects.)

The Lighting Variable

The level of illumination was the controlled variable for this experiment. Seventy foot-candles and five foot-candles were the lighting conditions under which each subject's physical reactions and task performance were tested. Half of the subjects were tested first with the high illumination condition and the other half were tested first with the low illumination condition in order to eliminate any possible influence of the lighting condition that was tested first as compared with the lighting condition that was tested second. The high illumination was achieved by using several portable spot lights in addition to the permanent overhead lighting fixture. All of the light sources were diffused by reflecting the light from the walls or by covering the source with oiled paper. The low illumination was achieved by using a small lamp with a heavy glass diffusing bowl, attached to the edge of the left side of the desk. The foot-candles of light were checked at the center of the desk with a foot-candle meter. All natural light was blocked out.

The Physiological Measurements

Three physiological conditions, pulse rate, blood pressure, and galvanic skin response were measured at the beginning and at the end of the subjects' performance under the two levels of illumination. In addition a base for these three physiological measurements was established.

Pulse Rate

The pulse rate was measured at the radial artery by counting the pulse beats for a full minute, timed by a stop watch. The pulse rate is the number of regular throbbings of the arteries which is caused by successive contractions of the heart.

Blood Pressure

The blood pressure was measured by the pressure cuff Baumanameter manufactured by the W. A. Baum Company, New York. The blood pressure of a human is expressed as systolic and diastolic pressure. The systolic is the maximum pressure which is caused by the normal rhythmical contractions of the heart; this occurs at the same time as the apex of the pulse wave in the artery in which the measurement is made. The diastolic pressure is the minimum pressure which occurs at the bottom of the pulse wave.

Galvanic Skin Response

The galvanic skin response was measured by psychogalvanometer number 601 manufactured by the Lafayette Instrument Company, Lafayette, Indiana. The psychogalvanometer finger electrodes were made from a combination of brass and chrome. This instrument is an AC operated DC amplifier with a wheatstone bridge circuit in the input stage to permit the measuring of resistance changes in ohms at balanced conditions. The psychogalvanometer depends on the subject to form one arm of the wheatstone bridge, and a very small constant current is maintained through the subject. As the constant current flows through the wheatstone bridge circuit, the subject provides a voltage drop which is proportional to the resistance and allows the use of a flexible, easily calibrated nulling system. At the beginning a balance is achieved by manual adjustment of a calibrated resistor. This resistor reading provides the base or "subject starting resistance". The fluctuation of the resistance around the balance point causes voltage fluctuations which are amplified and indicated directly by the meter or recorder. These fluctuations are linear and therefore may be read in ohms directly from the resistor.

The Performance Task

The rate and accuracy of copying names, addresses, and telephone numbers from a telephone book were recorded and checked for error for each subject.

The Base Measurements

Prior to the tests under the different levels of illumination, the base measurements for pulse rate, blood pressure, and galvanic skin response were established for each subject. The subject rested for seven minutes before any measurements were taken. Then the pulse rate, blood pressure, and galvanic skin response were measured. The subjects copied names, addresses, and telephone numbers from a telephone directory for a timed period and the pulse rate, blood pressure, and galvanic skin response were measured again. The base conditions were measured for each subject on three consecutive days and then averaged to establish a base for each subject for each of the three measurements.

<u>The Experimental Testing</u>

The actual experiments on the subjects' reactions to the two levels of illumination were conducted on two consecutive days for each subject. On one day seventy foot-candles were provided; on the other, five foot-candles were provided. The physiological measurements and task performance for each subject under each level of illumination was measured and recorded. The physiological measurements, blood pressure, pulse rate, and galvanic skin response, were taken at the beginning and at the end of the seeing-writing task.

Specifically, the experimental testing was as follows. The subject rested in a supine position for seven minutes in the experimental room. In order to provide optimum comfort for the subject, she was permitted to request the galvanometer electrodes placed on either the hand or foot, provided the same was used under both experimental conditions. Before attaching these electrodes, the fingers or toes of the subject were washed with water and dried well in order to eliminate any possible influence of body salts on the operation of the psychogalvanometer.

For the next three minutes, the subject rested in a sitting position. The physiological measurements were taken at the end of this timed rest period. The performance task was begun which consisted of copying telephone numbers from a telephone directory for ten minutes. The physiological measurements were taken at the end of this timed performance task.

The Data

The data were analyzed with Fisher's "t" formula to determine whether there were statistically significant differences in the pulse rates, the systolic blood pressures, the diastolic blood pressures, or the galvanic skin responses of subjects.

CHAPTER IV

FINDINGS

Findings concerning the physiological measurements are discussed from two view points: (1) considering the direction of change of each measurement from base and from the beginning of a test period, (2) regardless of the direction of change from base and from the beginning of a test period. In addition, differences in changes between the low illumination test period and the high illumination test period are presented.

Each of the physiological measurements--pulse rate, systolic and diastolic blood pressure, and galvanic skin response--are presented separately in the section concerned with the direction of the change. For the purpose of clarity the physiological measurements are combined in the section in which the direction of change was disregarded.

The findings concerned with the rate and accuracy of copying names and addresses from the telephone directory are reported following the physiological findings.

Physiological Measurements Considering the Direction of Change

Pulse

The base pulse rate averaged 81.96 beats per minute for the twenty subjects. Under the low level of illumination, it averaged 82.00 beats per minute at the beginning and 81.35 at the end of the ten minute writing task. Under the high level of illumination, the pulse rate averaged 84.0 beats per minute at the beginning and 83.95 at the end of the task. Note that there was little change in the average pulse rate under each of these lighting conditions. See Table 23 in the appendix.

Under low illumination.--There was an average increase in the pulse rate of .04 of a point from the base to the beginning of the task under the low illumination. From base to the end of the task, the average difference was a decrease of .61 of a point. From the beginning to the end of the task under the low illumination, the pulse rate readings fell an average of .65 of a point. These changes under low illumination were not statistically significant. See Table 1.

Under high illumination.--There was an average increase of 2.04 points between base and the beginning of the task under high illumination, and an average increase of 1.99 points from base to the end of the task. From the beginning to the end of the task under high illumination, the pulse rate fell an average of .05 of a point. None of these changes were statistically significant. See Table 1.

The differences from the end of the task under low illumination to the end of the task under high illumination was 2.60 points on the average. The differences were not statistically significant.

Differences between the changes under low and under high levels of illumination.--Since this experiment was primarily concerned with how the pulse, blood pressure, and GSR would be affected by low and by high levels of illumination, it is most pertinent to study the differences in these measurements during these two lighting levels. The changes from the beginning to the end of each test condition, low and high illumina-

TABLE 1

PULSE RATE CHANGES BETWEEN TIMES MEASURED WHEN THE DIRECTION OF CHANGE IS CONSIDERED

	Amount of Change		"t"	Significance
From	Total	Average	Value	Level
I to II	.8	.04	.0278	N. S.
I to III	-12.2	- .61	.3526	N. S.
I to IV	40.8	2.04	1.4014	N. S.
I to V	39.8	1.99	1.3696	N. S.
II to III	-13.0	- .65	.8065	N. S.
IV to V	- 1.0	- .05	.2242	N. S.
III to V	52.0	2.60	1.6100	N. S.

Key: I - Base

II - Beginning of the task under low illumination

III - End of the task under low illumination

IV - Beginning of the task under high illumination

V - End of the task under high illumination

tion, and the differences between these changes becomes a measure of differences that might be attributed to level of illumination. For the pulse rate, when the direction of change was considered, these differences between the changes from the beginning to the end of the task for the two levels of lighting averaged .6 of a point. These differences were not statistically significant. See Table 2.

Systolic Blood Pressure

The base systolic blood pressure averaged 108.3 points for the twenty subjects. Under the low level of illumination, it averaged 111.7 points at the beginning and 108.2 at the end of the ten minute writing task. Under the high level of illumination, it averaged 106.2 points at the beginning and 104.8 points at the end of the task. Note that the systolic blood pressure was higher than base at the start under the low illumination, and was lower than base at the start under the high illumination. Under both levels of light, the systolic blood pressure was lower at the end than at the beginning of the task. See Table 25 in the appendix.

Under low illumination.--If the subjects at the beginning of the experiment were in the base condition, the readings at the start could not be significantly different from base. However, at the beginning of the task under five foot-candles the systolic blood pressure readings averaged 3.5 points higher than base and statistically were significantly different from base at the five per cent level. See Table 3. The difficulty of seeing and copying under the low level of illumination--five foot-candles--may have immediately been reflected in the increase in the systolic blood pressure.

TABLE 2

PULSE RATE CHANGES DURING LOW AND DURING HIGH LEVELS OF ILLUMINATION AND DIFFERENCES BETWEEN THEM WHEN THE DIRECTION OF CHANGE IS CONSIDERED

Change from Start to Finish of:	Amount of Change		"t" Value	Significance Level
	Total	Average		
1. Task Under Low Illumination	-13.0	-.65	.8065	N. S.
2. Task Under High Illumination	-1.0	-.05	.2242	N. S.
Differences Between 1. and 2.	-12.0	-.60	.6795	N. S.

TABLE 3

SYSTOLIC BLOOD PRESSURE CHANGES BETWEEN TIMES MEASURED WHEN THE DIRECTION OF CHANGE IS CONSIDERED

From	Amount of Change: Total	Amount of Change: Average	"t" Value	Significance Level
I to II	70.0	3.5	2.1834	5%
I to III	0	0	0	---
I to IV	-40.0	-2.0	1.060	N. S.
I to V	-68.0	-3.4	2.8840	1%
II to III	-70.0	-3.5	2.2783	5%
IV to V	-28.0	-1.4	1.0899	N. S.
III to V	-68.0	-3.4	2.2617	5%

Key: I - Base

II - Beginning of the task under low illumination

III - End of the task under low illumination

IV - Beginning of the task under high illumination

V - End of the task under high illumination

Under the low light there was an average decrease of 3.5 points in this measurement from the beginning to the end of the ten minute task. The differences in the systolic blood pressure from the beginning to the end of the ten minute writing task were statistically significantly different at the five per cent level. See Table 3. Since the changes in blood pressure under low illumination from base to the beginning of the task and from the beginning to the end of the task were of the same average amplitude--and opposite in direction--one would suspect that the differences from the beginning to the end of the task under low illumination would also be statistically significant. This assumption was found to be true.

At the end of the task the systolic blood pressures were not significantly different from base. The differences between base and end of task averaged zero.

The statistically significant differences from base at the start of the task make it difficult to interpret the subsequent differences found between the start and the finish of the test period. It may be considered that the systolic blood pressures returned to base and hence indicate an adjustment to the low level of illumination. Could the subjects have adjusted to the difficulty of reading and copying numbers under the unfavorable lighting? Could it be that the difficulty of seeing under low illumination was no longer reflected in the systolic blood pressures after a ten minute task period? Or on the other hand, was it that the differences in the systolic blood pressures from the beginning to the end of the test period were related to the difficulties of seeing under low levels of illumination?

Under high illumination.--There were no statistically significant differences in the systolic blood pressure of the subjects between base and the start of the test period under this level of light. Nor were there statistically significant differences from the beginning to the end of this test period. However, there was an average decrease of 3.4 points from base to the end of the task under high illumination. These data were significantly different at the one per cent level. See Table 3.

The difference in systolic blood pressure between the end of the task under low illumination and the end of the task under high illumination averaged 3.4 points. Statistically the differences were significant at the five per cent level.

Differences between the changes under low and under high levels of illumination.--The most relevant analysis for the purpose of this study, was the analysis of the changes from the beginning to the end of the task under low illumination as compared with the changes during the task under high illumination. For the systolic blood pressure, when the direction was considered, these differences averaged 2.1 and were not statistically significant. See Table 4.

Diastolic Blood Pressure

The base diastolic blood pressure averaged 72.95 points for the twenty subjects. Under the low illumination, it averaged 76.05 points at the beginning and 75.65 at the end of the task. Under the high level of illumination, it averaged 72.45 points at the beginning and 72.30 points at the end of the task. As was true for systolic blood pressure, the average diastolic blood pressure was higher than base at the start under low illumination and slightly lower than base at the start under high illumination. Under both levels of light,

TABLE 4

SYSTOLIC BLOOD PRESSURE CHANGES DURING LOW AND DURING HIGH LEVELS OF ILLUMINATION AND DIFFERENCES BETWEEN THEM WHEN THE DIRECTION OF CHANGE IS CONSIDERED

Change from Start to Finish of:	Amount of Change Total	Amount of Change Average	"t" Value	Significance Level
1. Task Under Low Illumination	-70	-3.5	2.2783	5%
2. Task Under High Illumination	-28	-1.4	1.0899	N. S.
Differences Between 1. and 2.	-42	-2.1	.9091	N. S.

the average diastolic blood pressure was slightly lower at the end than at the beginning of the task. See Table 27 in the appendix.

Under low illumination.--At the beginning of the task under five foot-candles of light, the diastolic blood pressure readings averaged 3.1 points higher than base, and statistically were significantly different from base at the one per cent level. See Table 5. These statistically significant differences show that the subjects were no longer in base condition after the start of the experiment. Under the low illumination, there was an average decrease of .4 of a point in the diastolic blood pressure from the beginning to the end of the ten minute copying task. Statistically the readings from the beginning to the end of the task were not significantly different. However, at the end of the task the diastolic blood pressure readings were still significantly different from base as they had been at the beginning. The level of significance was five per cent. See Table 5

The difficulty of performing the task under the low illumination may have been reflected in the immediate average increase in the diastolic blood pressure which remained throughout the ten minute task.

Under high illumination.--There were no statistically significant differences in the diastolic blood pressure of the subjects between base and the start or between base and the finish of the test period. Nor were there statistically significant differences from the beginning to the end of this test period. See Table 5.

The readings for diastolic blood pressure at the ends of the tasks under the two lighting levels differed from one another by an average of 3.35 points and were statistically significant at the five per cent level.

TABLE 5

DIASTOLIC BLOOD PRESSURE CHANGES BETWEEN TIMES MEASURED WHEN THE DIRECTION OF CHANGE IS CONSIDERED

From	Amount of Change: Total	Amount of Change: Average	"t" Value	Significance Level
I to II	62.0	3.10	3.6047	1%
I to III	54.0	2.70	2.2267	5%
I to IV	-10.0	- .50	.4854	N. S.
I to V	13.0	.65	.6066	N. S.
II to III	- 8.0	- .40	.2926	N. S.
IV to V	- 3.0	- .15	.1387	N. S.
III to V	-67.0	-3.35	2.6821	5%

Key: I - Base

II - Beginning of the task under low illumination

III - End of the task under low illumination

IV - Beginning of the task under high illumination

V - End of the task under high illumination

Differences between the changes under low and under high levels of illumination.--Since this experiment was primarily concerned with how some physiological measurements would be affected by low and by high levels of illumination, it is most pertinent to study the differences in these measurements during the two lighting levels. For the diastolic blood pressure, when the direction is considered, these differences between the changes from the beginning to the end of the task for the two levels of lighting were an average of .65 of a point. These differences were not significantly different from one another. See Table 6.

Galvanic Skin Response

The base GSR averaged 331.25 thousand ohms for the twenty subjects. Under the low level of illumination, it averaged 307.45 at the beginning and 367.45 at the end of the ten minute writing task. Under the high level of illumination it averaged 254.6 thousand ohms at the beginning and 241.65 at the end of the task. Note that the GSR was lower than base at the beginning of the task under both levels of illumination. The GSR at the end of the task under low illumination was higher than base while the end under high illumination was lower than base. See Table 29 in the appendix.

Under low illumination.--The beginning of the task under low illumination was, on the average, 23.80 thousand ohms lower than base. This difference was not statistically significant. At the end of the task, the GSR, on the average, was 36.20 thousand ohms higher than base and was not statistically significant. At the end of the task it was 60 thousand ohms higher than the beginning of the task, and was statistically significant at the five per cent level. Since an increase

TABLE 6

DIASTOLIC BLOOD PRESSURE CHANGES DURING LOW AND DURING HIGH LEVELS OF ILLUMINATION AND DIFFERENCES BETWEEN THEM WHEN THE DIRECTION OF CHANGE IS CONSIDERED

Change from Start to Finish of:	Amount of Change Total	Average	"t" Value	Significance Level
1. Task Under Low Illumination	-8.0	-.40	.2926	N. S.
2. Task Under High Illumination	-3.0	-.15	.1387	N. S.
Differences Between 1. and 2.	-13.0	-.65	1.1149	N. S.

in GSR is generally interpreted as a relaxation of the body, this increase may be an indication that the body adjusts to working under low levels of illumination. See Table 7.

Under high illumination.--There was an average decrease of 77.65 thousand ohms between base and the start of the task under this level of lighting. These differences were statistically significant at the five per cent level. There was a decrease of 59.60 thousand ohms from base to the end of the task. These differences were statistically significant at the one per cent level. These lower than base readings of GSR at the beginning and at the end of the task might be interpreted as an indication of stimulation or excitement of the subjects while exposed to the high level of illumination.

The GSR's from beginning to end of the task under the high illumination fell an average of 12.95 thousand ohms and were not statistically significant.

The GSR at the end of the task under low illumination averaged 125.80 thousand ohms higher than they were at the end of the task under high illumination. Statistically, the readings were significantly different at the one per cent level of confidence. See Table 7.

Differences between the changes under low and under high levels of illumination.--The analysis of the changes from beginning to end of the task under high illumination as compared with the changes during the task under low illumination are pertinent for the purpose of this study. For GSR, on the average, there was a difference of 72.95 thousand ohms. This difference was not statistically significant. See Table 8.

TABLE 7

GALVANIC SKIN RESPONSE CHANGES BETWEEN TIMES MEASURED
WHEN THE DIRECTION OF CHANGE IS CONSIDERED

From	Amount of Change Total (thousand ohms)	 Average	"t" Value	Significance Level
I to II	-476	-23.80	.6367	N. S.
I to III	724	36.20	.9243	N. S.
I to IV	-1533	-76.65	2.8180	5%
I to V	-1792	-89.60	3.2319	1%
II to III	1200	60.00	2.6087	5%
IV to V	-259	-12.95	.4575	N. S.
III to V	-2516	-125.80	2.9881	1%

Key: I - Base

II - Beginning of the task under low illumination

III - End of the task under low illumination

IV - Beginning of the task under high illumination

V - End of the task under high illumination

TABLE 8

GALVANIC SKIN RESPONSE CHANGES DURING LOW AND DURING HIGH LEVELS OF ILLUMINATION AND DIFFERENCES BETWEEN THEM WHEN THE DIRECTION OF CHANGE IS CONSIDERED

Change from Start to Finish of:	Amount of Change		"t" Value	Significance Level
	Total	Average		
	(thousand ohms)			
1. Task Under Low Illumination	1200	60.00	2.6089	5%
2. Task Under High Illumination	- 259	-12.95	.4575	N. S.
Differences Between 1. and 2.	1459	72.95	.6449	N. S.

Physiological Measurements
Regardless of the Direction of Change

Researchers have found that individual reactions to stressful conditions vary from day to day. For some individuals stress is indicated at one time by an increase in a physiological measurement, and may be indicated by a decrease under the same condition on another day. If true base is established and a change from base is stress, then regardless of whether the measurement is more or less, any change from base regardless of the direction is an indication of stress. Therefore, according to this theory, the plus and minus signs which show the direction of the change should be disregarded when studying the amount and significance of change.

For each of the physiological measurements--pulse rate, systolic blood pressure, diastolic blood pressure, and galvanic skin response--all of the comparisions of the base readings with the readings at the beginning of the task, and all of the comparisions of readings for base with those at the end of the task were found to be statistically significant at the one per cent level when analyzed according to the amount of change regardless of direction. See Tables 9 through 16. Likewise all comparisions for each of these physiological measurements from the beginning to the end of the tasks under both levels of illumination resulted in statistically significant difference at the one per cent level when direction of change was disregarded. In addition, for each of these physiological measurements the statistical analysis of the significance of the differences between readings at the end of the tasks under the two levels of illumination resulted in a significance at the one per cent level. Note that all of these analysis were statistically significant at the one per cent level of confidence.

TABLE 9

PULSE RATE CHANGES BETWEEN TIMES MEASURED REGARDLESS OF THE DIRECTION OF CHANGE

Amount of Change				
From	Total	Average	"t" Value	Significance Level
I to II	97.4	4.87	6.4454	1%
I to III	121.4	6.07	5.8365	1%
I to IV	110.6	5.53	6.5550	1%
I to V	120.8	6.04	5.5000	1%
II to III	55.0	2.75	6.1521	1%
IV to V	67.0	3.35	5.2923	1%
III to V	92.0	4.60	4.4231	1%

Key: I - Base

II - Beginning of the task under low illumination

III - End of the task under low illumination

IV - Beginning of the task under high illumination

V - End of the task under high illumination

TABLE 10

PULSE RATE CHANGES DURING LOW AND DURING HIGH LEVELS OF ILLUMINATION AND DIFFERENCES BETWEEN THEM REGARDLESS OF THE DIRECTION OF CHANGE

Change from Start to Finish of:	Amount of Change		"t" Value	Significance Level
	Total	Average		
1. Task Under Low Illumination	55.0	2.75	6.1521	1%
2. Task Under High Illumination	67.0	3.35	5.2923	1%
Differences Between 1. and 2.	52.0	2.60	5.6760	1%

TABLE 11

SYSTOLIC BLOOD PRESSURE CHANGES BETWEEN TIMES MEASURED
REGARDLESS OF THE DIRECTION OF CHANGE

Amount of Change			"t"	Significance
From	Total	Average	Value	Level
I to II	111.8	5.59	5.9279	1%
I to III	93.6	4.68	4.3394	1%
I to IV	129.8	6.49	5.1920	1%
I to V	93.0	4.65	5.0160	1%
II to III	114.0	5.70	5.0000	1%
IV to V	80.0	4.00	4.1929	1%
III to V	122.0	6.11	6.3940	1%

Key: I - Base

II - Beginning of the task under low illumination

III - End of the task under low illumination

IV - Beginning of the task under high illumination

V - End of the task under high illumination

TABLE 12

SYSTOLIC BLOOD PRESSURE CHANGES DURING LOW AND DURING HIGH LEVELS OF ILLUMINATION AND DIFFERENCES BETWEEN THEM REGARDLESS OF THE DIRECTION OF CHANGE

Change from Start to Finish of:	Amount of Change		"t" Value	Significance Level
	Total	Average		
1. Task Under Low Illumination	114.0	5.7	5.0000	1%
2. Task Under High Illumination	80.0	4.0	4.1929	1%
Differences Between 1. and 2.	108.0	5.4	6.7500	1%

TABLE 13

DIASTOLIC BLOOD PRESSURE CHANGES BETWEEN TIMES MEASURED REGARDLESS OF THE DIRECTION OF CHANGE

Amount of Change			"t"	Significance
From	Total	Average	Value	Level
I to II	79.6	3.98	6.2188	1%
I to III	88.2	4.41	4.8675	1%
I to IV	68.0	3.40	3.6876	1%
I to V	71.4	3.57	3.4327	1%
II to III	92.0	4.60	4.7967	1%
IV to V	75.0	3.75	3.9520	1%
III to V	99.0	4.95	5.3398	1%

Key:
I - Base
II - Beginning of the task under low illumination
III - End of the task under low illumination
IV - Beginning of the task under high illumination
V - End of the task under high illumination

TABLE 14

DIASTOLIC BLOOD PRESSURE CHANGES DURING LOW AND DURING HIGH LEVELS OF ILLUMINATION AND DIFFERENCES BETWEEN THEM REGARDLESS OF THE DIRECTION OF CHANGE

Change from Start to Finish of:	Amount of Change		"t" Value	Significance Level
	Total	Average		
1. Task Under Low Illumination	92.0	4.60	4.7967	1%
2. Task Under High Illumination	75.0	3.75	3.9520	1%
Differences Between 1. and 2.	77.0	3.85	5.6493	1%

TABLE 15

GALVANIC SKIN RESPONSE BETWEEN TIMES MEASURED REGARDLESS OF THE DIRECTION OF CHANGE

Amount of Change			"t"	Significance
From	Total	Average	Value	Level
I to II	2676	133.60	6.0901	1%
I to III	2952	147.60	6.8683	1%
I to IV	2389	119.50	6.9477	1%
I to V	2648	132.40	8.1177	1%
II to III	1775	88.75	6.1376	1%
IV to V	1587	79.35	3.6216	1%
III to V	3629	181.45	6.1446	1%

Key: I - Base

II - Beginning of the task under low illumination

III - End of the task under low illumination

IV - Beginning of the task under high illumination

V - End of the task under high illumination

TABLE 16

GALVANIC SKIN RESPONSE CHANGES DURING LOW AND DURING HIGH LEVELS OF ILLUMINATION AND DIFFERENCES BETWEEN THEM REGARDLESS OF THE DIRECTION OF CHANGE

Change from Start to Finish of:	Amount of Change (thousand ohms) Total	Average	"t" Value	Significance Level
1. Task Under Low Illumination	1775	88.75	6.1376	1%
2. Task Under High Illumination	1587	79.35	3.6216	1%
Differences Between 1. and 2.	1604	80.20	19.2000	1%

In other words for each of the four physiological measurements taken--pulse, systolic blood pressure, diastolic blood pressure, and galvanic skin response--seven "t" tests were computed to determine the significance of the differences between measurements taken at different times. These comparisons were between base and the beginning of task, base and the end of task, and beginning and end of task for both levels of illumination. The seventh comparison was between the readings for the end of the task under one level of illumination as compared with the end of the task under the other level of illumination. For each of the physiological measures, in all seven of these comparisons when the direction of change was disregarded, the differences were statistically significant at the one per cent level of confidence. In addition, the comparison of the amount of change under the two levels of illumination from beginning to end of the task were statistically significant at the one per cent level of confidence. Note that there was no discrimination whatsoever between base and specific times during the task under low and high illumination. All were significantly different at the one per cent level of confidence.

Rate and Accuracy of the Task

The average rate and accuracy score for the task during the ten minute test period under the low illumination was 16.82 for the twenty subjects. For the high illumination, it was 15.22. See Table 17. These scores were not statistically significantly different from one another. It was somewhat surprising to find that the differences in the scores for the performance of a rather tedious writing task, that required accuracy of vision, were no greater than chance. One

TABLE 17

RATE AND ACCURACY SCORES DURING LOW AND DURING HIGH LEVELS OF ILLUMINATION AND THE DIFFERENCE BETWEEN THESE SCORES

Scores at End of:	Average Scores	"t" Value	Significance Level
1. Task Under Low Illumination	16.82		
2. Task Under High Illumination	15.22		
Differences Between 1. and 2.	1.60	1.4870	N. S.

might suppose that under the low illumination the subjects would not be able to perform the task either as rapidly or as accurately as under high illumination.

TABLE 18

AVERAGE DIFFERENCES BETWEEN TIMES PHYSIOLOGICAL MEASUREMENTS WERE TAKEN WHEN DIRECTION OF CHANGE IS CONSIDERED

Time of Physiological Measurements Taken	Pulse	Systolic Blood Pressure	Diastolic Blood Pressure	GSR	Rate and Accuracy of Task
Low Illumination					
1. Base With Beginning of Task	.04	3.5	3.10	-23.80	-
2. Base With End of Task	- .61	0	2.70	36.20	-
3. Beginning With End of Task	- .65	-3.5	- .40	60.00	-
High Illumination					
1. Base With Beginning of Task	2.04	-2.0	- .50	-76.65	-
2. Base With End of Task	1.99	-3.4	.65	-89.60	-
3. Beginning With End of Task	- .05	-1.4	- .15	-12.95	-
End of Task Under Low Illumination With End Under High Illumination	2.60	-3.4	-3.35	-125.80	1.60
Differences in the Changes Under Low and High Illumination From Beginning to End of the Task	- .60	-2.1	- .65	72.95	-

TABLE 19

STATISTICAL SIGNIFICANCE OF DIFFERENCES BETWEEN TASK SCORES AND BETWEEN TIMES PHYSIOLOGICAL MEASUREMENTS WERE TAKEN WHEN DIRECTION OF CHANGE IS CONSIDERED

Time of Physiological Measurements Taken	Pulse	Systolic Blood Pressure	Diastolic Blood Pressure	GSR	Rate and Accuracy of Task
Low Illumination					
1. Base With Beginning of Task	N. S.	5%	1%	N. S.	-
2. Base With End of Task	N. S.	N. S.	5%	N. S.	-
3. Beginning With End of Task	N. S.	N. S.	N. S.	5%	-
High Illumination					
1. Base With Beginning of Task	N. S.	1%	N. S.	1%	-
2. Base With End of Task	N. S.	5%	N. S.	5%	-
3. Beginning With End of Task	N. S.	N. S.	N. S.	N. S.	-
End of Task Under Low Illumination With End Under High Illumination	N. S.	5%	5%	1%	N. S.
Differences in the Changes Under Low and High Illumination From Beginning to End of the Task	N. S.	N. S.	N. S.	N. S.	-

TABLE 20

AVERAGE DIFFERENCES BETWEEN TIMES PHYSIOLOGICAL MEASUREMENTS WERE TAKEN WHEN DIRECTION OF CHANGE IS CONSIDERED

Time of Physiological Measurements Taken	Pulse	Systolic Blood Pressure	Diastolic Blood Pressure	GSR	Rate and Accuracy of Task
Low Illumination					
1. Base With Beginning of Task	4.87	5.59	3.98	133.8	-
2. Base With End of Task	6.07	4.68	4.41	147.6	-
3. Beginning With End of Task	2.75	5.70	4.60	88.75	-
High Illumination					
1. Base With Beginning of Task	5.53	6.49	3.40	119.5	-
2. Base With End of Task	6.04	4.65	3.57	132.4	-
3. Beginning With End of Task	3.35	4.00	3.75	79.35	-
End of Task Under Low Illumination With End Under High Illumination	4.60	6.10	4.95	181.45	-
Differences in the Changes Under Low and High Illumination From Beginning to End of the Task	2.60	5.40	3.85	80.20	-

significant. See Table 19. Under high illumination the systolic blood pressure averaged two points lower at the beginning of the task than at base and was significantly different. The indicated significant changes from base to the beginning of the task for the two blood pressures under low illumination and for the one under high illumination may indicate an immediate response of the body to the challenge or annoyance of a task to be performed.

Under low illumination the diastolic blood pressure was still significantly different from base at the end of the task; under high illumination the systolic blood pressure was still significantly different from base at the end of the task. Both of these significant differences may be a continuation of the significant differences from base that were present at the start of the task. Neither systolic nor diastolic blood pressures were significantly different from one another from the beginning to the end of the task.

At the end of the task both systolic and diastolic blood pressure measurements averaged more than three points less under high than under low levels of illumination and both were significantly different at the five per cent level. However, the differences between the changes during the task under low illumination and under high illumination were not statistically significant when the direction of change was considered.

Average differences between varying times blood pressures were measured, regardless of the direction of change are summarized in Table 20. When analyzed according to change, regardless of direction, all of the times the blood pressures were analyzed were significantly different from one another at the one per cent level.

During the task under low illumination, the galvanic skin responses increased an average of 60 thousand ohms. See Table 18. These differences were statistically significant at the five per cent level. See Table 19.

Under high illumination significant differences in galvanic skin responses were indicated between base and the beginning of the task, and between base and the end of the task. In addition the GSR's at the end of the task under low and under high illumination differed significantly from one another.

When the direction of change was not considered, the galvanic skin responses differed significantly from one another between each of the seven comparisons of times measured. See Table 20.

The task, copying names and addresses from a telephone directory, was performed with greater speed and accuracy under low than under high illumination. However the differences between the speed-accuracy scores for the two levels of illumination were not significant.

The hypotheses that there is no statistically significant difference in the pulse rates, in the systolic blood pressures, in the diastolic blood pressures, or in the galvanic skin responses of subjects performing the same task under test conditions providing five foot-candles and providing seventy foot-candles of illumination were rejected.

A similar hypothesis for pulse was also rejected when direction of change in pulse rates was not considered. However when the direction of change was considered the hypothesis regarding the differences in pulse rates was found tenable.

Further research to uncover objective measurements which might indicate human reactions to quantity or quality of light is recommended.

Further study in the establishment of base measurements is recommended. In addition the experimental type of research is recommended due to the proven value of such research, not only in results, but also in the training provided for students interested in careers of teaching or research.

CHAPTER V

SUMMARY AND CONCLUSIONS

Whether some common physiological measurements reflect human reactions to different lighting conditions was the question posed for this experimental study. Twenty students attending the Woman's College for the summer session of 1960 were the subjects.

The experimental design consisted of recording three physiological measurements--pulse rate, blood pressure, and galvanic skin response--at the beginning and end of a seeing task performed by subjects under each of the two levels of illumination--five foot-candles and seventy foot-candles. Thus the controlled variable was the intensity of well diffused light. The base for each subject for each physiological measurement was established on three consecutive days prior to the experiments.

A study of the differences between pulse rates at varying times indicated that they varied both in a plus and a minus direction from base and from one another. See Table 18. Statistically, the differences analyzed were not significant when the direction of change was considered. See Table 19. However when considering change regardless of direction, all comparisons of pulse rates between varying times taken were statistically significant at the one per cent level. See Table 20.

The blood pressure for both systolic and diastolic increased an average of about three points from base to beginning of task under low illumination. See Table 18. These differences were statistically

APPENDIX

TABLE 21

DATA REGARDING SUBJECTS

SUBJECT NUMBER	AGE (years)	HEIGHT (feet and inches)	WEIGHT (pounds)	GLASSES
1	40	5'5¼"	197	Yes
2	27	5'7 3/4"	260	No
3	45	5'6"	137	Yes
4	47	5'7¼"	125 3/4	Yes
5	54	5'1½"	137 3/4	Yes
6	42	5'5½"	134½	Yes
7	36	5' ½"	130½	No
8	39	5'3"	137	Yes
9	53	5'9"	145	Yes
10	40	5'3"	124	Yes
11	30	5'3½"	125½	No
12	37	5'6½"	138½	No
13	42	5' ½"	184½	Yes
14	55	5'5½"	139½	Yes
15	38	5'3 3/4"	179	No
16	40	5'1"	116	Yes
17	38	5'4¼"	103	Yes
18	45	5'3"	127	Yes
19	53	5' ½"	124	Yes
20	55	5'1"	155	Yes

TABLE 22

PULSE RATE READINGS FOR BASE AND AT THE BEGINNING AND AT THE END OF A WRITING TASK UNDER HIGH AND UNDER LOW LEVELS OF ILLUMINATION

Subject Number	Base Condition	Level of Illumination Five ftcs. Begin	 End	 Seventy ftcs. Begin	 End
	(I)	(II)	(III)	(IV)	(V)
1	77.3	80	86	88	86
2	100.0	98	94	90	92
3	68.6	66	67	62	72
4	79.1	82	88	88	92
5	82.0	90	88	86	90
6	83.1	72	70	78	72
7	82.3	84	84	82	82
8	96.4	102	102	96	98
9	72.4	70	72	75	74
10	82.2	80	82	80	83
11	82.6	84	80	92	90
12	73.5	90	90	84	86
13	82.8	82	78	88	80
14	78.7	70	64	78	72
15	89.1	92	88	93	92
16	75.1	68	68	78	84
17	72.2	72	76	72	70
18	82.6	90	86	92	86
19	83.8	78	76	92	92
20	95.4	90	88	86	86
Mean	81.96	82.00	81.35	84.00	83.95

TABLE 23

INDIVIDUAL CHANGES IN PULSE RATE FOR THE SUBJECTS BETWEEN TIMES MEASURED WHEN THE DIRECTION OF CHANGE IS CONSIDERED

Subject Number	I to II	I to III	I to IV	I to V	II to III	IV to V	III to V
1	2.7	8.7	10.7	8.7	6	-2	0
2	- 2.0	- 6.0	-10.0	- 8.0	-4	2	-2
3	- 2.6	- 1.6	- 6.6	3.4	1	10	5
4	2.9	8.9	8.9	12.9	6	4	4
5	8.0	6.0	4.0	8.0	-2	4	2
6	-11.1	-13.1	- 5.1	-11.1	-2	-6	2
7	1.7	1.7	- .3	- .3	0	0	-2
8	5.6	5.6	- .4	1.6	0	2	-4
9	- 2.4	- .4	2.6	1.6	2	-1	2
10	- 2.2	- .2	- 2.2	.8	2	3	1
11	1.4	- 2.6	9.4	7.4	-4	-2	10
12	16.5	16.5	10.5	12.5	0	2	-4
13	- .8	- 4.8	5.2	- 2.8	-4	-8	2
14	- 8.7	-14.7	- .7	- 6.7	-6	-6	8
15	2.9	- 1.1	3.9	2.9	-4	-1	4
16	- 7.1	- 7.1	2.9	8.9	0	6	16
17	- .2	3.8	- .2	- 2.2	4	-2	-6
18	7.4	3.4	9.4	3.4	-4	-6	0
19	- 5.8	- 7.8	8.2	8.2	-2	0	16
20	- 5.4	- 7.4	- 9.4	- 9.4	-2	0	-2

Key: I - Base

II - Beginning of the task under low illumination

III - End of the task under low illumination

IV - Beginning of the task under high illumination

V - End of the task under high illumination

TABLE 24

SYSTOLIC BLOOD PRESSURE READINGS AT THE BEGINNING AND AT THE END OF A WRITING TASK UNDER HIGH AND UNDER LOW LEVELS OF ILLUMINATION

Subject Number	Base Condition	Level of Illumination			
		Five ftcs.		Seventy ftcs.	
		Begin	End	Begin	End
	(I)	(II)	(III)	(IV)	(V)
1	125.5	120	114	120	120
2	130.2	136	114	110	118
3	101.7	108	100	104	104
4	127.1	130	130	124	126
5	107.3	110	108	104	100
6	122.2	128	118	108	108
7	94.2	96	96	94	97
8	103.1	106	104	97	98
9	103.7	104	100	108	96
10	101.3	100	98	90	98
11	96.7	114	108	110	98
12	96.6	104	96	102	98
13	120.8	134	136	126	120
14	105.7	116	106	104	108
15	113.3	112	116	112	110
16	98.6	92	102	89	89
17	94.4	102	100	94	94
18	105.4	108	100	106	106
19	104.0	108	106	96	94
20	112.2	106	112	126	114
Mean	108.2	111.7	108.2	106.2	104.8

TABLE 25

INDIVIDUAL CHANGES IN SYSTOLIC BLOOD PRESSURE FOR THE SUBJECTS BETWEEN TIMES MEASURED WITH REGARD TO DIRECTION OF CHANGE .

Subject Number	I to II	I to III	I to IV	I to V	II to III	IV to V	III to V
1	- 5.5	-11.5	- 5.5	- 5.5	- 6	0	6
2	5.8	-16.2	-20.2	-12.2	-22	8	4
3	6.3	- 1.7	2.3	2.3	- 8	0	4
4	2.9	2.9	- 3.1	- 1.1	0	2	- 4
5	2.7	.7	- 3.3	- 7.3	- 2	- 4	- 8
6	5.8	- 4.2	-14.2	-14.2	-10	0	-10
7	1.8	1.8	- .2	2.8	0	3	1
8	2.9	.9	- 6.1	- 5.1	- 2	1	- 6
9	.3	- 3.7	4.3	- 7.7	- 4	-12	- 4
10	- 1.3	- 3.3	-11.3	- 3.3	- 2	8	0
11	17.3	11.3	13.3	1.3	- 6	-12	-10
12	7.4	- .6	5.4	1.4	- 8	- 4	2
13	13.2	15.2	- 1.7	- .8	2	- 6	-16
14	10.3	.3	5.2	2.3	-10	4	2
15	- 1.3	2.7	- 1.3	- 3.3	4	- 2	- 6
16	- 6.6	3.4	- 9.6	- 9.6	10	0	-13
17	7.6	5.6	- .4	- .4	- 2	0	- 6
18	2.6	- 5.4	.6	.6	- 8	0	6
19	4.0	2.0	- 8.0	10.0	- 2	- 2	-12
20	- 6.2	- .2	13.8	1.8	6	-12	2

Key: I - Base

II - Beginning of the task under low illumination

III - End of the task under low illumination

IV - Beginning of the task under high illumination

V - End of the task under high illumination

TABLE 26

DIASTOLIC BLOOD PRESSURE READINGS AT THE BEGINNING AND AT THE END OF A WRITING TASK UNDER HIGH AND UNDER LOW LEVELS OF ILLUMINATION

Subject Number	Base Condition	Level of Illumination Five ftcs. Begin	End	Seventy ftcs. Begin	End
	(I)	(II)	(III)	(IV)	(V)
1	84.2	90	90	84	90
2	90.0	94	90	80	80
3	61.7	70	74	64	74
4	78.0	80	78	80	78
5	70.2	70	74	70	68
6	78.0	84	68	76	78
7	70.8	67	69	70	69
8	72.4	74	72	69	69
9	70.8	72	70	68	64
10	68.0	70	66	60	66
11	67.1	68	74	66	70
12	64.0	64	74	70	64
13	79.4	90	94	90	80
14	76.6	84	80	76	76
15	74.3	78	80	76	70
16	65.1	70	68	62	66
17	62.6	64	64	60	58
18	74.8	80	74	76	80
19	76.2	82	74	72	70
20	74.8	70	80	80	76
Mean	72.95	76.05	75.65	72.45	72.30

TABLE 27

INDIVIDUAL CHANGES IN DIASTOLIC BLOOD PRESSURE
FOR THE SUBJECTS BETWEEN TIMES MEASURED
WITH REGARD TO DIRECTION OF CHANGE

Subject Number	I to II	I to III	I to IV	I to V	II to III	IV to V	III to V
1	5.8	5.8	- .2	5.8	0	6	0
2	4.0	0	-10.0	-10.0	- 4	0	-10
3	8.3	12.3	2.3	12.3	4	10	0
4	2.0	0	2.0	0	- 2	- 2	0
5	- .2	3.8	- .2	- 2.2	4	- 2	- 6
6	6.0	-10.0	- 2.0	0	-16	2	10
7	- 3.8	- 1.8	- .8	- 1.8	2	- 1	0
8	1.6	- .4	- 3.4	- 3.4	- 2	0	- 3
9	1.2	- .8	- 2.8	- 6.8	- 2	- 4	- 6
10	2.0	2.0	- 8.0	- 2.0	- 4	6	0
11	.9	6.9	- 1.1	2.9	6	4	- 4
12	0	10.0	6.0	0	10	- 6	-10
13	10.6	14.6	10.6	.6	4	-10	-14
14	7.4	3.4	- .6	- .6	- 4	0	- 4
15	3.7	5.7	1.7	- 4.3	2	- 6	-10
16	4.9	2.9	- 3.1	9.0	- 2	4	- 2
17	1.4	1.4	- 2.6	- 4.6	0	- 2	- 6
18	5.2	- .8	1.2	5.2	- 6	4	6
19	5.8	- 2.2	- 4.2	- 6.2	- 8	- 2	- 4
20	- 4.8	5.2	5.2	1.2	10	- 4	- 4

Key: I - Base

II - Beginning of the task under low illumination

III - End of the task under low illumination

IV - Beginning of the task under high illumination

V - End of the task under high illumination

TABLE 28

GALVANIC SKIN RESPONSE READINGS AT THE BEGINNING AND AT THE END OF A WRITING TASK UNDER HIGH AND UNDER LOW LEVELS OF ILLUMINATION

Subject Number	Base Condition	Level of Illumination			
		Five ftcs.		Seventy ftcs.	
		Begin	End	Begin	End
	(I)	(II)	(III)	(IV)	(V)
1	148	315	233	277	201
2	323	392	567	382	544
3	361	188	217	239	226
4	251	136	92	147	159
5	301	183	104	125	82
6	317	281	364	168	157
7	424	321	536	322	260
8	262	186	168	222	205
9	295	566	637	535	150
10	734	354	538	423	498
11	289	191	123	183	150
12	285	218	305	218	296
13	337	197	332	125	83
14	483	690	685	399	285
15	360	412	694	338	264
16	349	192	253	202	492
17	247	253	362	225	173
18	314	629	578	215	260
19	314	200	256	135	137
20	231	246	305	212	211
Mean	331.25	307.45	367.45	254.60	241.65

TABLE 29

INDIVIDUAL CHANGES IN GALVANIC SKIN RESPONSE
FOR THE SUBJECTS BETWEEN TIMES MEASURED
WITH REGARD TO DIRECTION OF CHANGE

Subject Number	I to II	I to III	I to IV	I to V	II to III	IV to V	III to V
1	-167	- 84	-129	- 52	82	76	32
2	- 69	-244	- 59	-221	-175	-162	23
3	173	144	122	135	- 29	13	- 9
4	115	159	104	92	44	- 12	- 67
5	118	196	176	218	79	43	22
6	36	- 47	149	159	- 83	11	206
7	103	-111	102	164	-215	62	276
8	76	94	40	57	18	17	- 37
9	-271	-341	-240	145	- 71	385	487
10	380	196	311	235	-184	- 75	40
11	98	165	106	138	68	33	- 27
12	67	- 20	67	- 11	- 87	- 78	9
13	140	5	212	254	-135	42	249
14	-207	-201	84	198	5	114	400
15	- 52	-334	22	96	-282	74	430
16	157	95	147	-143	- 61	-290	-239
17	- 6	-115	22	73	-109	52	189
18	-315	-264	99	53	51	- 45	318
19	114	57	179	176	- 56	- 2	119
20	- 15	- 73	19	20	- 59	1	94

Key: I - Base

II - Beginning of the task under low illumination

III - End of the task under low illumination

IV - Beginning of the task under high illumination

V - End of the task under high illumination

TABLE 30

RATE AND ACCURACY SCORES OF A WRITING TASK UNDER HIGH AND LOW LEVELS OF ILLUMINATION AND THE DIFFERENCES BETWEEN THESE SCORES

Subject Number	Level of Illumination		
	Low Five ftcs.	High Seventy ftcs.	Difference
1			
2	29.50	28.66	0.89
3	11.00	13.33	-2.33
4	18.66	13.33	5.33
5	- 0.50	- 6.00	5.50
6	18.33	17.33	1.00
7	25.00	23.00	2.00
8	30.00	28.00	2.00
9	15.00	11.66	3.34
10	17.66	17.00	0.66
11	21.33	15.66	5.67
12	19.00	23.66	-4.66
13	10.00	9.66	0.34
14			
15	21.33	16.00	5.67
16	23.66	33.33	-9.67
17	19.00	19.33	-0.33
18	24.33	27.33	-3.00
19	18.00	4.50	13.50
20	14.66	8.66	6.00
Mean	16.82	15.22	1.60

LIST OF REFERENCES

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Books

1. Cannon, Walter S. Bodily Changes in Pain, Hunger, Fear, and Rage. Boston: Charles T. Branford Co., 1953.

2. Cotton, Harry. Principles of Illumination. New York: John Wiley & Sons, Inc., 1960.

3. Duffy, Elizabeth. Activation and Behavior. New York, London: John Wiley & Sons., Inc., 1962.

4. Kleitman, N. Sleep and Wakefulness. Chicago: University of Chicago Press, 1939.

5. McCurdy, James H. and Larson, Leonard. The Physiology of Exercise. Philadelphia: Lea and Febiger, 1939.

6. Rothman, Stephen. Physiology and Biochemistry of the Skin. Chicago: University of Chicago Press, 1954.

7. Selye, Hans. The Stress of Life. Toronto: McGraw-Hill Book Co., Inc., 1956.

8. Stedman's Medical Dictionary. Baltimore: The Williams and Wilkins Company, 1961.

9. Webster's New Collegiate Dictionary. Massachusetts: G. & C. Merriam Co., 1956.

Articles and Periodicals

10. Baker, L. M., and Taylor, W. M. The relationship under stress between changes in skin temperature, electrical skin resistance, and pulse rate. J. Exp. Psychol., 1954, 48, 361-366.

11. Blackwell, Richard H. Development and use of a quantitative method for specification of interior illumination levels on the basis of performance data. Illum. Eng., 1959, 6, 317-353.

12. Darrow, C. W. Sensory, secretory, and electrical changes in the skin following bodily excitation. J. Exp. Psychol., 1929, 10, 197-199.

13. Davis, R. C., Buchwald, A. M., and Frankmann, R. W. Autonomic and muscular responses, and their relationship to simple stimuli. Psychol. Monog., 1955, 69, No. 20 (Whole No. 405).

14. Edelberg, R., Greiner, T., and Burch, N. R. Role of a selective membrane in the galvanic skin reflex. Fed. Proc., 1957, 16, 33.

15. Elbel, E. R., and Ronkin, R. R. Palmer skin resistance as a measure of physical fitness. Amer. J. Physiol., 1946, 147, 1-12.

16. Engel, B. T. Some physiological correlates of hunger and pain. J. Exp. Psychol., 1959, 57, 389-396.

17. Grollman, Arthur. The effect of psychic disturbances on cardiac output, pulse, blood pressure, and oxygen consumption of man. Amer. J. Physiol., 1929, 89, 584-688.

18. Hemphill, R. E. Forms of behavior of the electrical resistance of the skin related to certain psychiatric and endocrine conditions. J. Ment. Sci., 1942, 88, 285-305.

19. Hennis, Gail, and Ulrich, Celeste. Study of psychic stress in freshman college women, Res. Quar., 1958, 29, 172-179.

20. Hickam, John B., Cargill, Walter, and Golden, Abner. Cardiovascular reactions to emotional stimuli: effect on the cardiac output, arteriovenous oxygen difference, arterial pressure, and peripheral resistance. J. Clin. Invest., 1948, 27, 290-298.

21. Lacey, J. I., Bateman, D. E., and VanLehn, R. Automatic response specificity--an experimental study. Psychosom. Med., 1953, 15, 8.

22. Landis, C. Electrical phenomena of the skin. Psychol. Bull., 1932, 29, 693-752.

23. Landis, C., and Gullette, R. Studies of emotional reactions. III. systolic blood pressure and inspiration-expiration ratios. J. Comp. Psychol., 1925, 5, 221-253.

24. Luckiesh, M., and Moss, F. K. A correlation between illumination intensity and nervous muscular tension resulting from visual effort. J. Exp. Psychol., 1933, 16, 540-555.

25. Malmo, R. B. Activation: a neurophysiological dimension. Psychol. Rev., 1959, 66, 367-386.

26. Malmo, R. B., and Shagass, C. Psychodynamic themes and localized muscular tension during psychotherapy. Psychosom. Med., 1954, 16, 295-313.

27. Maulsby, R. L., and Edelberg, R. The interrelationship between the galvanic skin reflex, basal resistance and temperature. J. Comp. Psychol., 1960, 54, 475-479.

28. McCleary, R. A. The nature of the galvanic skin response. Psychol. Bull., 1950, 47, 97-117.

29. McCormick, N. A., and Niven, J. I. Effect of varying intensities upon the performance of a motor task, Am. J. Physiol., 1944, 142, 328-349.

30. Richter, C. P. The significance of changes in the electrical resistance of the body during sleep. Proc. Nat. Acad. Sci., 1926, 12, 214-222.

31. Schneider, Robert A., and Zangari, Violet M. Variations in clotting time, relative viscosity, and other physiochemical properties of the blood accompanying physical and emotional stress in the normotensive and hypertensive subjects. Psychosom. Med., 1951, 13, 289-303.

32. Silverman, A. J., Cohen, S. I., and Shmavonian, B. M., Investigation of psychophysiologic relationships with skin resistant measures. J. Psychosom. Res., 1959, 4, 65-86.

33. Tinker, M. A., Effect of intensity of illumination upon speed of reading six-point italic print. Amer. J. Psychol., 1952, 65, 600-602.

34. Valk, J. M. Van Der, Blood pressure changes under emotional influences, in patients with essential hypertension, and control subjects. J. Psychosom. Res., 1957, 2, 134-146.

35. Why we are where we are . . . . lighting research. Illum. Eng., 1956, 1, 139-143.