Sponsoring Committee: Professor Florence S. Downs, Chairman
Associate Professor Gean M. Mathwig
Professor Morris A. Shamos

AN INVESTIGATION OF THE RELATIONSHIP BETWEEN LIGHTWAVES AND CARDIAC RATE

Tara A. Cortes

Submitted in partial fulfillment of the
requirements for the Doctor of Philosophy
degree in the School of Education,
Health, Nursing and Arts Professions
of New York University

1976

I hereby guarantee that no part of the dissertation which I have submitted for publication has been heretofore published and (or) copyrighted in the United States of America, except in the case of passages quoted from other published sources; that I am the sole author and proprietor of said dissertation; that the dissertation contains no matter which, if published, will be libelous or otherwise injurious, or infringe in any way the copyright of any other party; and that I will defend, indemnify and hold harmless New York University against all suits and proceedings which may be brought and against all claims which may be made against New York University by reason of the publication of said dissertation.

9/9/77 [redacted]

TABLE OF CONTENTS

An Abstract of

AN INVESTIGATION OF THE RELATIONSHIP BETWEEN LIGHTWAVES AND CARDIAC RATE

Tara A. Cortes

Submitted in partial fulfillment of the requirements for the Doctor of Philosophy degree in the School of Education, Health, Nursing and Arts Professions of New York University

September 1975

Sponsoring Committee: Professor Florence S. Downs, Chairman
Associate Professor Gean M. Mathwig
Professor Morris A. Shamos

[redacted]

The purpose of this study was to investigate the relationship between exposure to planned environmental visual stimulation, in the form of colored light, and heart-rate response. Man is characterized as a living open system in constant interaction with his environment. Both man and environment are comprised of electrical and magnetic energy fields, and change in the patterning of the energy waves of either gives rise to a simultaneous change in the other.

One modality through which the human organism and environment may interact is the energy pattern of the electromagnetic spectrum. Lacey has suggested that the autonomic nervous system, as reflected in the cardiac rate, acts as an index of response to environmental stimulation. Using this as a basis, it was hypothesized that cardiac rate would be related to the type of patterns of the electromagnetic spectrum to which the individual was exposed. Four hypotheses were tested.

1. Heart rate will increase from the onset of exposure to red light to the termination of exposure to red light.

2. Heart rate will increase from the onset of exposure to blue light to the termination of exposure to blue light.

3. Heart rate will be greater at the onset of exposure to red light than at the onset of exposure to blue light.

4. Heart rate will be greater at the termination of exposure to red light than at the termination of exposure to blue light.

The sample consisted of 103 females between the ages of 18 and 35 years. The cardiac rate was determined by using a cardiac monitor which was connected to each subject by paste-on electrodes attached to both forearms. The colored-light environment was provided by General Electric "monochromatic" fluorescent lights and carefully controlled for equal intensity under blue and red color conditions.

The subjects were seated in the laboratory, which provided a uniform white environment. A total of 40 minutes was spent in the laboratory during which time each subject was exposed to equal time intervals of different lights. Red and blue lights were randomly presented. Each of these color conditions was preceded by white light to determine the baseline heart rate.

The data were analyzed by t-tests with the level of significance set at .05. The analyses showed that only Hypothesis 2 was supported by the data.

Conclusions

1. Heart rate does not significantly change in subjects during exposure to an environment of red light.

2. Heart rate does significantly change in subjects during exposure to an environment of blue light.

3. There is no significant difference between heart rate at the onset of exposure to red light and at the onset of exposure to blue light.

4. There is no significant difference between heart rate at the termination of exposure to red light and at the termination of exposure to blue light.

5. The time of day during which a subject is exposed to environments of different colors is not related to change in heart rate during that exposure.

6. Heart rate is significantly greater when a subject is first introduced to a novel environment of colored light than when the environment is repeated with a different color.

7. There is no relation between a subject's color preference and his heart-rate change when exposed to that color.

ACKNOWLEDGMENTS

I wish to express my sincere gratitude to the members of my sponsoring committee: Dr. Florence S. Downs, Dr. Gean M. Mathwig, and Dr. Morris A. Shamos. Their guidance, support and encouragement throughout the various stages of this study are deeply appreciated.

A special thank you is expressed to Mildred Nelson, a fellow doctoral student, for her encouragement and support throughout our collection of data. She helped to make the process enjoyable.

Thanks are also given to Maureen O'Sullivan Heasley, Janet Quinn, Suzanne Gill, and Barbara Ellicson for their assistance in the collection of data; the Electronics for Medicine Company for kindly lending a cardiac monitor for use in this study; and to the 132 people who so willingly gave of their time to participate in this study.

To

My Husband--for his encouragement, support and assistance during the years of doctoral study

My Son-- whose imminent presence hastened the completion of this dissertation

My Parents--who gave me the background that made all this possible

LIST OF TABLES

CHAPTER I

THE PROBLEM

Introduction

Man and his environment interact continually through changing energy patterns. One of the energy patterns with which man interacts is light, or more specifically, the visible portion of the electromagnetic spectrum. This paper deals with changing patterns of man as seen through cardiac rate changes as the organism interacts with visible light of different colors.

General Statement

The purpose of this study was to investigate the relationship between exposure to planned environmental visual stimulation, in the form of colored light, and heart rate response.

Specific Problems

1. What is the difference in heart rate from the onset of exposure to red light to the termination of exposure to red light?

2. What is the difference in heart rate from the onset of exposure to blue light to the termination of exposure to blue light?

3. What is the difference in heart rate at the onset of exposure to red light and at the onset of exposure to blue light?

4. What is the difference in heart rate at the termination of exposure to red light and at the termination of exposure to blue light?

Definitions

Visual Stimulation.--The retinal response to a subject's visual field. For the purpose of this study it was the retinal response to red or blue colored light introduced into the subject's visual field.

Color.--A general name for the response of the retina of the eye and its attached nervous mechanisms to different wavelengths (colors) of light. This activity is in nearly every case in the normal individual a specific response to radiant energy of given wavelengths and intensities.[1]

Red Light.--Light in the wavelength region of approximately 720-620 millimicrons.[2] For the purpose of this study it was produced by a General Electric Fluorescent Bulb F40R with a peak wavelength of 630 millimicrons (see Appendix A).

Blue Light.--Light in the wavelength region of approximately 490 to 420 millimicrons.[3] For the purpose of this

---

[1] L. T. Troland, "Report of Committee on Colorimetry," Journal of the Optical Society of America, 6:528, 1922.

[2] C. Dull, H. C. Metcalfe, and W. Brooks, Modern Physics (New York: Henry Holt and Co., 1955), p. 440.

[3] Ibid., p. 439.

study it was produced by a General Electric Fluorescent Bulb F48T12/5PB/HO with a peak wavelength of 430 millimicrons (see Appendix B).

Heart-Rate Response.--The difference between the maximal or minimal (if the response is decreasing or decelerative) heart rate achieved during stimulation and the prestimulus heart rate.[1]

Delimitations

1. In an effort to eliminate changes in the heart rate due to cardiac pathology, this study was limited to subjects who are free from known cardiac pathology.

2. The age of the population ranged from 18 to 35 years. This age group should have assured the best possible color vision. According to Burnham, color vision in humans reaches a peak at 25 years of age and declines slowly until the age of 65 when the eyes become less sensitive to the shorter waves.[2]

3. To eliminate aberrations due to perceptual impairment, this study was limited to subjects with normal or corrected vision and with no history of color-blindness. All subjects were screened by the experimenter through the use

---

[1] E. Lipton, A. Steinschneider, and J. Richmond, "Autonomic Function in the Neonate: III: Methodological Considerations," Psychosomatic Medicine, 23:466-67, November-December 1961.

[2] R. Burnham, R. M. Hanes, and C. J. Bartleson, Color: A Guide to Basic Facts and Concepts (New York: John Wiley and Sons, Inc., 1963).

of the Ishihara Color-Blindness Chart.[1]

4. Because of visual effects experienced with certain drugs, the population for this study did not include any individuals who had a history of the use of drugs which influence the central nervous system. These drugs have been found to affect color discrimination. Aiba found that the neural threshold for red stimulation was higher when a depressant drug, amylobarbitone, was administered and was lower when a stimulant, dexamphetamine, was administered.[2] The ability of subjects to discriminate colors by hue was found impaired by Hollister who studied this effect using Mescaline, Lysergic Acid Diethylamide and Psilocybin.[3]

5. To decrease the probability of the occurrence of color-blindness, the study was limited to female subjects.[4]

Hypotheses

1. Heart rate will increase from the onset of exposure to red light to the termination of exposure to red light.

2. Heart rate will increase from the onset of exposure to blue light to the termination of exposure to blue light.

---

[1]S. Ishihara, Ishihara's Test for Color-Blindness (Tokyo: Kanehara Co., Ltd., 1973).

[2]S. Aiba, "The Effects of Stimulant and Depressant Drugs on the Bidwell PHenomena," British Journal of Psychology, 51:311, November 1960.

[3]L. E. Hollister and A. M. Hartman, "Mescaline, Lysergic Acid Diethylamide and Psilocybin: Comparison of Clinical Syndromes, Effects on Color Perception and Biochemical Measures," Comprehensive Psychiatry, 3:237-38, August 1962.

[4]George Burns, The Science of Genetics (New York: Macmillan & Co., 1972).

3. Heart rate will be greater at the onset of exposure to red light than at the onset of exposure to blue light.

4. Heart rate will be greater at the termination of exposure to red light than at the termination of exposure to blue light.

Significance of Study

Man lives in a world that provides multiple and continual changes in energy patterns. Man seldom, if ever, has the opportunity to differentiate how any one of these affects his own behavioral patterns. Hebb suggests that organisms regulate their activity so as to produce an optimal level of excitation.[1]

Studies on sensory deprivation and overload are abundant in their support of the theory that man requires an optimal level of environmental input. Berlyne claims that the organism will strive to keep arousal potential near its optimum, which will usually be some distance from the upper and lower extremes.[2] From a neurophysiological approach, Lindsley also supports the theory by proposing that either understimulation or overstimulation may disrupt the ascending reticular activating system with either condition disrupting

---

[1]Donald Hebb, "Drives and the Central Nervous System," Psychological Review, 62:243-54, 1955.

[2]D. E. Berlyne, Conflict, Arousal and Curiosity (New York: McGraw Hill Book Co., Inc., 1960).

cortical functioning.[1]

If man does indeed seek out those stimuli which provide optimal functioning of the organism, it is important to determine the way in which different patterns available are utilized. Rogers postulates that there is a rhythmic flow of energy waves which order and reorder the human field, and the nature, amount and speed of the wave patterns enhance or disrupt the essence of man's being.[2] Therefore, if the character of wave patterns that contribute to the optimal functioning of the organism can be determined, the environment might be made more optimal by manipulating the available patterning.

In the delivery of health care, professionals sometimes subject people to environments which are not conducive to therapeutic recovery, nor to self-maintenance. Examples of this can be seen in acute care areas, where patients are bombarded with monotonous and unmeaningful environmental patterns. If the behavioral responses to changing and specific environmental patterns can be determined, a more therapeutic environment could be provided.

This study attempted to measure the changes in attention and internal processing that took place as the subject

---

[1] D. B. Lindsley, "Common Factors in Sensory Deprivation, Sensory Distortion, and Sensory Overload," in Sensory Deprivation, ed. by Peter Solomon et al. (Cambridge: Harvard University Press, 1965).

[2] M. Rogers, The Theoretical Basis of Nursing (Philadelphia: F. A. Davis Co., 1970), p. 123.

was exposed to different visual patterning through the observation of heart rate.

CHAPTER II

RELATED LITERATURE

Theoretical Rationale

Man is characterized as a living open system in constant interaction with his environment. Both man and environment are comprised of electrical and magnetic energy fields, and change in the patterning of the energy waves of either gives rise to a simultaneous change in the other.[1]

One of the ways in which the individual perceives patterns of various wavelengths and frequencies is through the perceptual senses. Seldom is there conscious differentiation among these patterns to discern those which, if any, are most important to optimal functioning. Nor is there an awareness of the automatic regulation of interaction through augmentation or reduction of receptor sensitivity, or the active seeking out or avoidance of certain types of stimuli.[2]

This ability to seek out or avoid certain types of stimuli has been researched by Lacey and his co-workers. This work suggests that there are differences in the direction of autonomic response related to the conditions imposed

---

[1] M. Rogers, The Theoretical Basis of Nursing.

[2] A. Petrie, Individuality in Pain and Suffering (Chicago: University of Chicago Press, 1967).

upon experimental subjects and that these are associated with either acceptance or rejection of the conditions.[1] Lacey utilized cardiac rate as an index of behavioral change and related cardiac acceleration to situations in which the subject focused attention on self or on a situation involving mental concentration or cognitive processing such as in mathematical computations.[2] Lacey's experiments showed that cardiac deceleration accompanied and perhaps even facilitated the ease of environmental interaction, whereas cardiac acceleration accompanied or facilitated an avoidance of interaction with certain environmental patterns.

The ability of human beings to interact selectively with the environment is further supported by Berlyne and Hebb. Berlyne claims that arousal potential that deviates in either an upward or downward direction from optimal for the organism will be either drive-inducing or aversive.[3] Hebb supports this by stating that organisms act so as to produce an optimal level of excitation.[4] Within this framework the organism is seen as one that actively monitors the

---

[1]John Lacey et al., "The Visceral Level Situational Determinates and Behavioral Correlates of Autonomic Response Patterns," in Expression of the Emotions in Man, ed. by P. H. Knapp (New York: International Universities Press, 1963), pp. 161-96.

[2]Ibid.

[3]D. E. Berlyne, Conflict, Arousal and Curiosity.

[4]D. O. Hebb, "Drives and the Conceptual Nervous System."

quality and quantity of environmental interaction and chooses that sensory environment which is most conducive to its optimal well-being.

It appears, therefore, that if individuals are exposed to an environment that offers specific energy patterns, they will select whether or not to focus attention on these specific patterns. If the environment is pleasant and stimulating, attention will be directed to the available stimuli. As an index of this interaction, cardiac rate decelerates as the cognitive processes focus upon the available environment. If, however, the environment is found to be unpleasant or monotonous, attention will be withdrawn from the stimuli. This is facilitated by acceleration of cardiac rate, which simultaneously accompanies the avoidance of interaction as the individual focuses his cognitive processes on himself.

Color and Physiological Response

One modality through which the human organism and environment interact is the energy patterns of the electromagnetic spectrum. All energy waves of this spectrum are electromagnetic in nature and have the same speed in free space. They differ in wavelength and frequency only, which generally means that the sources which give rise to them are rather different.[1] Part of this spectrum is a band of visible light called color. Colors are visible light having different

---

[1]D. Halliday and R. Resnick, Physics: Parts I and II (New York: John Wiley and Sons, Inc., 1966), p. 993.

wavelengths and frequencies in the electromagnetic spectrum that excite responses in the human visual cortex. The rays of the electromagnetic spectrum possess usable energy and perform definite functions. Therefore, it follows that light, as part of the spectrum, possesses usable energy.

Color is an aspect of visual experience that may be referred to in scales of hue, saturation, and brightness, comprising a three-dimensional complex apart from the spatial and temporal aspects of visual experience.[1] Burnham and his co-workers define hue as the scale of perception of color range, saturation as the purity of the wavelength or color involved, and intensity as the range from dimness to brightness.[2] These three characteristics of color are significant in the differentiation of the spectrum and the impact of the color upon the eye and subsequent nervous, mental and muscular activity.

Red color is comprised of longer wavelengths and on the electromagnetic spectrum it lies in the lower-frequency region of visible light. Blue color, on the other hand, is comprised of shorter wavelengths and on the electromagnetic spectrum it lies in the higher-frequency region of visible light. Smets suggests that looking at saturated hues with longer wavelengths, such as red which is designated as a

---

[1]R. Burnham, R. Hanes, and C. J. Bartleson, Color: A Guide to Basic Facts and Concepts.

[2]Ibid.

warm color, and saturated hues with shorter wavelengths, such as blue which is designated as a cool color, has different physiological effects.[1] Warm colors bring out greater physiological and behavioral activity and are experienced as more "dynamic." Smets also refers to the difference in the spatial expression of red and blue color in that cold colors recede into space while warm colors tend to come forward.[2] This work gives evidence of the relationship that color has to the organism.

The work of Luckiesh and Pacini concurs with the above findings. These researchers proposed that the visible light of the electromagnetic spectrum effects man through visual sensation and provides sympathetic innervation which results in a sympathetic response. In the presence of red light, the individual may have a quickening of motor responses and find the interaction invigorating, while blue light is found to be soothing, calming and occasionally depressing.[3]

Féré found that muscular activity increased progressively upon exposure to successive colors in the order of white to blue to green to yellow to orange to red.[4] This supports the idea that the longer the wavelength (and hence

---

[1] G. Smets, "Time Expression of Red and Blue," <u>Perceptual and Motor Skills</u>, 29:511-14, 1969.

[2] Ibid.

[3] M. Luckiesh and A. J. Pacini, <u>Light and Health</u> (Baltimore: The Williams and Wilkens Co., 1926).

[4] C. Féré, <u>Sensation and Movement</u> (Paris: Alcan, 1900).

the lower the frequency) of the color, the higher the degree of muscular activity experienced by the exposed subject.

Gerard also studied the relationship of color to human behavior. He exposed subjects to colored light projected on a screen with a 100-watt bulb placed behind a red- or blue-colored filter. The color of the light was changed every fifteen minutes from white to red and white to blue. He found that anxiety was more pronounced under red light than under blue, and intermediate under white light. He also found that red light produced increased muscular tension, blood pressure and respiratory rate in the exposed subject, while blue light produced decreased muscular tension, blood pressure and respiratory rate in the subject.[1] However, Gerard did not find a significant difference in the cardiac rate as measured by an electrocardiogram during the subject's exposure to the different colors. This may be due to the fact that Gerard failed to control the intensity of the light under the different color conditions.

After investigating the influence of color on mental and motor efficiency of six subjects, Pressey reported no significant differences among red-, blue- and green-colored lights in their effects on pulse rate and respiration. However, he also failed to control the intensity of the lights used.

---

[1]R. M. Gerard, "The Differential Effects of Colored Lights on Psychophysical Functions" (unpublished Ph.D. dissertation, University of California, Los Angeles, 1957).

Other studies dealing with sympathetic responses to colored environments were done by Wilson and Nourse, who used the Galvanic Skin Response (GSR) as a measurement of the interaction. Wilson found a greater GSR to the red color (lower-frequency area of the spectrum)[1] while Nourse found the GSR was greater to violet than to green (violet having a higher frequency than green).[2] This discrepancy may have been due to the fact that the purity or saturation of violet is difficult to control since the color itself (when produced artificially) contains some red.

Heart Rate

Heart rate is one of the patterns that can be used to assess man's behavior as he interacts with his environment. Normally the heart rate is determined by the frequency with which the sino-atrial node generates the impulses which spread over the atrium and ultimately activate the heart.[3] The frequency of these impulses can be recorded through the use of an electrocardiogram.[4] For the purposes of this study,

---

[1] G. D. Wilson, "Arousal Properties of Red versus Green," Perceptual and Motor Skills, 23:947-49, 1966.

[2] J. C. Nourse and R. B. Welch, "Emotional Attributes of Color: A Comparison of Violet and Green," Perceptual and Motor Skills, 32:403-06, 1971.

[3] A. Guyton, Textbook of Medical Physiology (Philadelphia: W. B. Saunders, 1972), p. 196.
R. Rushmer, Cardiovascular Dynamics (Philadelphia: W. B. Saunders, 1965), p. 53.

[4] W. Gagnong, Review of Medical Physiology (Los Altos, California: Lange Medical Publications, 1973), p. 313.

the heart rate was determined by the ventricular contraction which is recorded on the electrocardiogram as a QRS complex.

As the environment changes there are simultaneous changes in the patterning of the heart rate. This type of cardiovascular activity was used by Lacey to describe the way in which an individual responds to certain types of environmental stimuli. More specifically, Lacey proposed that cardiovascular activity is directly related to facilitating the organism in the rejection or acceptance of its environment.[1] This concept can be related to evidence that afferent feedback from the baroreceptors of the aortic arch and carotid sinuses suppresses the ascending reticular activating system and inhibits cortical arousal.[2] Therefore, decreases in heart rate would decrease the afferent feedback system and facilitate the intake of environmental stimuli. Conversely, sympathetic-like changes in cardiovascular activity which speed up the cardiac rate result in an increased afferent feedback effect. In this case, the reticular activating system and cortex would be stimulated and the intake of environmental stimuli would be minimized.

In another study by Lacey, heart rate was monitored

---

[1] John Lacey, "Psychophysiological Approaches to the Evaluation of Psychotherapeutic Process and Outcome," in Research in Psychotherapy, ed. by E. A. Rubenstein and M. B. Parloff (Washington, D.C.: American Psychological Association, 1959).

[2] P. C. Dell, "Humoral Effects in the Brain Stem Reticular Formation," in Reticular Formation of the Brain, ed. by H. J. Jasper et al. (Boston: Little and Co., 1958).

from the time a warning signal was produced to the time the subject made a motor response.[1] It was found that the heart rate decreased progressively until a minimum was reached when the motor response occurred. Thus the heart rate decreased as attention was focused on the warning stimulus. According to Lacey's theory, the decrease in cardiac rate increases the organism's sensitivity to the environment.

An early study conducted by Obrist supported the above theory by finding evidence that the heart rate was modified cortically as would be expected if it played a role in monitoring perceptual events.[2] He found that all of the 28 subjects in the study demonstrated a heart-rate change when exposed to certain experiences such as looking at colored landscape slides, listening to semihumorous essays on the dangers of modern inventions, and finding hidden faces of people in a black-and-white drawing. Deceleration of heart rate occurred when signs of the barareceptor reflex inhibition were absent and the subject was attending to the stimulus. Heart-rate acceleration was found to occur in subjects who were not attending to the stimulus and later stated they were bored. London also found that an inadequate flow of environmental information resulted in increased

---

[1]John Lacey, "Somatic Response Patterning and Stress," in Psychological Stress, ed. by M. H. Appley and R. Trumball (New York: Appleton-Century-Crofts, 1967).

[2]Paul Obrist, "Cardiovascular Differentiation of Sensory Stimuli," Psychosomatic Medicine, 25:450-59, 1963.

sympathetic arousal.[1] The findings of both of these studies are supported by the fact that a monotonous environment decreases cortical arousal which leads to increased autonomic arousal.[2] A subject will therefore lose interest in a non-changing environment. This will stimulate autonomic arousal, which is accompanied by an increase in heart rate. As stated previously, cardiac acceleration inhibits cortical activity as the organism attempts to "reject" the environment. Therefore, the higher heart rate results in raised thresholds for environmental interaction and a less enduring impact.

Other work has been done on unchanging environments and their relationship to cortical behavior by Goldberger. Goldberger found that the cortex reflects its inherent activity by the hypersynchronous firing of neuronal cells.[3] Subjects in unchanging environments for up to eight hours were found to exhibit signs of disorganization, which is characteristic of inhibited cortical activity. When this occurred, Goldberger found that subjects had a shift of attention from an external focus to an internal focus as a determinate of cognition. In other words, conscious interaction with the

---

[1]H. London, D. Schubert, and D. Washburn, "Increase of Autonomic Arousal by Boredom," Journal of Abnormal Psychology, 80:29-36, August, 1972.

[2]D. E. Berlyne, "Arousal and Reinforcement," in Nebraska Symposium on Motivation, ed. by D. Levine (Lincoln: University of Nebraska Press, 1967).

[3]L. Goldberger, "The Role of Sensory Deprivation in the Hospital" (unpublished paper, New York University, 1968).

environment ceased and the subjects' cognitive processes became focused on their own thoughts. When there was a diminishing relevance of stimulus information to the environment, habituation occurred.[1] This may account for the shift in the direction of attention.

There are, according to research, four patterns of behavior used as the organism responds to environmental changes. The orienting response is an unconditioned motor, autonomic and central response elicited by any change in the environment, independent of the quality and occurring simultaneously with the change.[2] The adaptive response adjusts the organism to the new environment and is evoked when the environmental change is repeated.[3] The defense response occurs when the change is disturbing or painful.[4] The startle response is dependent upon the intensity of the environmental change reached within the first few milliseconds.[5] The primary physiological differences between the orienting response and the defense response is that the orienting

---

[1]E. H. van Olst, The Orienting Reflex (The Hague: Mouton, 1971), p. 150.

[2]F. Graham and R. Clifton, "Heart Rate Changes as a Component of the Orienting Response," Psychological Bulletin, 65:305-20, 1966.

[3]R. Lynn, Attention, Arousal and the Orientation Reaction (London: Pergamon Press, 1966).

[4]Ibid.

[5]F. Graham and R. Clifton, "Heart Rate Changes as a Component of the Orienting Response."

response is accompanied by peripheral vasoconstriction and cephalic vasodilation, while the defense response includes peripheral and cephalic vasoconstriction. Therefore, if the defense response, which occurs when the organism is exposed to an undesirable environment, is accompanied by the vasoconstriction of peripheral and cephalic areas, the corresponding autonomic activity of heart-rate acceleration should occur.

Graham and Clifton investigated the relationship of heart rate and autonomic responses.[1] They hypothesized that heart-rate acceleration was a part of the defense response and deceleration a part of the orienting response. Their study showed that heart-rate acceleration is a component of the defense response which limits the interaction of the organism and the environment. Heart-rate deceleration was shown to be a major component of the orientation reflex with rapid habituation. This study reinforces Lacey's theory that cardiac acceleration inhibits cortical activity as the organism attempts to "reject" its environment.

According to Spence, if heart-rate deceleration is a type of orienting response, then it should: 1) indicate the point in time when a stimulus is first noticed, and 2) enhance sensitivity to the stimulus input.[2] The first function is the one discussed above as being associated with the orienting

---

[1]Ibid.

[2]D. Spence, M. Lugo, and R. Youdin, "Cardiac Correlates of Cognitive Processing" (unpublished paper, Research Center for Mental Health, New York University).

response and the second function is supported by Sokolov, who postulated that one of the functions of heart-rate deceleration is to increase the organism's sensitivity of the perceptual system.[1]

These functions of heart rate have been supported by Lewis, Kagen, Campbell and Kalafat. This group studied heart-rate deceleration in infants and found that decleration accompanied attention to a flashing light pattern and that the magnitude of deceleration correlated directly with the duration of fixation on the stimulus.[2] The researchers concluded that the "taking in" of the environment was accompanied and facilitated by heart-rate deceleration.

Elliott raises an important question in his discussion of heart-rate changes when he compares the afferent feedback model endorsed by Lacey and the cardiac-somatic model.[3] The cardiac-somatic model, as set forth by Elliott, conceptualizes heart-rate change as one of many responses that make up the outcome of the interaction of the organism with the environment. Heart rate would therefore reflect a behavioral pattern of the total organism, and cardiac-rate change could

---

[1]E. N. Sokolov, Perception and the Conditioned Reflex (New York: Macmillan and Co., 1963).

[2]M. Lewis, J. Kagen, H. Campbell, and J. Kalafat, "The Cardiac Response as a Correlate of Attention in Infants," Child Development, 37:63-71, 1966.

[3]R. Elliott, "The Significance of Heart Rate for Behavior," Journal of Personality and Social Psychology, 22: 398-419, 1972.

be considered purely a part of or the result of another behavioral pattern. The afferent feedback model projects that the heart works in ways to facilitate the interaction (acceptance or rejection) of the environment. The cardiac-somatic model differs, therefore, from the afferent feedback model in that heart-rate deceleration may occur as a subsidiary response to another response, not purely as an environmental facilitator.

Elliott was not able to support Lacey's theory in a study he conducted with 64 subjects. The subjects were asked to perform three tasks: reading the names of colors, naming the hues of different colors, and naming the hue, not the word, in which a color word was printed. To control for habituation, the order of performance of the task was reversed for half of the subjects. Elliott hypothesized that the final task described would be accompanied by cardiac acceleration due to the difficulty of the task and subsequent accompanying stress as the subject "rejected" the task at hand. To the contrary, Elliott found that there was a deceleration of heart rate when this task was performed.[1] The results of this study point out a further problem with Lacey's theory. The terms "acceptance," "rejection," "pleasant environment" and "unpleasant environment" can be subjective and variable.

---

[1]R. Elliott, "Tonic Heart Rate: Experiments on Effects of Collative Variables Lead to a Hypothesis about Motivational Significance," Journal of Personality and Social Psychology, 12:211-28, 1969.

Campos and Johnson also failed to support Lacey's theory when they performed an experiment in which a group of subjects was shown a series of seven colored slides.[1] The only significant heart-rate deceleration occurred when the scene of a highway accident was projected--a scene that the subjects rated as most unpleasant. The same study did, however, show some support for Lacey's theory in that the subjects demonstrated a deceleration in heart rate when they were listening to instructions to describe the viewed scenes.

Obrist offered support for Lacey's afferent feedback model in his earlier work, but later work supported the cardiac-somatic model.[2] In this research he presented evidence that cardiac deceleration effects, such as are experienced during attention to tasks, are accompanied by a decrease in irrelevant motor-skeletal activity. There is thus a concomitant slowing of the heart rate.

Studies concerning the way in which the organism interacts with the environment are varied and describe changes in behavioral patterns in different ways. Conclusive evidence is still lacking. Lacey postulates that the best way to obtain this conclusive evidence is through the study of situational-type experiences which are in keeping with the

---

[1]J. J. Campos and H. J. Johnson, "The Effects of Verbalization Instructions and Visual Attention on Heart Rate and Skin Conductance," Psychophysiology, 2:305-10, 1966.

[2]P. Obrist, "Cardiovascular Differentiation of Sensory Stimuli."

integrity of an intact organism without surgical mutilation, anesthesia or drugs.[1]

---

[1] J. Lacey, "Psychophysiological Approaches to the Evaluation of Psychotherapeutic Process and Outcome," pp. 30-31.

CHAPTER III

METHODOLOGY

Sample

The experimental sample population consisted of 103 females who were exposed to environments of changing colors. This number of subjects allowed for an alpha level of .05 and a power of .85 for a minimum difference between means of one-half standard deviation.[1]

A group of 29 females was exposed for the same amount of time to an environment consisting of white light only. Measurements from this group were used to ensure that any changes in cardiac rate in the experimental group were indeed due to the color changes in the environment and were not a function of the study environment itself. This group also served to point out any inadequacies in the experimental procedure or instrumentation.

Instrument

The instrument used to measure heart rate was an ER-1 rate meter. This is a portable cardiac monitor which provides readings from 10 to 200 beats per minute with an accuracy of better than 2%. The monitor was connected to the

---

[1] J. Cohen, Statistical Power Analysis for the Behavioral Sciences (New York: Academic Press, 1969), pp. 266-69.

subject by using electrodes which could be attached to either the arms or chest and allowed free movement. A volume-controlled audible tone "beeper" and a built-in "flash" indicator monitored the heart rate, which was indicated on a meter scale. Because of the relatively poor precision of this meter scale (±2%), the pulse rate was counted from the number of beeps heard during one minute. Specifications for the instrument are given in Appendix C.

Procedure

The laboratory setting was a 19'5" X 12'6" room. The walls and the ceiling of the room are off-white and the floor was covered with a white sheet to provide maximum reflection. Off-white produces 78-80% reflection and white produces 80% reflection.[1] There was a 9'8" X 3'9" one-way window through which the subject could be observed. The room was nonsound-proof, but it was located in an area of relative quietness removed from voices, traffic and construction noises.

The lighting in the room was produced by General Electric fluorescent bulbs. Red light was produced by General Electric Fluorescent Bulb F40R, which has a peak wavelength of approximately 630 millimicrons. Blue light was produced by General Electric Fluorescent Bulb F48T12/5PB/HO, which has a peak wavelength of approximately 430 millimicrons.

---

[1] Illuminating Engineering Society, Artificial Light and Its Application in the Home (New York: McGraw-Hill, Inc., 1932).

White light was produced by General Electric Fluorescent Bulb C50, a Chromaline lamp which "approximates a noon sky plus sunlight" (see Appendix D).

In order to control the brightness of the bulbs and ensure equal illumination under all three conditions it was necessary to have the same number of lumens per unit area (illuminance) for each of the three colors used. A lumen is defined as the amount of light emitted in a unit solid angle by a light source of one candle intensity.[1] Since each color of fluorescent bulb emitted a different number of lumens, the bulbs were used in the proportion of 4 red bulbs to 3 blue bulbs to 1 white bulb to provide approximately 8 footcandles under incedent or direct light and 6 footcandles under reflected light. This is the number of lights that were used in fixtures suspended from the ceiling of the laboratory. This distribution and position ensured an equal illumination from the sources of the three colors at the point where the subjects were seated. This illumination was verified by a light meter (see Appendix E).

Volunteer subjects were asked to fill out a personal data sheet. This included information about the subject's availability, her age, address, telephone number, physical and mental health (past and current), drug history, and meditation or biofeedback-training history (see Appendix F).

The subject was notified of her scheduled time for

---

[1]Ibid.

the experiment one week prior to the appointment, and an instruction sheet was mailed to her (see Appendix G). When the subject arrived for the experiment, ten minutes were allowed for the experimenter to orient and prepare the subject. During this time an assessment of her physiological state was made. This included taking the pulse rate, testing for color-blindness and noting any mannerisms which might suggest that the subject was under the influence of any drug that might have an effect on her heart rate.

The subject was told that during the experimental period she would be seated in a chair and would have paste-on electrodes attached to her forearms which would continually monitor heart rate. In order to prevent anxiety about what was to happen, with subsequent altering of the heart rate, the subject was told that she would be in an environment in which the color of the lights would be changed after certain periods of time. The subject was assured that there would be no other changes in the environment during the 40 minutes she would be in the laboratory. She was told that if at any time she wished to terminate the experiment, she could do so (see Appendix H). The subject was asked to empty her bladder before starting the experiment.

Subjects in the pretest group underwent the same preparation but were told that they would be exposed only to an unchanging environment of white light during the 40 minutes in the laboratory.

Once the subject entered the laboratory the electrodes were attached to her forearms and the color of the environment was changed by light switches located outside the laboratory. In all cases the primary 10-minute exposure was to white light in order for the subject to adjust to the environment. The environment was then changed to red or blue lighting. The color of the environment presented first in the sequence was randomized between red and blue so that 49 subjects were exposed to red light first and 54 subjects to blue light first. This ensured that any changes in heart rate were not due to the particular sequence of colors or to the amount of time in the laboratory. The heart rate was measured during the first minute of exposure to the colored environment. This measurement determined the individual's initial response to the color change since stimulation by a steady light source is normally required for about .05 to .2 seconds to permit a color response in humans to build up to maximum strength.[1] The second measurement of heart rate was taken during the sixth minute of exposure to the colored environment. It has been found that humans react synergistically within 5 minutes after being exposed to any color.[2] This measurement determined the level of "rejection" or "acceptance" of the environment as previously discussed in

---

[1] R. Burnham et al., Color: A Guide to Basic Facts and Concepts, p. 65.

[2] Corrine Heline, Healing and Regeneration through Color (Santa Barbara, California: J. F. Rowney Press, 1972).

Lacey's theory. The subject was then returned to white light for 10 minutes to readjust to the surrounding environment and was then returned to an environment of the alternate color. The same procedure was repeated and the heart rate measured during the first and sixth minutes of exposure. The subject was then taken out of the laboratory for a period of debriefing.

This research was conducted in cooperation with another investigator studying the relationship of time estimation and light waves.[1]

The sequence of the experimental procedure is shown below:

EXPERIMENTAL PROCEDURE

Environment	Sequence in Minutes	Activity
Pre-Experimental	0-9	orientation
		explanation of equipment
		check pulse
		check color vision
		observe subject
		check temperature
White Light	10-15	start experiment
	16	measure pulse for 60 secs.
	18	time estimation for 40 secs.
Red Light	20	measure pulse for 60 secs.
(Blue Light)	26	measure pulse for 60 secs.
	28	time estimation for 40 secs.
White Light	30	measure pulse for 60 secs.
	36	measure pulse for 60 secs.
	38	time estimation for 40 secs.

[1] Mildred Nelson, "An Investigation of the Relationship between Light Waves and Time Estimation" (unpublished outline of a proposed thesis, New York University, 1975).

Blue Light	40	measure pulse for 60 secs.
(Red Light)	46	measure pulse for 60 secs.
	48	time estimation for 40 secs.
White Light	50	measure pulse for 60 secs.
Post-Experimental	51-60	debriefing

CHAPTER IV

ANALYSIS OF DATA

In order to analyze the heart-rate response as the difference between the maximal or minimal heart rate achieved during stimulation and the pre-stimulus heart rate, the following paradigm was set up:

R_o = pulse rate at onset of exposure to red light (1st minute of exposure)

R_t = pulse rate at termination of exposure to red light (6th minute of exposure)

B_o = pulse rate at onset of exposure to blue light (1st minute of exposure)

B_t = pulse rate at termination of exposure to blue light (6th minute of exposure)

W_{16} = pulse rate at minute 16 of experiment (pre-stimulus heart rate)

W_{36} = pulse rate at minute 36 of experiment (pre-stimulus heart rate)

Using these readings, the following relative differences were calculated for each subject:[1]

$$\Delta_1 = \frac{R_o - W_{16}}{W_{16}} \quad \text{or} \quad \frac{R_o - W_{36}}{W_{36}}$$

$$\Delta_2 = \frac{R_t - W_{16}}{W_{16}} \quad \text{or} \quad \frac{R_t - W_{36}}{W_{36}}$$

---

[1]The use of W_{16} or W_{36} as the pre-stimulus heart rate in each formula was dependent upon whether red or blue was the first experimental color condition.

$$\Delta_3 = \frac{B_o - W_{16}}{W_{16}} \quad \text{or} \quad \frac{B_o - W_{36}}{W_{36}}$$

$$\Delta_4 = \frac{B_t - W_{16}}{W_{16}} \quad \text{or} \quad \frac{B_t - W_{36}}{W_{36}}$$

Since physiological changes are more meaningful when the inferences are based on the relative change from some original point, the mean scores of heart-rate change are reported as relative changes.

Table I presents the means and standard deviations of each of the relative differences in heart rate as calculated from the difference between the heart rate during the pre-stimulus period and the heart rate during the onset or termination of the experimental condition.

The following results of the experiment are presented in the order of the hypotheses tested.

Hypothesis 1

Heart rate will increase from the onset of exposure to red light to the termination of exposure to red light.

Table II presents the results of the matched t-tests for which the mean relative differences for pulse rates from the onset of exposure to the termination of exposure to red light were analyzed. These relative differences were calculated by subtracting the pulse rate during the sixth minute of the preceding white-light condition from the pulse rate during the first minute of exposure to red light and from

TABLE I

Means, Standard Deviations and Significance of the Relative Heart-Rate Changes from the Pre-Stimulus Rate to the Experimental Rate Grouped by Color Presented First in Experiment.

Relative Heart-Rate Changes	Mean	S.D.	+
$\Delta_1 \left(\frac{R_o - W_{16}}{W_{16}} \right)$	-0.007	0.061	1.166
Red First	-0.019	0.046	2.87**
Blue First	0.003	0.070	.333
$\Delta_2 \left(\frac{R_t - W_{16}}{W_{16}} \right)$	-0.000	0.062	0
Red First	-0.003	0.063	.333
Blue First	0.003	0.062	.357
$\Delta_3 \left(\frac{B_o - W_{36}}{W_{36}} \right)$	-0.020	0.048	3.33***
Red First	-0.012	0.048	1.73*
Blue First	-0.027	0.048	4.15***
$\Delta_4 \left(\frac{B_t - W_{36}}{W_{36}} \right)$	0.007	0.063	1.166
Red First	0.002	0.052	.270
Blue First	0.012	0.071	1.237

Δ_1 = minute 1 of exposure to red

Δ_2 = minute 8 of exposure to red

Δ_3 = minute 1 of exposure to blue

Δ_4 = minute 8 of exposure to blue

*significant at the .05 level

**significant at the .01 level

***significant at the .001 level

TABLE II

Mean Relative Difference of Heart-Rate Change from the Onset of Exposure to the Termination of Exposure to Red Light

Mean	S.D.	N	t	p
0.007	0.064	103	1.148	NS

the pulse rate during the sixth minute of exposure to red light. This difference was then divided by the pulse rate during the sixth minute of the preceding white-light condition. The formula used was $\bar{\Delta}_2 = \bar{\Delta}_1$

$$\text{or } \frac{R_t - W_{16}}{W_{16}} = \frac{R_o - W_{16}}{W_{16}}.$$

The mean relative difference was .007 and the standard deviation was .064. The critical t-value was 1.662 and the obtained value was 1.148, which was not significant at the .05 level. Therefore, Hypothesis 1 was not accepted.

Hypothesis 2

Heart rate will increase from the onset of exposure to blue light to the termination of exposure to blue light.

Table III presents the results of the matched t-test for which mean relative differences in pulse rates from the onset of exposure to blue light to the termination of exposure to blue light were analyzed. These relative differences were calculated by subtracting the pulse rate during the sixth minute of the preceding white-light condition from the

TABLE III

Mean Relative Difference of Heart-Rate Change from the Onset of Exposure to the Termination of Exposure to Blue Light

Mean	S.D.	N	t	p
0.027	0.058	103	4.764*	.001

*significant at the .001 level

pulse rate during the first minute of exposure to blue light and from the pulse rate during the sixth minute of exposure to blue light. These differences were then divided by the pulse rate during the sixth minute of the preceding white-light condition. The formula used was $\bar{\Delta}_4 = \bar{\Delta}_3$

$$\text{or} \quad \frac{B_t - W_{36}}{W_{36}} = \frac{B_o - W_{36}}{W_{36}}.$$

The mean relative difference was 0.027 and the standard deviation was .058. The critical t-value was 1.662 and the obtained t-value was 4.764, which was significant at the .001 level. Therefore, Hypothesis 2 was accepted.

Hypothesis 3

Heart rate will be greater at the onset of exposure to red light than at the onset of exposure to blue light.

Table IV presents the results of the matched t-test for which the mean relative pulse-rate changes at the onset of exposure to red and blue light were analyzed. The relative change in heart rate at the onset of exposure to red light was calculated by subtracting the heart rate during

TABLE IV

Mean Relative Difference between Heart-Rate Change at the Onset of Exposure to Red Light and the Onset of Exposure to Blue Light

Mean	S.D.	N	t	p
-.013	0.083	103	-1.571	NS

the sixth minute of the preceding white-light condition from the heart rate during the first minute of exposure to red light. This difference was then divided by the heart rate during the sixth minute of the preceding white-light condition. The formula for this calculation is

$$\frac{R_O - W_{16}}{W_{16}}.$$

The relative change in heart rate at the onset of exposure to blue light was calculated by subtracting the heart rate during the sixth minute of the preceding white-light condition from the heart rate during the first minute of exposure to blue light. This difference was then divided by the pulse rate during the sixth minute of the preceding white-light condition. This calculation is shown by the formula

$$\frac{B_O - W_{36}}{W_{36}}.$$

The mean relative difference between these changes was -0.013 and the standard deviation was 0.083. The critical t-value was 1.662 and the obtained t-value was -1.571, which was not significant at the .05 level. Therefore, Hypothesis 3 was not accepted.

Hypothesis 4

Heart rate will be greater at the termination of exposure to red light than at the termination of exposure to blue light.

Table V presents the results of the matched t-test for which the mean relative pulse-rate changes at the termination of exposures to red and blue light were analyzed. The relative change in heart rate at the termination of exposure to red light was calculated by subtracting the heart rate during the sixth minute of the preceding white-light condition from the heart rate during the sixth minute of exposure to red light and dividing this difference by the pulse rate during the sixth minute of the preceding white-light condition. This calculation is shown as

$$\frac{R_t - W_{16}}{W_{16}}.$$

The relative change in heart rate at the termination of exposure to blue light was calculated by subtracting the heart rate during the sixth minute of the preceding white-light condition from the heart rate during the sixth minute of exposure to blue light. This difference was then divided by the heart rate during the sixth minute of the preceding white-

TABLE V

Mean Relative Difference between Heart-Rate Change at the Termination of Exposure to Red Light and the Termination of Exposure to Blue Light

Mean	S.D.	N	t	p
0.007	0.097	103	0.755	NS

light condition. The formula for this is

$$\frac{B_t - W_{36}}{W_{36}}.$$

The mean relative difference was .007 and the standard deviation was .097. The critical t-value was 1.662 and the obtained t-value was 0.755, which was not significant at the .05 level. Therefore, Hypothesis 4 was not accepted.

Matched t-tests were also done on the 29 subjects who were exposed for the same amount of time to an environment consisting of white light only. The same statistical procedure as for the experimental color conditions was used. The calculations were based on readings taken during the same time periods as were done with the colored-light conditions. None of the results of these tests were significant. These data are shown in Table VI.

Additional Analyses

An additional matched t-test was done to compare the change that occurred in the heart rate during the red-light exposure and during the blue-light exposure. The change in

TABLE VI

Mean Relative Differences of Heart-Rate Change during White-Light Exposure

	Mean	S.D.	N	t	p
$\Delta_1\Delta_2$	0.001	0.044	29	1.257	NS
$\Delta_3\Delta_4$	-0.003	0.045	29	-0.346	NS
$\Delta_1\Delta_3$	0.019	0.073	29	1.352	NS
$\Delta_2\Delta_4$	0.005	0.090	29	0.309	NS

$\Delta_1\Delta_2$ = relative difference in heart rate from minute 11 to minute 18 of white light
$\Delta_3\Delta_4$ = relative difference in heart rate from minute 31 to minute 38 of white light
$\Delta_1\Delta_3$ = relative difference in heart rate between minute 11 and minute 31 of white light
$\Delta_2\Delta_4$ = relative difference in heart rate between minute 18 and minute 38 of white light

heart rate under the blue light exposure was again found to be significantly greater at the .05 level than the change in heart rate under red light. The mean relative difference between the two conditions was -.020 and standard deviation was .089. The critical t-value was 1.662 and the obtained t-value was -2.82, which is significant at the .05 level. The results are shown in Table VII.

A t-test was done to test the difference between changes in heart rate due to colored light and the time of day, i.e., either A.M. or P.M. The relationship between the time of presentation and cardiac-rate change due to red or

TABLE VII

Mean Relative Difference of Heart-Rate Change during Exposure to Red Light and to Blue Light

Mean	S.D.	N	t	p
-0.020	0.089	103	-2.82*	.025

*significant at the .05 level

blue color was not found significant at the .05 level. These results are shown in Table VIII.

TABLE VIII

Mean Relative Heart-Rate Change for A.M. and P.M. Groups

Mean	S.D.	N	t	p
-0.020	0.089	103	-0.991	NS

A two-way analysis of variance was used to test the relationship between the order of presentation of the experimental-light condition and the cardiac rate. Table IX shows the source table for the analysis. These data show that regardless of the color presented first, the heart-rate response was significantly higher ($p < .05$) than when either color was presented second.

An analysis of variance was done to test the heart-rate response to the red- and blue-light conditions and color preference of individuals. The results were not significant at the .05 level. The data are shown in Table X.

TABLE IX

Analysis of Variance for Relative Heart-Rate Change and Colored-Light Condition Presented First

Source	Sum of Squares	DF	Mean Square	F
First Color	.001	1	.001	.297
Between	.354	101	.004	-
Color	.019	1	.019	4.907*
First Color X Color	.022	1	.022	5.622*
Within	.389	101	.004	-

*significant at the .05 level

TABLE X

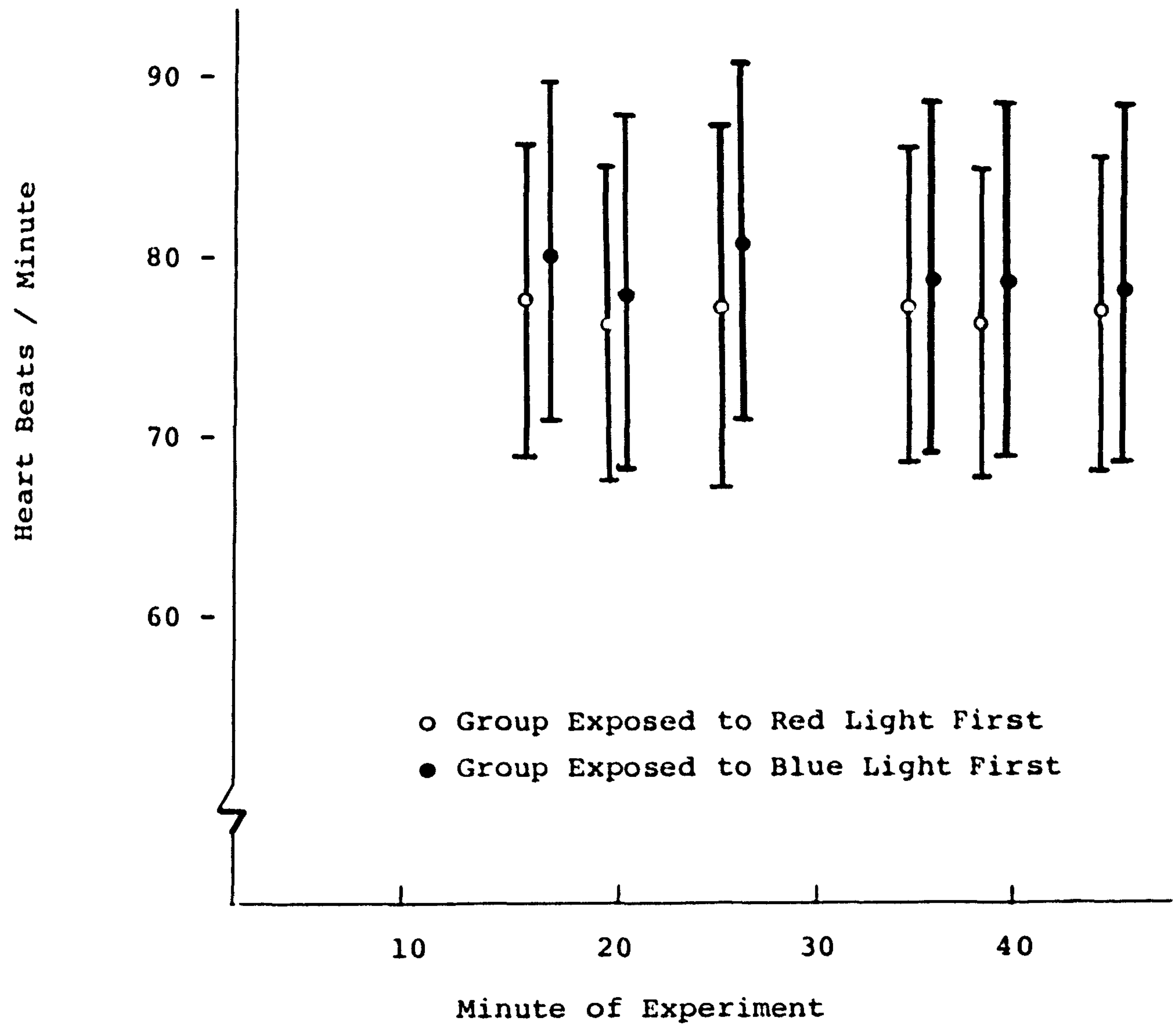
Analysis of Variance for Relative Heart-Rate Change during Red and Blue Light and Color Preference of Subjects

Source	Sum of Squares	DF	Mean Square	F
Color Preference	0.002	3	0.001	0.204
Between	0.325	94	0.003	-
Color	0.019	1	0.019	5.903*
Color Preference X Color	0.024	3	0.008	2.531
Within	0.302	94	0.003	-

*significant at the .05 level

TABLE XI

Graphical Representation of Final Data



Notes: 1. Vertical lines represent standard deviation.

2. Each pair of points have the same abscissa, but are shown slightly displaced for greater clarity.

CHAPTER V

DISCUSSION

The purpose of this study was to determine if there was a demonstrable difference in the heart rate of young females when exposed to planned environmental visual stimulation in the form of colored light.

The theoretical basis of the study was derived from the work done by Lacey and his co-workers which suggested that autonomic response in experimental subjects was related to the environmental conditions to which these subjects were exposed. The studies indicated that cardiac acceleration accompanied situations involving mental concentration or cognitive processing, while cardiac deceleration was related to situations in which the subject was more involved with his environment and focusing his attention on it.[1]

Hypothesis 1 stated that the heart rate would increase from the onset of exposure to the termination of exposure to red light. The experimental results did not support this hypothesis at the .05 level. The mean relative change in heart rate during this period of time was .007.

In accordance with Lacey's theory it was hypothesized

---

[1]J. Lacey et al., "The Visceral Level Situational Determinates and Behavioral Correlates of Autonomic Response Patterns."

that the subject would initially respond to the environment and this response, the orienting response, would be accompanied by a decrease in heart rate. This initial response would then be followed by habituation during which the subject would tire of the environment, "reject the environment," and focus on internal cognitive processing which would be accompanied by an increase in heart rate. Therefore, Lacey's theory is not supported under this condition. If, however, the initial orienting response is regarded by itself (Δ_1), it is seen that there is a mean relative decrease in heart rate of -.019 when red was the first experimental colored-light condition in the randomized sequence ($p < .01$). Since Lacey theorized that cardiac deceleration accompanies "acceptance" of the environment, these findings suggest that the subjects actively responded to red light as the first color condition.

Hypothesis 2 stated that the heart rate would increase from the onset of exposure to the termination of exposure to blue light. The experimental results supported this hypothesis at the .001 level of significance with a mean relative change of heart rate of .027. These findings support Lacey's theory in that the subjects, when exposed to an environment which was not conducive to their functioning, "rejected" this environment and this rejection was accompanied by cardiac acceleration.

It is interesting to note, however, that the initial response, or orienting response, to this environment was accompanied by a significant decrease in cardiac rate. The mean relative change in heart rate during the first minute of exposure to blue-colored light (Δ_3) was -.027 ($p < .001$) when blue was the first experimental colored-light condition in the randomized sequence and -.012 ($p < .05$) when it was second in the sequence. This decrease in heart rate shown by subjects at the onset of exposure to blue-colored light supports Lacey's theory in that the subjects were responding to the environment and this interaction is accompanied by cardiac deceleration.

Hypothesis 3 stated that the heart rate would be greater at the onset of exposure to red light than at the onset of exposure to blue light. This hypothesis was not supported at the .05 level of significance. It was hypothesized that the subject would "reject" the red-colored-light environment more readily and show a smaller decrease in heart rate than under the blue-colored light, which would be more "acceptable" to the organism. Although this hypothesis was not supported, the data showed that there was a decrease in heart rate under the red and blue conditions during the initial minute of exposure. Under red light the mean relative of change (Δ_1) was -.007 ($p > .05$), and under blue light the mean relative of change (Δ_3) was -.020 ($p < .001$).

These findings seem to suggest that a novel condition in the environment will evoke a response from a subject and that this response is related to cardiac deceleration. This is supported by Hare, who presented a series of colored slides to subjects and found that heart rate decreased during the orienting response in subjects when they were initially viewing the slides.[1]

Hypothesis 4 stated that the heart rate would be greater at the termination of exposure to red light than at the termination of exposure to blue light. This hypothesis was not supported at the .05 level, nor was there a significant relative change in subjects' heart rates under either the red- or blue-light condition at the termination of exposure to the lights. This may be due to habituation which would occur sometime after the initial orienting response. Porges reported that in studies dealing with cardiac variability during attention-demanding tasks there was a decrease in heart rate concomitant with sustained attention.[2] Therefore, after being exposed to an environment of unvaried stimuli where attention can only be focused on the same thing, the organism makes a variety of peripheral adjustments to reduce the impact of the stimuli on the central nervous system. One of these adjustments may be a decrease in heart rate as the subject seeks to reduce his arousal potential.[3]

[1] R. Hare et al., "Autonomic Responses to Affective Visual Stimulation," Psychophysiology, 7:408-17, November 1970.

[2] S. Porges, "Heart Rate Variability and Deceleration as Indexes of Reaction Time," Journal of Experimental Psychology, 92:103-10, January 1972.

[3] H. Peeke and M. Herz, Habituation (New York: Academic Press, 1973).

Another analysis tested the relationship between the sequence of presentation of the color and the heart-rate response. The results showed that the color that was presented first evoked a significantly higher heart-rate response ($p < .05$). This was true of both red and blue light, although the heart-rate response to blue when it was presented first was higher than when red was presented first. This may be a function of the startle reflex, which depends upon the intensity of the change in the environment.[1] It is plausible that when the second environmental color change was produced, the subject was better oriented to the environment, and therefore the startle response with its accompanying vasoconstriction and autonomic stimulation was not as great.

This response was in the negative direction and also may be attributed to the effect of novelty on the organism. Berlyne has studied the effects of unexpectedness or surprise on the organism by measuring the attention span in subjects exposed to varying stimuli.[2] He found that the immediate level of arousal was positively related to unexpected stimuli and negatively related to stimulus constancy, repetition or familiarity.[3] These findings, therefore, support Lacey's

---

[1]F. Graham and R. Clifton, "Heart Rate Changes as a Component of the Orienting Experience."

[2]D. E. Berlyne, "Curiosity and Exploration," Science, 153:25-33, 1966.

[3]J. P. Zubek, ed., Sensory Deprivation: Fifteen Years of Research (New York: Appleton-Century-Crofts, 1969).

theory in that when subjects are aroused and focusing on the stimuli in the environment, there is an accompanying decrease in heart rate. However, once the subject habituates to the environment or when the environment is repeated, the arousal is lower and the subject is not as responsive to the environment. According to Lacey's theory, this phenomenon is accompanied by heart-rate acceleration. This was not supported by these findings. These findings suggest further investigation needs to be carried out relative to specific response patterns to environmental phenomena and physiological correlates.

Since cardiac rate may be related to individual responses in novel situations, the orienting and adaptive responses may have directional variability within individuals. These responses vary with each individual as he interacts with different levels of stimulation in the environment. Some levels of excitability may be more optimal for one individual than for another. Duffy and Lacey support the fact that there may be individual differences in the patterning of autonomic activity.[1] For example, one person may not respond to an environmental condition with an increased heart rate while another person may respond to the same

---

[1]E. Duffy, "The Psychological Significance of the Concept of 'Arousal' or 'Activation,'" Psychological Review, 64:265-75, 1957.

J. I. Lacey, D. E. Bateman, and R. Van Lehn, "Autonomic Response Specificity and Rorschach Color Responses," Psychosomatic Medicine, 14:256-60, 1952.

condition with a decreased heart rate. These individual differences may account somewhat for the large standard deviations and variances found in the experimental results.

It is also necessary to consider the cardiac-somatic model which suggests that heart-rate change is one of many responses that make up the outcome of the interaction of the organism with the environment.[1] With this model the heart rate would reflect a behavioral pattern of the total organism and cardiac-rate change could be considered a part of or result of another behavioral pattern and not purely an environmental facilitator as suggested by Lacey. However, analysis of color preference and cardiac-rate change during exposure to red and blue light did not reflect differences in behavioral patterns.

This theory may lend some credence to the cardiac-rate change that has been explained as a function of the startle or orienting response. In order to test this, it would be necessary to study further the physiological correlates of these responses to elicit information about the direction and degree of cardiac-rate change and to assess if rate change is a part of or a result of the responses.

According to Lacey's theory, cardiac acceleration accompanies situations involving mental concentration or cognitive processing, while cardiac deceleration is related

---

[1]R. Elliott, "Tonic Heart Rate: Experiments on the Effects of Collative Variables Lead to a Hypothesis about Its Motivational Significance."

to situations in which the subject is more involved with his surrounding environment and focusing his attention on it.[1] This focusing of attention can be determined through the alpha waves recorded on an electroencephalogram (EEG). In an adult who is at rest and letting his mind wander, the most prominent component of the EEG is a fairly regular pattern called the alpha rhythm.[2] Lindsley found that a subject in the "quiet, relaxed wakefulness of blue light" showed optimal alpha waves in the EEG.[3] Gerard supported this in his report that there were significantly more thoughts and associations reported by subjects exposed to a blue-chromatic condition.[4]

In view of these findings of Lindsley and Gerard, the results of this study support the proposal that blue light is conducive to cognitive processing and free thought association, and therefore is accompanied by cardiac acceleration. As previously noted from the literature, red is usually thought of as being more anxiety-producing and dynamic, while blue is often said to be more tranquil and peaceful.

---

[1]John Lacey et al., "The Visceral Level Situational Determinates and Behavioral Correlates of Autonomic Response Patterns."

[2]W. Gagnong, Review of Medical Physiology, p. 121.

[3]D. B. Lindsley, "Psychological Phenomena and the Electroencephalogram," EEG Clinical Neurophysiology, 4:443-56, 1952, p. 445.

[4]R. M. Gerard, "The Differential Effects of Colored Lights on Psychophysical Functions," p. 134.

These are affective characteristics of color components, and the physiological component--specifically the cardiac rate--indicates that the adult shows less change when interacting with an environment comprised of the longer wave, "dynamic and anxiety-producing" red color. The greater change is seen in cardiac rate when the subject is interacting with the shorter wave, "tranquil and peaceful" blue color. Which of these environmental patterns is more optimal to the functioning of the organism? It would seem that it should be the environment which is more conducive to maintenance of structure and pattern. Since the longer wavelength produced a significantly smaller cardiac-rate change, it seems that an environment which uses light predominantly from the longer wavelength region of the visible electromagnetic spectrum would be optimal in situations in which an increase in heart rate would be detrimental to the system. This may, however, vary with individuals as some individuals require a greater degree of stimulation, a different quality of stimulation, or perhaps a greater degree of change in their own patterning to maintain their structure.

There may also be situations in which the lightwaves from the shorter wavelength region of the spectrum could be used therapeutically. This light might be used when an individual is focusing on his surrounding environment to a great degree and is unable to focus on any cognitive processing. The blue light might also be used in combination with drugs administered to people who have bradycardia. This combination may decrease the amount of drugs needed and reduce or eliminate the side effects that these drugs produce.

Since there was no significant change in heart rate during exposure to white light, it seems that the use of white light might be indicated in situations in which an increase or decrease in heart rate would be detrimental to the organism. This absence of cardiac response to white light may be attributed to the fact that white light is a combination of light waves from all regions of the visible electromagnetic spectrum. Since this study found a significant cardiac-rate change only during exposure to light from the shorter wavelength region of the visible electromagnetic spectrum, the light of longer wavelengths present in white light may reduce or eliminate cardiac-rate change.

An additional analysis was carried out to assess the relationship between the time of day that the subject was exposed to the experimental environment and the heart-rate response. This did not prove significant ($p > .05$), which may be due to the fact that there were unweighted means as the result of an unequal number of subjects in the group tested in the morning and the group tested in the afternoon and evening. Since the time of day was not a focus of this study, there was no control of the sleep-wake patterns or body rhythms of the subjects. Metabolic rates are a function of circadian rhythms and these rates are intrinsically related to cardiac rate.[1] Since individuals have different patterns of circadian rhythms, which relate to their sleep-wake patterns, the lack of significance in this analysis may have been due to individuality and lack of control for this factor.

Another analysis was carried out to determine if there was a relationship between cardiac-rate change and color preference of the subjects. There were no significant findings in this analysis ($p > .05$). This may have been due to the fact that when subjects stated their color preference, their response was probably based on their reactions to pigmented colors with which they were familiar. The visual effect of the "monochromatic" red and blue lights may have been quite different from the visual effect produced by pigmented colors.

Post-session interviews were conducted, but they did not produce any particular pattern of response. Significantly, there was no correlation between the colored environment that subjects "liked" or "disliked," or in which they felt "comfortable" or "uncomfortable," and any cardiac change. Most subjects did not have a preference for any one environmental condition.

One problem in the experimental setting was detected through the post-session interviews. This was that the light switches were audible to the subject in the laboratory.

---

[1]G. G. Luce, Body Time (New York: Bantam Books, 1973).

The sound of the switches may have inadvertently added to the element of startle response whenever the color of the environment was first changed. Any future parallel study should eliminate this problem by the use of silent switches.

Many subjects also felt that the blue and red lights really did not look like blue and red color. The visual effect of "monochromatic" light may have been quiet different from the visual effect of pigmented colors with which most people are familiar. Since the purpose of this study was to determine one of the physiological responses to visible lightwaves and not the emotional response to color, the visual effect of the light in the environment may have helped to eliminate some of the emotional attitudes subjects may have felt about a particular color.

It is also necessary to consider that the intensity of the lights was carefully controlled and maintained during the red, blue and white conditions. Perhaps if the intensity had been greater or lesser, or if the subject had been able to control the intensity, the results would have been different.

The experiment supported the theoretical rationale set forth in that it demonstrated that response to lightwaves of shorter wavelengths produces a significant increase in cardiac rate. The experiment also showed that people react to novel stimuli in the environment with a significantly greater response, in this case a deceleration in cardiac rate, than they do when the stimuli are continued or repeated.

CHAPTER VI

SUMMARY, CONCLUSIONS AND IMPLICATIONS

Summary

The purpose of this study was to investigate the relationship between exposure to planned environmental visual stimulation, in the form of colored light, and heart-rate response. Man and his environment are postulated to interact continually through changing energy patterns. Therefore, any change in these patterns is determined by the simultaneous interaction of the human field and environmental field at any given point in space-time.

Using heart rate as one pattern of human behavior, the following hypotheses were tested:

1. The heart rate will increase from the onset of exposure to red light to the termination of exposure to red light.

2. The heart rate will increase from the onset of exposure to blue light to the termination of exposure to blue light.

3. The heart rate will be greater at the onset of exposure to red light than at the onset of exposure to blue light.

4. The heart rate will be greater at the termination of exposure to red light than at the termination of exposure

to blue light.

The sample consisted of 103 women between the ages of 18 and 35 years. The heart rate was measured by an ER-1 cardiac monitor. The colored environment was produced by General Electric monochromatic lights and controlled for intensity.

The subjects were seated inside the laboratory for 40 minutes during which time they were exposed to periods of white light, red light and blue light. A 10-minute period of white light preceded each experimental light condition and was used to establish a baseline heart rate. The experimental light conditions were also 10 minutes in length and the subjects were randomly exposed to red or blue as a first colored-light condition.

The data were analyzed by matched t-tests with the level of significance set at .05. The analysis showed that only Hypothesis 2 was supported, while the other hypotheses were not supported by the data.

Conclusions

The heart rate showed a significant increase in subjects when exposed to an environment of blue light. It may be concluded that:

1. Heart rate does not significantly change in subjects during exposure to an environment of red light.

2. Heart rate does significantly change in subjects during exposure to an environment of blue light.

3. There is no significant difference between heart rate at the onset of exposure to red light and at the onset of exposure to blue light.

4. There is no significant difference between heart rate at the termination of exposure to red light and at the termination of exposure to blue light.

From a physiological point of view, Conclusion 3 or 4 should reflect significance in view of the positive finding of Conclusion 2. However, because of the statistical treatment and the level of significance adopted for the study ($p = .05$), this was not found. Had a less stringent level of significance been set (e.g., $p = .15$), Conclusion 3 would have been positive.

5. The time of day during which a subject is exposed to environments of different colors is not related to change in heart rate during this exposure.

6. Heart rate is significantly greater when a subject is first introduced to a novel experiment of colored light than when the environment is repeated with a different color.

7. There is no relation between a subject's color preference and his heart-rate change when exposed to that color.

Implications for Further Research

1. Replication of this study with observation of heart-rate changes during a continuous period of exposure to the colored environment. From this study an analysis could be made of the maximum and minimal heart-rate changes during

the exposure period. The beginning and end of the orienting response and habituation may also be better determined.

2. Replication of this study using an anxiety scale to assess levels of anxiety during the different colored environments. This study would enable the researcher to determine if there is any relation between anxiety under any of the colored-light conditions and the heart-rate change. This would help to determine if heart-rate change is a function of an anxiety response or if it is independent of anxiety. The study would also help to determine if any part of the visible spectrum is more anxiety-producing than another part.

3. Replication of this study using internal-external locus of control as a comparative basis. This study would determine if subjects who were more controlled by their environment had different heart-rate responses under different conditions than those subjects who were more internally controlled.

4. An investigation of the relationship between light-waves, cardiac rate and EEG patterns. This study would help to determine the relationship of lightwaves of different frequencies and the central nervous system response, as well as the heart-rate response and changes in the brainwave patterns.

5. An investigation of the relationship of the intensity of colored lights in the environment and cardiac-rate change. The study might allow the subjects to control the intensity of their own environment to determine optimal levels.

BIBLIOGRAPHY

Aiba, S. "The Effects of Stimulant and Depressant Drugs on the Bidwell Phenomena." British Journal of Psychology, 51:311, November 1960.

Babbitt, E. D. The Principles of Light and Color. Malaga, New Jersey: Spectro-Chrome Institute, 1925.

Bartholet, Mary N. "Effects of Color on the Dynamics of Patient Care." Nursing Outlook, 16:51-53, 1968.

Bergamini, S., and Bergamasco, B. Cortical Evoked Potentials in Man. Springfield, Illinois: Thomas Co., 1967.

Berlyne, D. E. "Curiosity and Exploration." Science, 153: 25-33, 1966.

________. "Arousal and Reinforcement." In Nebraska Symposium. Edited by D. Levine. Lincoln: University of Nebraska Press, 1967.

________. Conflict, Arousal and Curiosity. New York: McGraw-Hill Book Company, 1960.

Berrien, F. K. General and Social Systems. New Brunswick, New Jersey: Rutgers University Press, 1968.

Birren, Faber. Light, Color and Environment. New York: Van Nostrand and Reinhold, 1969.

Boernstein, Walter S. "Perceiving and Thinking: Their Interrelationship and Organismic Organization." Annals of New York Academy of Sciences, 169:673-82, June 1970.

Brownfield, Charles A. Isolation: Clinical and Experimental Approaches. New York: Random House, 1965.

Burnham, R.; Hanes, R.; and Bartleson, J. Color: A Guide to Basic Facts and Concepts. New York: John Wiley and Sons, 1963.

Burns, George. The Science of Genetics. New York: Macmillan Co., 1972.

Campos, J. J. "Affect, Verbalization and Directional Fractionation of Autonomic Responses." Psychophysiology, 3:285-90, 1967.

Cohen, Jacob. Statistical Power Analysis for the Behavioral Sciences. New York: Academic Press, 1969.

Coles, Michael G. "Cardiac and Respiratory Activity during Visual Search." Journal of Experimental Psychology, 96:371-79, January 1972.

Congrieve, G. R. "Dimensions of Subjective Response to Short Term Sensory Deprivation." Psychonomic Science, 22:220-21, February 1971.

Corso, John F. The Experimental Psychology of Sensory Behavior. New York: Holt, Rinehart and Winston, 1967.

Dell, P. C. "Humoral Effects in the Brain Stem Reticular Formation." In Reticular Formation of the Brain. Edited by H. J. Jasper et al. Boston: Little and Company, 1958.

Dériberé, Maurice. La Couleur dans les activités humaines. Paris: Dunod, 1968.

Deutsch, F. "Psychophysical Reactions of the Vascular System to Influences of Light and to Impressions Gained through Light." Folia Clinical Orientalia, 1:137-44, 207-18, 1937.

Duffy, Elizabeth. "The Psychological Significance of the Concept of 'Arousal' or 'Activation.'" Psychological Review, 64:265-75, 1957.

________. Activation and Behavior. New York: John Wiley and Sons, 1962.

Dull, Charles; Metcalfe, H. Clarke; and Brooks, William. Modern Physics. New York: Henry Holt and Company, 1955.

Elliott, Rogers. "The Significance of Heart Rate for Behavior: A Critique of Lacey's Hypothesis." Journal of Personality and Social Psychology, 22:398-409, 1972.

________. "Tonic Heart Rate: Experiments on the Effects of Collative Variables Lead to a Hypothesis about Its Motivational Significance." Journal of Personality and Experimental Psychology, 12:211-28, 1969.

Eysenck, H. J. "A Critical and Experimental Study of Color Preferences." American Journal of Psychology, 54:389, 1941.

Eysenck, H. J., and Aiba, S. "The Effects of Stimulant and Depressant Drugs on the Suppression of the Primary Visual Stimulus." Journal of Mental Health, 103:661-65, 1957.

Féré, C. Sensation and Movement. Paris: Alcan, 1900.

Freedman, Sanford J. "Sensory Deprivation: Facts in Search of a Theory." Journal of Nervous and Mental Disease, 132:17-21, 1961.

Gagnong, W. Review of Medical Physiology. Los Altos, California: Lange Medical Publications, 1973.

Gerard, R. M. "The Differential Effects of Colored Lights on Psychophysical Functions." Unpublished Ph.D. dissertation, University of California, Los Angeles, 1957.

Gibson, James. The Senses Considered as Perceptual Systems. Boston: Houghton-Mifflin Company, 1966.

Goldberger, Leo. "The Role of Sensory Deprivation in the Hospital" Unpublished paper, New York University, 1968.

Graham, Francis, and Clifton, Rachael. "Heart Rate Changes as a Component of the Orienting Response." Psychological Bulletin, 65:305-20, 1966.

Granger, G. W. "An Experimental Study of Color Preference." Journal of General Psychology, 52:20, 1955.

Guyton, Arthur. Textbook of Medical Physiology. Philadelphia: W. B. Saunders, 1972.

Halliday, D., and Resnick, R. Physics: Parts I and II. New York: John Wiley and Sons, 1966.

Hare, R., et al. "Autonomic Responses to Affective Visual Stimulation." Psychophysiology, 7:408-17, November 1970.

Hartshorne, Charles. The Philosophy and Psychology of Sensation. Chicago: University of Chicago Press, 1934.

Hebb, Donald. "Drives and the Central Nervous System." Psychological Review, 62:243-54, 1955.

Held, Richard. "Exposure History as a Factor in Maintaining Stability of Perception and Co-ordination." Journal of Nervous and Mental Disease, 132:26-32, 1961.

Heline, Corrinne. Healing and Regeneration through Color. Santa Barbara, California: J. F. Rowney Press, 1972.

Hollister, L. E., and Hartman, A. M. "Mescaline, Lysergic Acid Diethylamide and Psilocybin: Comparison of Clinical Syndromes, Effects on Color Perception and Biochemical Measures." Comprehensive Psychiatry, 3: 237-38, August 1962.

Illuminating Engineering Society of New York. Artificial Light and Its Application in the Home. New York: McGraw-Hill Company, 1932.

Ishihara, S. Ishihara's Test for Color-Blindness. Tokyo: Kanehara Co., 1973.

Kopell, B. S.; Wittner, W. K.; and Warrick, G. L. "The Effects of Stimulus Differences, Light Intensity and Selective Attention on the Amplitude of the Visual Averaged Evoked Potential in Man." Electroencephalogram Clinical Neurophysiology, 26:619-22, 1969.

Kunerth, William. A Textbook of Illumination. 2d ed. New York: John Wiley and Sons, 1936.

Lacey, J. I. "The Evaluation of Autonomic Responses: Toward a General Solution." Annals of the New York Academy of Science, 67:123-64, 1956.

Lacey, J. I.; Bateman, D. E.; and Van Lehn, R. "Autonomic Response Specificity and Rorschach Color Responses." Psychosomatic Medicine, 14:256-60, 1952.

Lacey, John. "Psychophysiological Approaches to the Evaluation of Psychotherapeutic Process and Outcome." In Research in Psychotherapy. Edited by E. A. Rubenstein and M. B. Parloff. Washington, D.C.: American Psychological Association, 1959.

________. "Somatic Response Patterning and Stress." In Psychological Stress. Edited by M. H. Appley and R. Trumball. New York: Appleton-Century-Crofts, 1967.

Lacey, John, et al. "The Visceral Leval Situational Determinates and Behavioral Correlates of Autonomic Response Patterns." In Expression of the Emotions in Man. Edited by P. H. Knapp. New York: International Universities Press, 1963.

Lewis, M.; Kagen, J.; Campbell, H.; and Kalafat, J. "The Cardiac Response as a Correlate of Attention in Infants." Child Development, 37:63-71, 1966.

Lindsley, D. B. "Psychological Phenomena and the Electroencephalogram." Electroencephalogram Clinical Neurophysiology, 4:443-56, 1952.

________. "Higher Functions of the CNS." Annals of Review of Physiology, 17:311-38, 1955.

________. "Common Factors in Sensory Deprivation, Sensory Distortion, and Sensory Overload." In Sensory Deprivation. Edited by Peter Solomon et al. Cambridge, Massachusetts: Harvard University Press, 1965.

Lipton, Earle; Steinschneider, Alfred; and Richmond, Julius. "Autonomic Function in the Neonate: Methodological Considerations." Psychosomatic Medicine, 23:466-67, November-December 1971.

London, H.; Schubert, D. S.; and Washburn, D. "Increase of Autonomic Arousal by Boredom." Journal of Abnormal Psychology, 80:29-36, August 1972.

Luce, G. G. Body Time. New York: Bantam Books, 1973.

Luckiesh, M., and Pacini, A. J. Light and Health. Baltimore: Williams and Wilkens Company, 1926.

Ludwig, A. M. "Self-Regulation of the Sensory Environment." Archives of General Psychology, 25:413-18, November 1971.

Lynn, R. Attention, Arousal and the Orientation Reaction. London: Pergamon Press, 1966.

Nakshian, Jacob. "The Effects of Red and Green Surroundings on Behavior." The Journal of General Psychology, 70: 143-61, 1964.

Norman, R. D., and Scott, W. A. "Color and Affect: A Review and Semantic Evaluation." Journal of General Psychology, 46:185-223, 1952.

Nourse, J. C., and Welch, R. B. "Emotional Attributes of Color: A Comparison of Violet and Green." Perceptual and Motor Skills, 32:403-6, 1971.

Obrist, Paul. "Cardiovascular Differentiation of Sensory Stimuli." Psychosomatic Medicine, 25:450-59, 1963.

Peeke, Harman, and Herz, Michael. Habituation. New York: Academic Press, 1973.

Perry, N. W., and Childers, D. G. The Human Visual Evoked

Response. Springfield, Illinois: Thomas Company, 1969.

Petrie, A. Individuality in Pain and Suffering. Chicago: University of Chicago Press, 1967.

Porges, Stephen. "Heart Rate Variability and Deceleration as Indexes of Reaction Time." Journal of Experimental Psychology, 92:103-10, January 1972.

Pressey, S. S. "The Influence of Color upon Mental and Motor Efficiency." American Journal of Psychology, 32:326-56, 1921.

Rogers, Martha. The Theoretical Basis of Nursing. Philadelphia: F. A. Davis Company, 1970.

Rushmer, R. Cardiovascular Dynamics. Philadelphia: W. B. Saunders, 1965.

Seagull, Mary. "The Relationship between Auditory Stimulation and Heart Rate Response of the Premature Infant." Unpublished Ph.D. dissertation, New York University, 1970.

Smets, Gerda. "Time Expression of Red and Blue." Perceptual and Motor Skills, 29:511-14, 1969.

Sokolov, E. N. Perception and the Conditioned Reflex. New York: Macmillan and Co., 1963.

Spence, D.; Lugo, M.; and Youdin, R. "Cardiac Correlates of Cognitive Processing." Mimeographed manuscript, Research Center for Mental Health, New York University.

Teichner, Warren, and Krebs, Marjorie. "Laws of the Simple Visual Reaction Time." Psychology Review, 79:344-58, July 1972.

Thornton, W. A. "Three Color Visual Response." Journal of the Optical Society of America, 6:457-59, March 1972.

Tinker, M. A. "Effect of Stimulus-Texture upon Apparent Warmth and Affective Value of Colors." American Journal of Psychology, 51:532-35, 1938.

Toffler, Alvin. Future Shock. New York: Random House, 1970, pp. 305-6.

Troland, L. T. "Report of Committee on Colorimetry." Journal of the Optical Society of America, 6:528, 1922.

Van Olst, E. H. The Orienting Reflex. The Hague: Mouton, 1971.

Wilson, Glenn. "Arousal Properties of Red vs. Green." Perceptual and Motor Skills, 23:947-49, 1966.

Wurtman, Richard J. "The Effects of Light on the Human Body." Scientific American, July 1975, pp. 69-77.

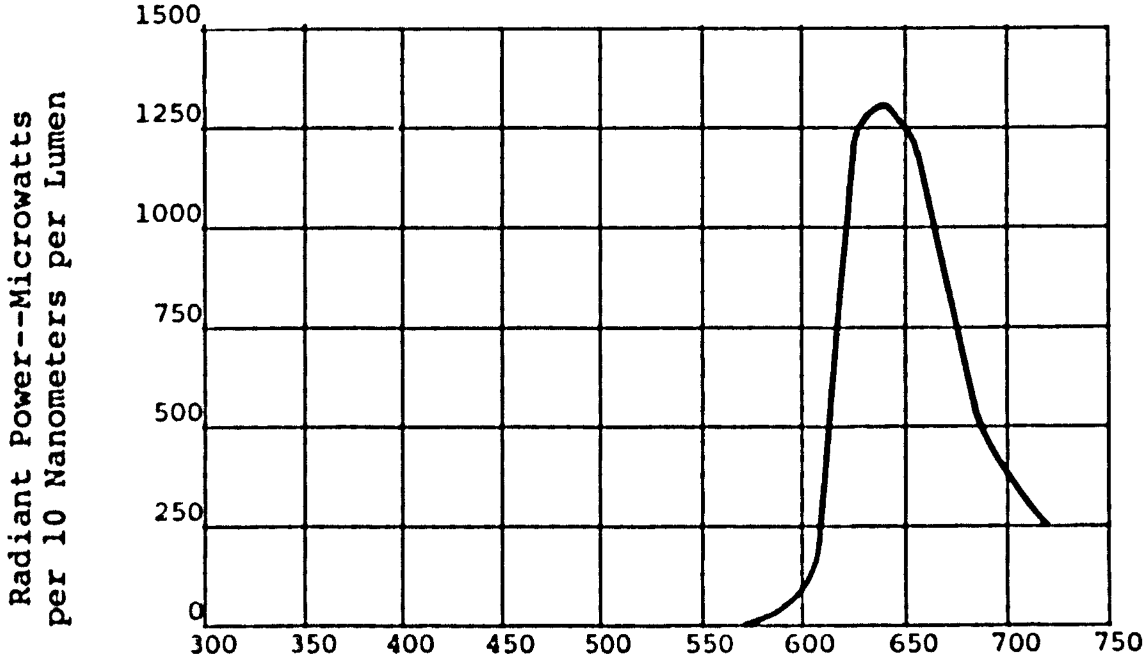
Zubek, J. P., ed. Sensory Deprivation: Fifteen Years of Research. New York: Appleton-Century-Crofts, 1969.

Zuckerman, Marvin, et al. "Sensory Deprivation vs. Sensory Variance." Journal of Abnormal Psychology, 76:76-82, 1970.

APPENDIX A

SPECTRAL DATA: F40R[1]

Lamp Description: RED FLUORESCENT



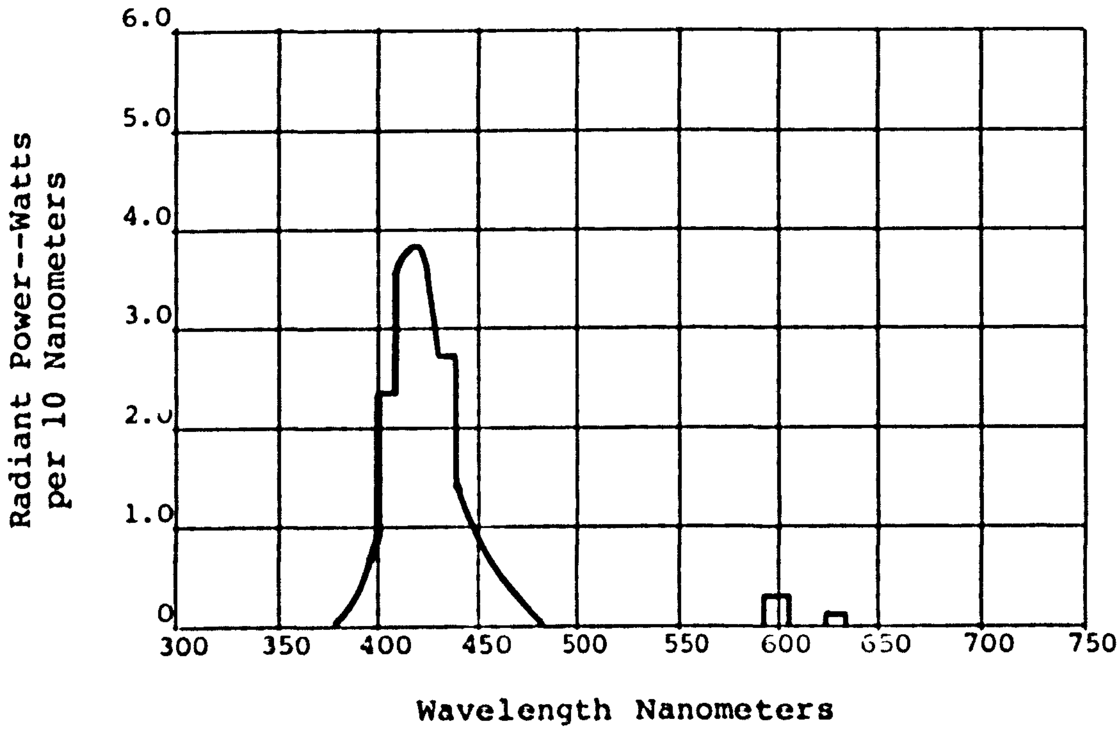
C.I.E. Chromaticity: X = .696 Y = .304

[1]Spectral Data: F40R (Cleveland, Ohio: General Electric, March 12, 1965).

APPENDIX B

SPECTRAL DATA: F48T12/SPB/HO[1]

Lamp Description: BLUE FLUORESCENT



C.I.E. Chromaticity: X = .177 Y = .050

[1]Spectral Data: F48T12/SPB (Cleveland, Ohio: General Electric, November 1973).

APPENDIX C

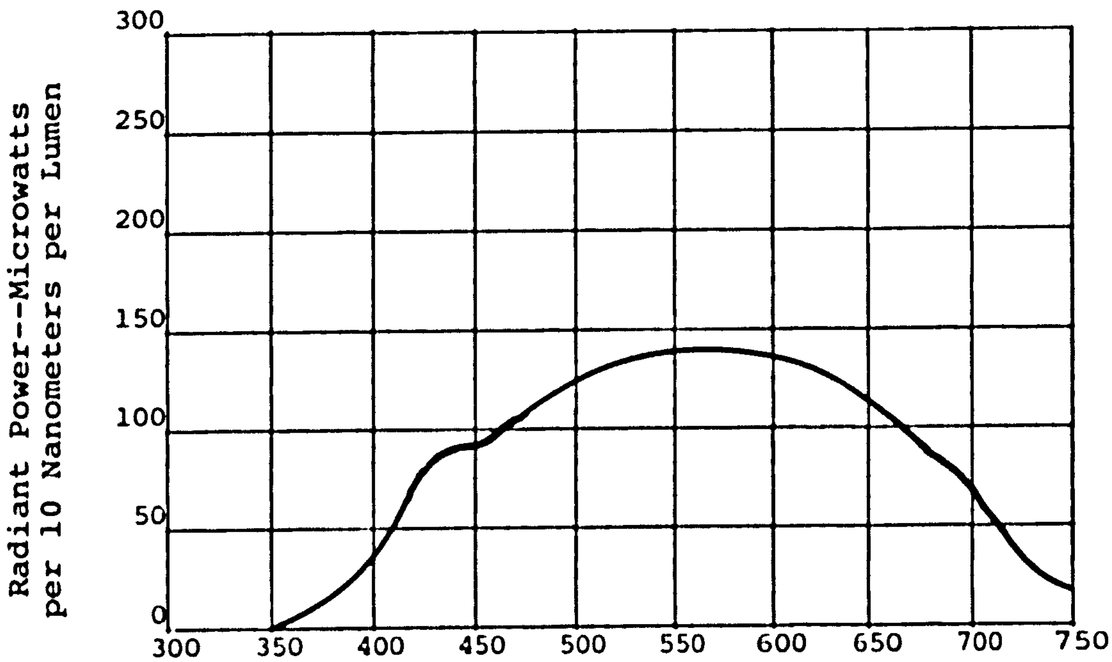
SPECIFICATIONS FOR ER-1 RATE METER

Manufacturer:	Electronics for Medicine
Range:	0-200 beats/minute
Accuracy:	better than 2% of full scale
Sensitivity:	0.4 mv. - 2.0 mv.; QRS complex of either polarity
Response time:	instantaneous for arrest, damped for increasing rate
Indication:	flashing light and audible beeper with volume control
Synchronization:	100 ms. pulse on first upward deflection of QRS complex
Leads:	auxiliary position for disposable electrodes
Impedance:	10 megohms each side to ground
Patient current:	less than 0.001 microampere
Calibration:	1 mv.
Sensitivity:	3cm deflection/mv.
Noise:	less than 20 uv. peak-to-peak
CM rejection:	60 db minimum
Frequency response:	0.2 - 200 cycles/sec.

APPENDIX D

SPECTRAL DATA: F40C50[1]

Lamp Description: WHITE FLUORESCENT
(Chroma 50)



"Chromaline lamps simulate both the whiteness and color rendering of natural daylight. C50, at 5000 K (degrees Kelvin), approximates noon sky plus sunlight."

---

[1]Fluorescent Lamp Spectral Data: General Electric Lamp Information 211-3066 ([n.p.]: General Electric, [n.d.]).

APPENDIX E

SPECIFICATIONS FOR MINOLTA AUTOMETER

Type:	Special high-sensitivity CdS-cell incident-light measuring type that also measures reflected light with attachment and gives direct readings from a scale-dial that moves itself continuously and automatically by battery power
Measuring range:	Incident: .03 ft-c to 30000 ft-c Reflected: .23 ft-c to 30000 ft-c
Light receptors:	Incident with spherical Diffuser Reflected light attachment with 10° angle of acceptance
Scale ranges:	EV: -7 to 25
Power source:	One 6v silver oxide battery, Eveready No. 544 or equivalent
Weight:	300 grams
Size:	42 X 67 X 131 mm.

APPENDIX F

LIGHT WAVES, TIME AND CARDIAC RATE STUDY

PERSONAL DATA SHEET

NAME____CODE #________________

ADDRESS____

TELEPHONE NUMBER____________________OCCUPATION_______________________

PRESENT SCHOOL__________________________________MAJOR________________

AGE_____HEIGHT (without shoes)____________WEIGHT (with clothes)_________

Have you ever been considered obese or weighed more than 20% above the average weight for your age group? YES___ NO___

If yes, when?_________________________________

Please check any of the following days and times during which you will be available to participate in this study.

	9AM	10	11	12	1PM	2	3	4	5	6	7
Monday											
Tuesday											
Wednesday											
Thursday											
Friday											
Saturday											
Sunday											

Do you have any physical problems? YES___ NO___

If yes, please describe____

____

Do you take any medications regularly? YES___ NO___

If yes, please describe____

____

Do you have any known sensory impairment?

Eyes: YES___ NO___
If yes, is your problem corrected with glasses? YES___ NO___

Ears: YES___ NO___
If yes, is your problem corrected by a hearing aid? YES___ NO___

Other:____

Do you have a problem with color-blindness? YES___ NO___

Were you born in the United States? YES___ NO___

Do you engage in meditative practice? YES___ NO___

Have you ever received biofeedback training? YES___ NO___

What is your favorite color?______________________________

Will you be in the New York area during Easter vacation? NO___ YES___

APPENDIX G

INSTRUCTIONS FOR PARTICIPANTS

Thank you for volunteering for this "Light" study. Your participation will involve TWO one-hour visits to New York Unversity. The first visit will consist of sitting under a series of red, white and blue lights while your pulse is monitored and you estimate a short period of time under each lighting situation.

The second visit will occur approximately three weeks following the first and will be identical to the first situation except that you will be requested to wear a comfortable eyemask which will eliminate your visible perception of light during the 40-minute experiment.

At the end of the completed study, a summary of the results will be sent to you for your information.

Please read and follow the instructions below.

1. Please wear comfortable clothing. A short-sleeved top is requested.

2. Twenty-four hours prior to your participation date, please refrain from taking any of the following:

   Amphetamines
   Barbiturates
   LSD
   Marijuana
   Muscle relaxants
   Tranquilizers

3. Twelve hours prior to the participation date, please refrain from taking any of the following:

   Coffee
   Tea
   Alcohol

4. You will be notified by phone to confirm a time for you to come to participate in the study. Please come to:

   Room 533 - Fifth Floor
   Shimkin Hall - 50 East 4th Street
   New York University
   Washington Square, New York

   Signs will direct you to the laboratory area.

5. If you have any additional questions, please feel free to call:

   Tara Cortes [redacted]

APPENDIX H

INSTRUCTIONS ON DAY OF TESTING

1. You will be sitting in a chair during the 40-minute experiment.

2. Please remain seated at the table.

3. Do not walk around or smoke.

4. It is important that you remain alert and do not fall asleep. Please be aware of your reactions to this experiment as you will be asked to describe your feelings at the end of the testing session.

5. You will have paste-on electrodes attached to your forearms which will continuously monitor your heart rate. There will be no pain from this device.

6. The color of the environment will be changed through red, blue and white lighting at certain times during the experiment. There will be no other changes in the environment during the experiment.

7. During the various red, blue and white lighting situations you will be advised through the intercom system to produce a 40-second interval of time. When you are notified to do so, please move the toggle switch on the desk to the "on" position and leave it in that position while you visualize a clock with a sweep-second hand. When the sweep-second hand reaches the 40-second position, please move the toggle switch to the "off" position. Would you please demonstrate this procedure at this time.

8. If at any time during the testing period you feel you wish to terminate the experiment, you may contact the investigator by depressing the pushbutton on the intercom and speaking into the system. The investigator will immediately answer you through the speaker and you may end the experiment.

9. Do you have any questions?