The Psychophysiology of Nearsightedness

by

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ABSTRACT

This dissertation dealt with the etiology of nearsightedness. A psychophysiological model was developed to explain the concepts of William Bates. The model suggested that nearsightedness results from habits of mental focusing—habitual ways of organizing mental processes in order to pay attention—which lead to chronic isometric contraction of the extraocular muscles which cause the eyeball to elongate producing nearsightedness. The neuropsychological aspects of this model were derived primarily from the research of Karl Pribram. The literature on the etiology of nearsightedness was compatible with myopic behavior as predicted by the model. A pilot study was described. Young adult myopes were examined for changes in refractive error. The majority of the subjects improved their myopia. A method of data analysis was described for use with small clinical samples. Implications were drawn about the use of refractive information to measure health characteristics of the social environment. The dissertation concluded that Bates' ideas should be given serious consideration by vision scientists and professionals; myopia is more flexible than is generally conceived; and it is important to develop a new paradigm of visual care which examines the more subtle implications of the nearsighted response and the possibilities of prevention and remediation.

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INTRODUCTION

> Almost all of our population require refractive correction during their lifetimes. Considering the proportion of the total population involved and the significance of good vision in the efficient performance of an infinity of everyday tasks, it is important to increase the state of our knowledge regarding the refractive anomalies of the eye. (Newell & Hirsch, 1967)

The problem of refractive error is generally not considered to be a problem at all. Nearsightedness is considered a normal fact of life by most professionals and by most nearsighted people and parents of nearsighted children. It is indeed normal for over one-eighth of our population (Baldwin, 1964) is nearsighted. When a child, for example, begins to experience poor distance vision, the parents take the child to a vision professional who prescribes glasses which clear up the condition. The lenses to be worn are called "corrective" lenses. They seem to correct the problem since they permit the nearsighted child to see clearly again. The problem is considered to have been solved and no one thinks about it until a year or two later when the symptoms of poor vision or visual discomfort may reoccur.

This dissertation takes issue with this procedure and with the assumptions about refractive error which dominate the vision care professions.

CHAPTER 1: THE PROBLEM OF MYOPIA

Introduction to the Problem

The use of refractive lenses to neutralize or palliate the symptoms of nearsightedness does not correct or cure the problem. To neutralize a problem is not to correct it, just as to treat a symptom is not the same as to eliminate its cause.

The training of professionals discourages interest in preventive and remedial treatment of refractive problems. Although most professionals would like to be able to eliminate refractive problems, this is not thought to be practical or even possible. The general attitude is summarized in the following statement:

> It should be noted that the thinking of optometrists and patients alike is to prefer correction to neutralization. This is understandable; correction or prevention are the highest aims and in keeping with good health procedures. However, it is dangerous to become so determined to correct, even the uncorrectable, or to prevent, even the unpreventable, that we overlook the value of neutralizing an error for which nothing else can be done.... If nothing other than neutralization can be done, it is better to know this and to educate and reconcile children to the situation than to join them and their parents in a chase of will-of-the-wisps. (Hirsch, 1963)

Attempts to prevent or remediate nearsightedness have generally tended to be oriented around the use of lenses which are designed to "relax" the strain of near work. The results of this style of prevention are ambiguous, and the majority of professionals are not convinced of its effectiveness (Borish, 1954). Other forms of therapy have been attempted.

Woods (1946) and Hildreth (1947) used optometric group training techniques; Berens, et al. (1957) used tachistoscopic training; Kelley (1958) and Fox (1959) attempted hypnotic suggestion; Kelley (1958) did extensive individual Bates training; Giddings and Lanyon (1971 and 1974) used behavior modification, conditioning, and reinforcement techniques, as did Zeiger (1976). While the results of these experiments have shown some success in improving acuity and, in a few cases, in reducing refractive error, these attempts are considered to be impractical and have not altered the consensus "that little genuine improvement in sight without glasses can occur with most people having defective vision..." (Kelley, 1971). Little is done in professional vision care besides neutralizing the optical error with lenses to compensate for the problem.

There is even an attitude that nearsightedness is a positive adaptation in our society since nearsighted individuals tend to be better readers with higher levels of academic achievement. Further, it is not "now known whether disadvantages of becoming myopic outweigh advantages" (Baldwin, 1964).

One obvious disadvantage of nearsightedness is the inconvenience of wearing artificial devices on the face. The dependency on mechanical devices which can be broken or misplaced prevents nearsighted individuals from pursuing certain vocations. Another disadvantage concerns the poor self-image and feelings of weakness or inferiority which are reported by the experimenter's nearsighted patients. Children with glasses are often ridiculed by their peers and pitied by adults. One attitude about glasses is exemplified in the following quote:

> Most human beings are, unfortunately, ugly enough without putting glasses upon them, and to disfigure any of the really beautiful faces that we have with such contrivances is surely as bad as putting an import tax upon art. (Bates, 1920)

The more subtle disadvantages of wearing lenses are generally disguised by our general life style. We have come to accept as normal some rather unhealthy conditions. The consequences of these "normal" conditions of modern civilization are just now being recognized by the general public. Such symptoms as cancer, circulatory and heart disorders, psychoneurotic chronic behavior, etc., are being linked to our life style (Pelletier, 1977). Nearsightedness, too, seems to be on the increase and it has been correlated with the progress of modern civilization (Bates, 1920; Young, 1965; Sato, 1964). What the consequences of nearsightedness and of wearing neutralizing lenses might be are still unknown. Is the loss of clear vision in supposedly healthy individuals a sign that some system in the organism is not functioning properly? Neutralization does not solve the basic problem; in fact, easy relief of the symptoms causes us to ignore the signal of distress which the body is sending. Indeed, paying attention to the ways human bodies respond to the environment can lead to information about improving conditions which affect our health and can provide clues to enhancing our potential as self-actualized human beings(Pelletier, 1977; Segall, Campbell, and Herskovits, 1966).

The less obvious disadvantages of nearsightedness are rarely dealt with in the literature. Methods of preventing and remediating nearsightedness are generally considered from a limited viewpoint. The neuropsychological factors concerning the etiology and mental functioning involved in the nearsighted response have not been examined in recent times. There is also a lack of attention directed to research about the variability of and changes in refractive error in the nearsighted population.

Statement of the Problem

William Bates (1920) wrote about the importance of changing the vision care paradigm. This dissertation explores his concepts about the etiology and implications of myopia. His thinging and experience have provided a model which forms the basis for this research.

Bates was an ophthalmologist who lived from 1860 to 1931. Before his involvement in the remediation and elimination of refractive errors and other anomalies of the visual system, he had been a respected scientist, physician, and surgeon. From 1886 to 1891 he was an instructor in ophthalmology at the New York Post-Graduate Medical School and Hospital. Later, in his ophthalmological practice in New York City, he became dissatisfied with fitting glasses. He found that once a person was fitted with glasses, the power of the lenses had to be changed and increased, getting stronger with each return visit. He began to experiment with alternative approaches to refractive problems and over a period of time developed what is now known as the Bates System of Vision Improvement.

Evidence in scientific literature that the Bates System works to eliminate myopia is practically non-existent. There are only a few cases of refractive error which any scientific study shows to have been improved (Kelley, 1958), and none for which refractive problems have been totally eliminated. Considering what is reported in the literature would likely lead to a rejection of Bates' method of visual care as "a nice idea which didn't work."

The prevailing sentiment for Bates can be best summarized by the following quote from the major text on the history of optometry:

> This was an era from which arose an unscientific and fallacious method of so-called eye exercises which unfortunately had popular appeal. The only reason this is included here is to disclaim it. In 1920, W.H. Bates, a physician of New York, published "The Cure of Imperfect Sight by Treatment Without Glasses." Health cultists grabbed the idea. Untrained people began giving eye training all over the country. These people were not optometrists. The methods they used were always disavowed by the profession. The Bates and such systems of exercises by untrained nonprofessional people undoubtedly served to discredit sound visual training...and unfortunately led many people to discard necessary glasses. (Gregg, 1965)

Bates' notions are greatly different from accepted theories of physiological optics (the science of vision):

> Bates' views are so entirely at variance with the accepted dicta of physiological optics, that the reviewer wishes to state his conviction (which he believes must be shared by ophthalmologists generally) that most of the statements quoted above are untenable. (Loeb, 1919)

In spite of an apparent lack of evidence which supports Bates, his concepts about vision problems have been reexamined. The author first encountered Bates in Aldous Huxley's (1942) book The Art of Seeing. After personal investigation led to the elimination of the experimenter's myopia, he became convinced of the positive aspects of his system. Since that time the experimenter has worked with patients and has achieved moderate success with the method. Bates' concepts have been chosen to research about vision problems. On the basis of personal experiences and intuitive sense of the essential correctness of his ideas the author has researched Bates' concepts and has found that his work is important and vision professionals should be aware of its possible utility in correcting and preventing myopia. The problem is an investigation of Bates' concepts in terms of recent evidence from the biological sciences. If his ideas can be substantiated by a search of the literature and if a psycho-physiological model can be developed to explain the details of his statements, then his credibility would be enhanced and research could be undertaken which might change the present vision care paradigm.

There have been difficulties in setting up programs to investigate the clinical changes in the experimenter's Bates patients. There is a need to develop a practical method of investigating refractive changes in order to better assess the clinical success of his methods. The second part of this dissertation deals with this aspect of the problem.

Research Questions

This dissertation involves two major parts; a review and development of an etiological model from the literature followed by a study of refractive changes in a sample of selected myopes. The first part examines the following questions:

1. Does recent psychophysiological evidence support Bates?
2. Can an etiological model be developed which is compatible with the literature on nearsightedness based on Bates' ideas and on psychobiological concepts?
3. Should further research be conducted to explore Bates' ideas?

The second part, a pilot investigation, asks a different type of question. The questions are as follows:

1. What are the most important variables to consider in analyzing changes in refractive error?
2. What are the most sensitive methods of measuring refractive change?
3. Will the results of the second study refute or support Bates' ideas as expressed in the first study?
4. Can baseline data be established that will be useful in future studies concerning variables which influence changes in refractive error?

Definition of Terms

Accommodation is the ability of the eye to change its focus to allow objects at varying distances from the eye to be in focus on the retina.

Acuity is the ability to discriminate details, can refer to the keenness of any sensory mode.

Ametropia is a condition in which the resting eye is not able to clearly focus light from distant objects.

Astigmatism is an optical condition of the eye wherein the lens system of the eye is not curved spherically but is toroidal (shaped with the curvature like that of a football or teaspoon).

Diopter (D) is the unit of lens power measure which refers to the distance from the lens to its focal point; the stronger the lens the shorter the distance and the stronger the dioptric power used to designate the degree of ametropia.

Emmetropia is the condition wherein the resting eye focuses light from a distant object clearly on the retina without the aid of spectacle lenses.

Farsighted is the ametropic condition in which the resting eye focuses light from a distant object behind the retina.

Hyperopia is a synonym for farsightedness.

Myopia is the ametropic condition wherein the resting eye focuses light from a distant object in front of the retina.

Myope is a nearsighted person or a person with nearsighted eyes.

Nearsighted is a synonym for myopic.

Refractive error is the measure of ametropia (in diopters).

Refraction is a procedure for measuring the refractive error and determining the lens power to neutralize the ametropia.

Rx is the prescription for glasses found through refraction and written in terms of dioptric measure.

Saccadic eye movement is the movement of the eyes from one target directly to another with a quick ballistic-like movement.

Snellen acuity is a system for designating the discriminating ability of the eye for letters, usually written in the form of 20/20, 20/200, etc.

20/20 is the ability to see at twenty feet distance the same size letter that someone with normal vision can see at twenty feet.

20/100 is the ability to see at twenty feet distance the same size letter that someone with normal vision can see at one hundred feet distance.

Rationale of the Study

The literature on the reduction of refractive error is inconclusive. It is well established that myopia begins to show an increase around the age of five or six; it begins to increase rapidly reaching a maximum rate of increase at about the age of thirteen when it begins to reduce its rate of change. The velocity of change reduces until the late teens when it appears to stabilize close to zero (Slataper, 1950). The data of Hirsch (1952) and Sorsby (1933) are similar to Slataper's data. Hirsch (1963) states that there is no change in refractive error between the ages of twenty and forty. However, Jackson (1932), Tassman (1932) and Walton (1950) found that there was a significant reduction in the percentage of myopes (in the total clinical population of each study) after the late teens. The decrease in percentage of myopes (by twenty-four percent) after the age of twenty indicates a decrease in refractive error to the extent that those myopes with low enough refractive error cease to be myopes. The findings are inconsistent with the conclusion that there is no reduction in myopia between ages twenty and forty. Grosvenor (1977) indicates that there is a lack of information about refractive changes in young adults and calls for more research.

If the research reported in the second study of this dissertation indicates that myopia can change toward improvement, this will add support for the need to engage in more intensive research to develop techniques to prevent and remediate refractive error.

Limitations of the Study

The study does not attempt to prove that myopia can be cured by Bates' or any other therapy method. It does attempt to show that myopia is a flexible condition and is related to psychophysiological factors.

Although the refractive problems of hyperopia, astigmatism, and presbyopia are common in our society, only myopia will be considered in this dissertation. This is because the majority of patients referred to the author were myopic.

In the development of the psychophysiological model of myopia the study is limited by the state of knowledge of brain function. This study represents the first attempt to establish a specific physiological process to describe the etiology of myopia. Physiological and psychological tests were not conducted on the patients in order to confirm the model. The correctness of this approach is inferred from past studies on the characteristics of myopic patients.

The study of refractive changes in the patients is not an experiment but a retroactive examination of optometric data collected in the office. This is a pilot study on existing data which is designed to aid in the development of future research, limited to little specific data about personality or life style characteristics of the patients. It is limited also by the small sample size (fifty five patients).

Summary and Overview of Remaining Chapters

This chapter has described the attitudes of the visual health care profession concerning the prevention and remediation of nearsightedness. On the one hand it is emphasized that it is important to increase the state of our knowledge regarding the refractive anomalies of the eye, and on the other are advised that it is impractical and even a disservice to patients to attempt to prevent or remediate nearsightedness.

The literature has not dealt with the humanistic implications of conditions which produce myopia in the affected one eighth of the population. It has also ignored the ideas of William Bates, a major researcher who established a holistic model of vision and a method of remediating refractive problems. This dissertation is an attempt to establish the credibility of Bates and to reexamine his ideas with reference to modern neurological concepts. There is no intent here to prove conclusively that Bates' method represents a cure for myopia. The present study is designed to explore the methods necessary to prepare a reliable data base for future experiments which might study the complex problems of refractive change in young adult myopes. In addition, the study may be able to determine the difficulties an experimenter can expect to encounter in designing such a study.

Chapter Two reviews the literature concerning refractive changes in the population and on approaches regarding the etiology of myopia. It includes an in depth investigation of Bates' concepts of the etiology of myopia. This section relied heavily on the work of Karl Pribram, whose research was reviewed with special emphasis on factors which relate to vision and attention. This research provides a neurophysiological framework for the examination of Bates' ideas about vision. It also provides a model of causation which is compared to earlier research on etiology of myopia.

Chapter Three presents the methods and procedures of the pilot study.

Chapter Four presents the results of the data analysis.

Chapter Five discusses the results, reviews the research questions, draws implications and provides suggestions for future research.

CHAPTER II: DEVELOPMENT OF A MODEL OF MYOPIA

The material presented in this chapter represents the first part of the dissertation. Three questions are asked: 1) Does evidence from the literature tend to support Bates? 2) Can an etiological model be developed on the basis of Bates' and psychophysiological concepts which is compatible with the literature on nearsightedness? 3) Should future research be conducted on the basis of Bates' conceptions? In other words, is it time to take another look at Bates?

Previous studies of refractive change in populations of subjects will be reported first. Literature concerning five approaches to studying the etiology of myopia as well as a critique of each approach is then presented. Next Bates' ideas are considered. Recent neurophysiological evidence on vision, attention, and brain function is then reviewed in light of Bates' model. This evidence emerges largely from the conceptions of Karl Pribram. A psychophysiological model of myopia is then developed on the basis of the information presented in this chapter. The model is compared with the literature on the etiology of myopia. The research questions are discussed and conclusions are drawn, and the discussion and implications for future research will be presented in the final chapter of the dissertation.

Studies of Refractive Change

Studies of refractive error have been reported in the literature in the past which examine variables of age, gender, dioptric level, and refractive changes over time. These methods of analysis were used in the present study. The results of the previous research will be an additional check on the reliability of this study.

The following studies are a review of data by which researchers examined samples of individuals over the past decades. In order to determine the most pertinent questions which relate myopic behavior to test probes, the past studies will be examined. These data will provide a standard or control to judge the reliability of the present study.

In the studies of nearly 20,000 patients by Tassman (1931), Jackson (1932), and Walton (1950) the percentage of myopes, emmetropes, and hyperopes at various ages shows that the relative frequency of hyperopes decreases over time; the emmetropes increase over time; and the myopes first increase, then decrease, then later increase in frequency with age. Information about individual variations in refractive error or refractive change is not indicated by this method of analysis, but it can be concluded from examining Figure 1 that myopia does spontaneously decrease in the young adult age group.

Analysis of the trajectory of refractive error (Bucklers, 1953) in Figure 2 shows that when one individual is measured over a number of years, the slope of the trajectory for some patients changes with age and that individuals seem to have their own unique rate of change. It will also be noted that some myopic patients seem to improve at various ages after the age of about twenty. Trajectory analysis provides one means for comparing refractive changes at specific age intervals.

Hofstetter (1954) in analyzing the refractive status of 579 patients taken from the files of a practitioner, computed the spherical equivalent of both eyes determined at each of two examinations. He further computed the average monthly change in this mean spherical equivalent for the twenty-one to thirty-four age group. The scatterplot for the distribution of changes is plotted in Figure 2. This method of data analysis spotlights the differences in speed for various refractive error levels. Examination of the plot shows little variation due to dioptric level; however, it will be noted that a number of myopic patients showed marked improvement in refractive error, i.e., they had velocity rates in the positive direction.

The next data analysis plots the changes in refractive velocity itself as a function of time. Figure 4 shows such a treatment by Slatper (1950). This method of analysis indicates that there are trends and predictive future changes; age is an important variable in the behavior of myopia; and that there is an indication of improvement in myopia in the late twenty year old population.

Four different methods of analysis have been presented showing the sensitivity of the probe for refractive information. The studies show that age is an important variable in refractive

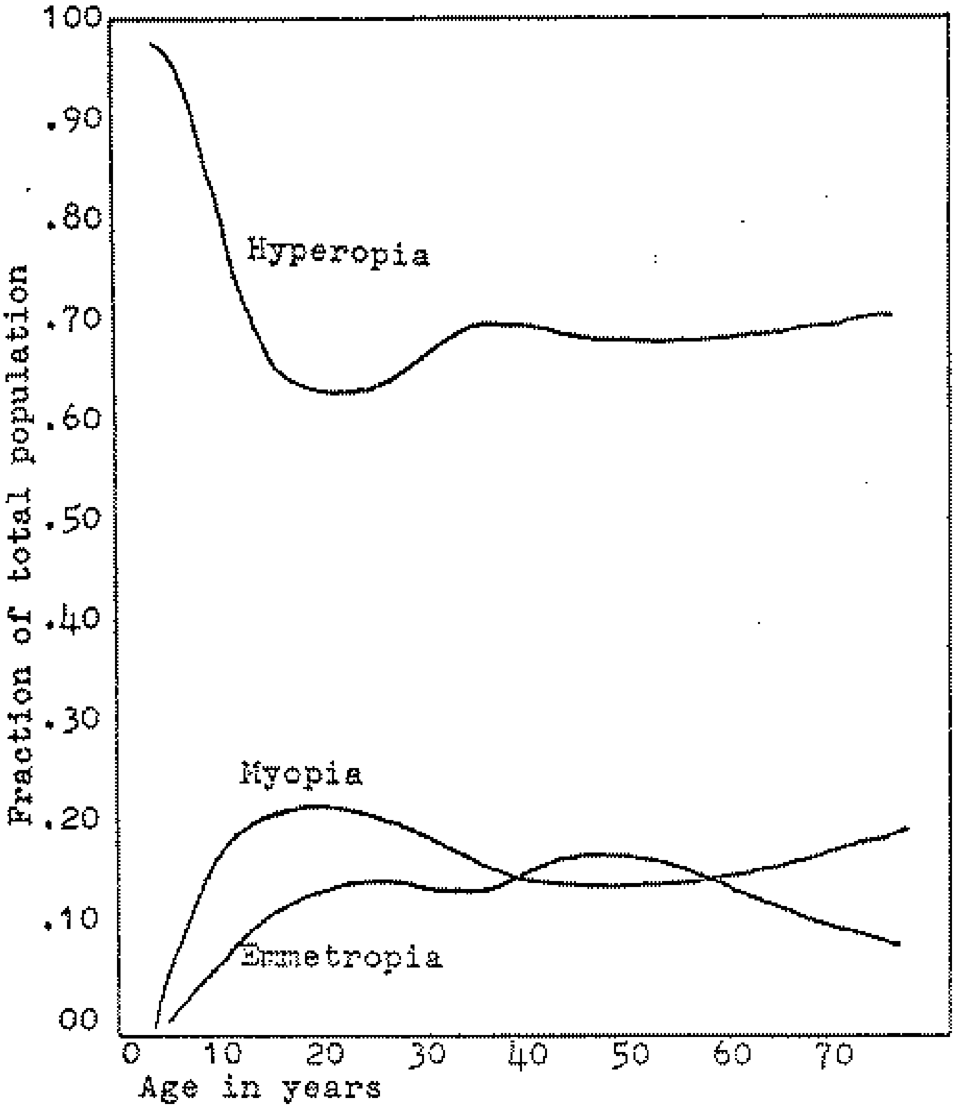


Figure 1 Fraction of total population with indicated ametropia at various ages

The fraction of emmetropes, hyperopes, and myopes for a total (non-clinical) population is plotted with respect to age. Myopia increased in this population until about age eighteen and then diminished steadily until about age forty-five when the fraction of human adults having myopia again increased. Adapted from Tassman, 1932.

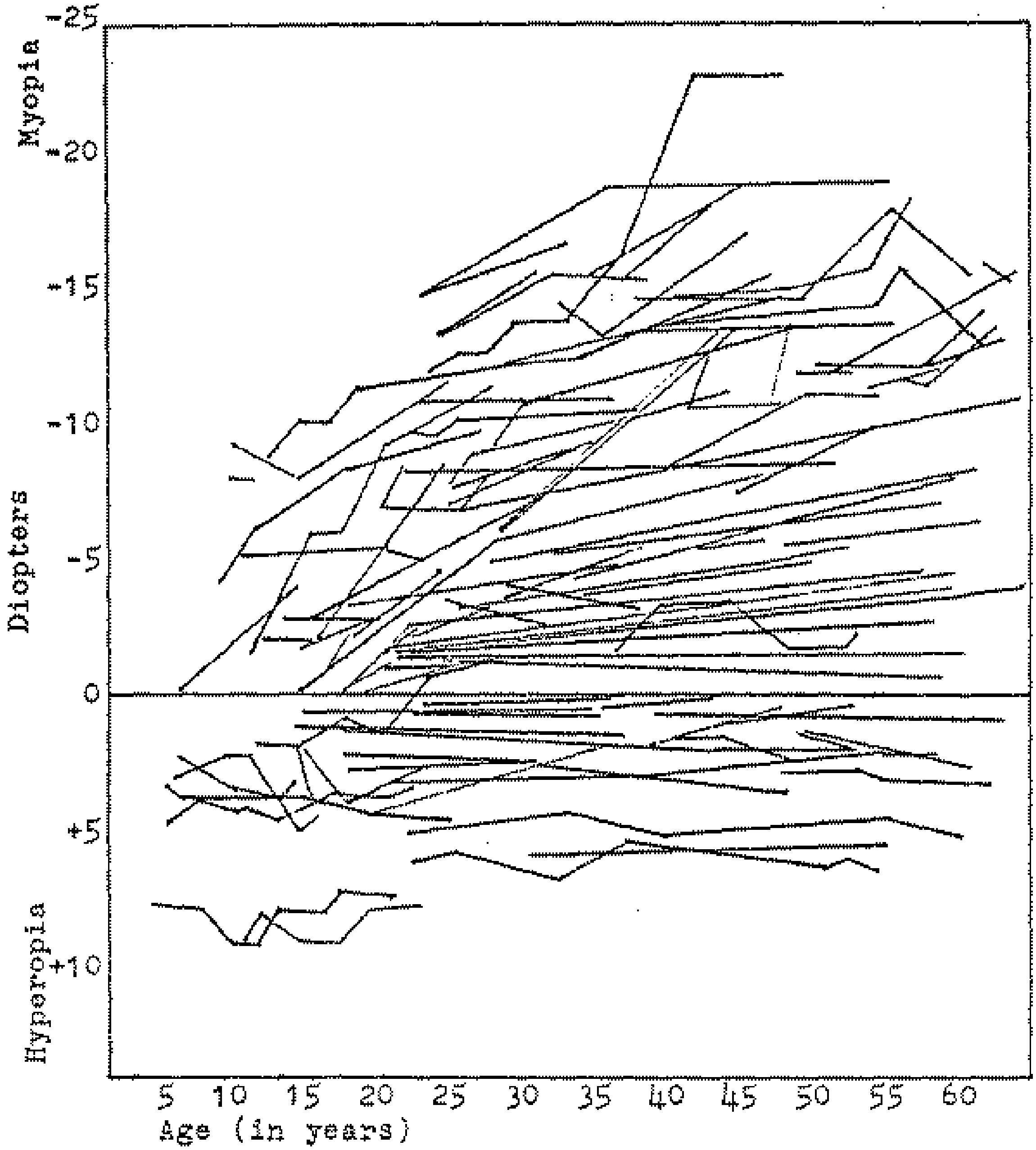


Figure 2 Trajectory of the refractive error at indicated age

Data was plotted from records of patients who were examined over a period of years. Each line represents one patient. The dioptric value of the refractive error is plotted with respect to the age at the time of examination. Note the apparent decrease in myopia for some patients. Adapted from Bucklers, 1953.

dynamic change but that level of refractive error is not so apparently myopic related. In all the studies there were indications that patients in their twenties and thirties often improve spontaneously.

The present sample of myopic patients will be analyzed by these methods and the results will be compared with the results of other studies.

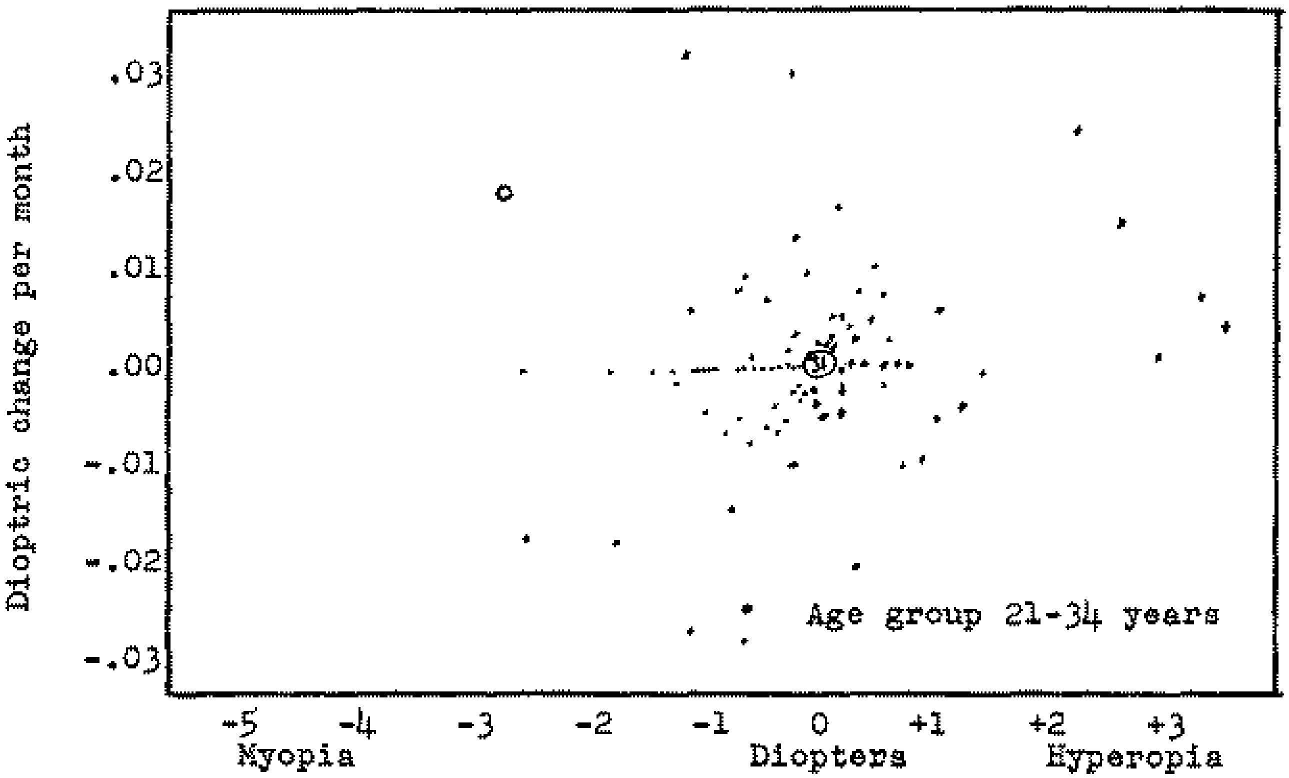


Figure 3 Dioptric velocity as a function of refractive error

Within this population (from Hofstetter, 1954) there appears to be little correlation, that is interrelatedness, between refractive error and monthly rate of change of refractive error. But note that some myopes (upper left-hand quadrant) appear to decrease. Each dot represents the average of two eyes. The average velocity for the present study is plotted as indicated by o.

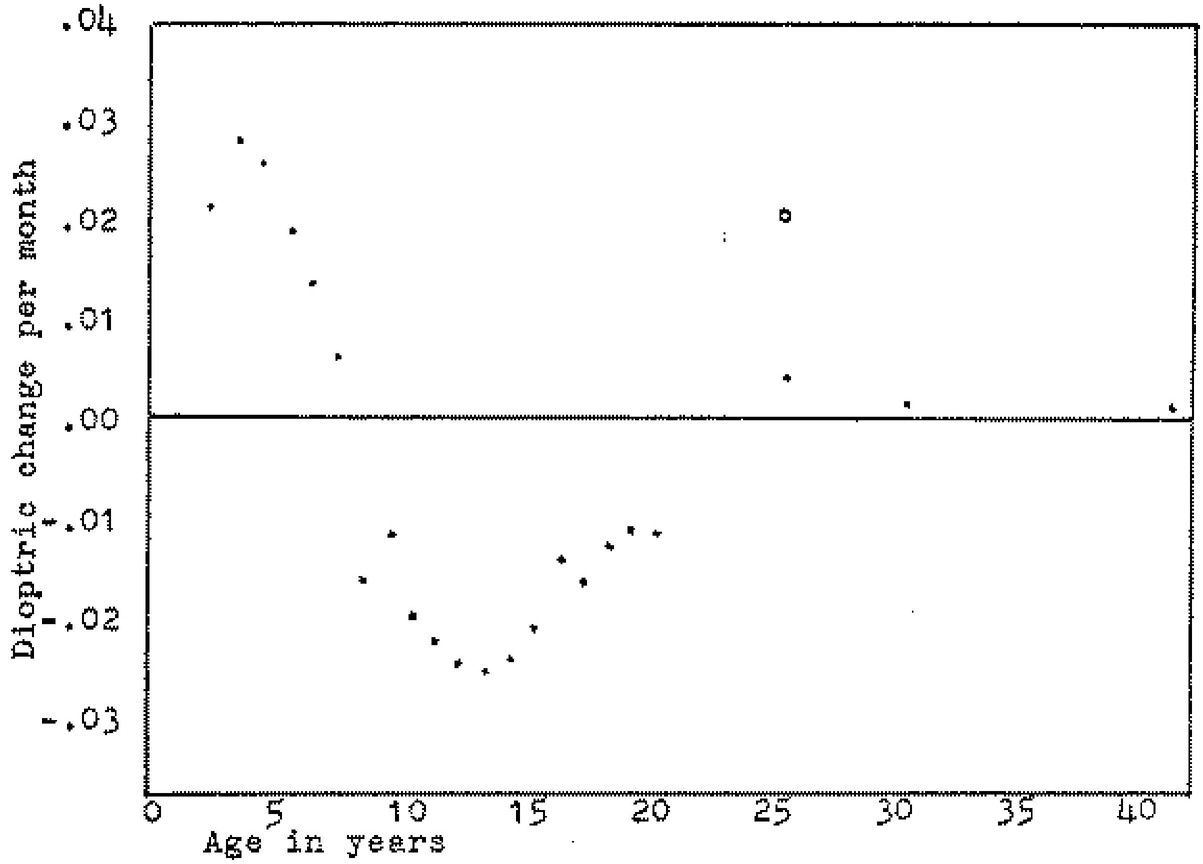


Figure 4 Dioptric velocity according to age

Each point represents the dioptric change per month averaged for a number of patients at a given age. The sign, plus or minus, of the dioptric velocity indicates the direction of change towards or away from myopia, but the magnitude is the magnitude of the change per month. The age group before age seven appears to be increasing in hyperopia but at a declining rate. After age seven myopia increases until about age twenty-five when it begins to decrease. The rate of change in the myopic direction increases after the age of seven, peaks at age fourteen, and diminishes until the mid-twenties when it reverses again away from myopia. The average rate of change for the average age in the present study is also plotted indicated as o. Adapted from Slataper, 1950.

Etiology of Myopia

There has been a wide range of efforts to determine various behavioral and physical characteristics of people with refractive problems. These efforts to determine the etiology of myopia have resulted in five general approaches to the subject (Kelley, 1958):

1. The Genetic Theory--Myopia is an inherited condition.
2. The Nutritional Metabolic Theory--Myopia is a product of the diet and/or metabolic factors.
3. The Conditions of Use Theory--Myopia is the result of the excessive use of eyes for near-point tasks.
4. The Normal Biological Variation Theory--Myopia and hyperopia are, in most cases, only the reflection of normal variation in the length of the eyeball and the strength of the eye's optical elements.
5. The Psychological, Personality, Emotion Theory--Myopia and hyperopia are symptoms of emotional habit attitudes, due to repressed emotion, as a direct defense against anxiety or as symbolic wish fulfillment, self-punishment, etc.

Genetic Theory: There are a large number of variables which make up the optical anatomy of the refractive accuracy of eyes (Figure 5). These include the curvature of the optical elements (surfaces of the cornea and the lens); the physical length (axial length) of the eyeball from the cornea to the retina; the positioning of the optical elements; the thickness of the optical elements; and the index of refraction of the cornea, lens, and media of the eye. Each of these variables might be influenced genetically. Until we know the nature of this influence on each of these components of the eye, we cannot know the genetic implications in the incidence of refractive error. A representative statement of this position has been made by Baldwin (1964):

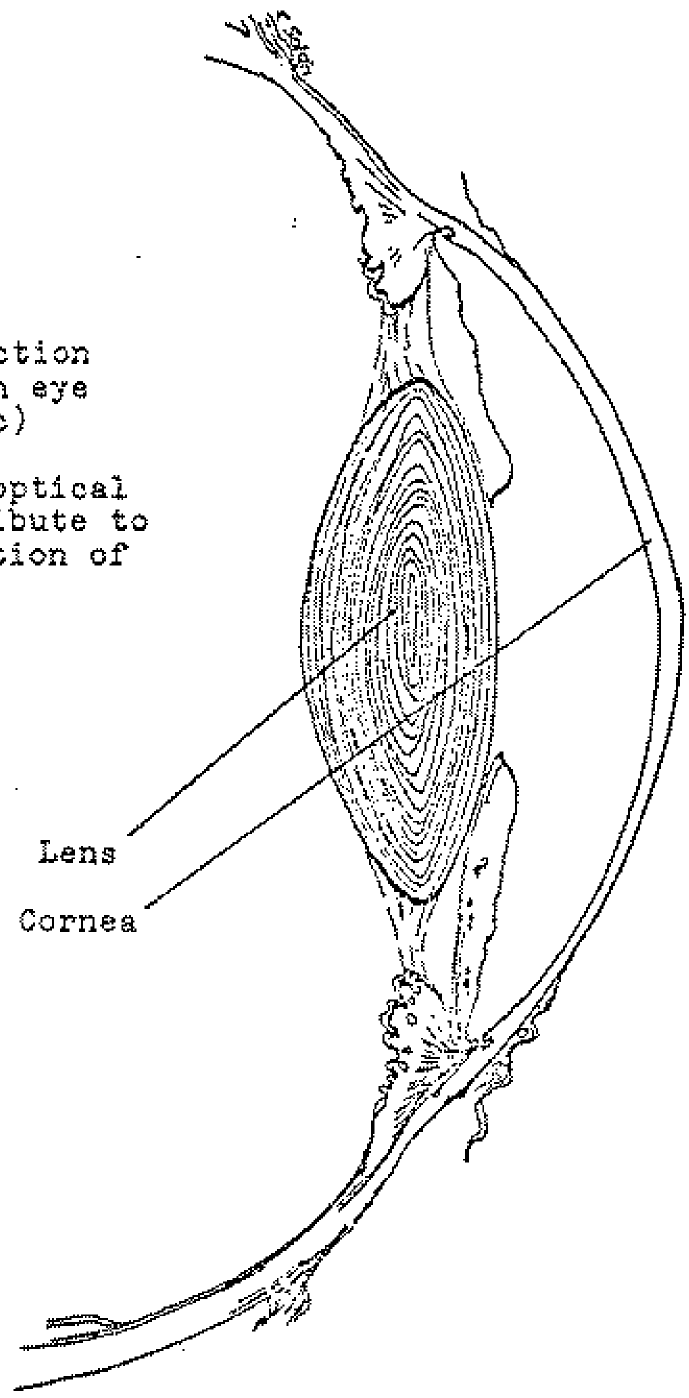
> It is known that myopia can be congenital without direct hereditary influence. It is also known that the incidence of both hyperopia and of myopia are influenced but not determined solely by heredity. These facts are demonstrable by studies of the refractive status of twins; studies of family pedigrees; and by noting the incidence of hyperopia and of myopia associated with genetic syndrones.

For a detailed review of the many investigations in this area see the textbooks of Frankeschetti (1953), Francois (1961), and Wardenburg (1962).

Some people do seem especially susceptible to conditions which cause refractive error, and the possiblity exists that these differences in people may be due to inherited constitutional factors (Henderson, 1934). The studies of identical twins by Hofstetter and Rife (1953), and Meyer-Schwickerath (1949) show a strong correlation among monozygotic twins but not to the degree required for a conclusive genetic theory.

Figure 5 Anterior section of the human eye (schematic)

Drawing shows the optical elements which contribute to the refractive condition of the eye.



Young (1958) concluded that it is unlikely that refractive error is determined primarily by hereditary factors.

Nutritional and Metabolic Theory: Price (1939) in a cross-cultural study, observed that myopia was less prevalent in those cultures which maintained their traditional diets. He attributed degenerative effects to the paucity of vitamins in cultures relying heavily on commercially prepared foods. He correlated the incidence of myopia with dental caries, as did Hirsch and Levin (1973). Young (1969) found a 59 percent incidence of myopia among sixth grade Eskimo school children, but only a 5 percent incidence in their parents, and none at all among their grandparents. This study yields evidence which counters the genetic theory of myopia, but it does not indicate that nutritional factors are necessarily the determining factor. Other cultural changes, such as the transition to electrical lighting and mass western educational methods also must be considered.

Livingston (1964), Reed (1947), Balcet (1948), and Smith (1951) found an increase in the incidence and degree of myopia among war prisoners and attributed this to malnutrition. McLaren (1960) observed a high incidence of myopia among children of the Gogo tribe in Tanganika who had suffered from two years of severe famine. Despite this finding he concluded from this and other studies in his publication, Malnutrition and the Eye, that: "an early and almost constant feature of nutritional deficiency is retardation of body growth. The eye is quite resistant to this influence, however."

The war prisoners and the Gogo and the Eskimo children were also subjected to other stresses of a serious and unusual nature; thus, malnutrition was not the only possible related variable.

Wood (1927), Feldman (1950), and Law (1934) found that young myopes tended to have depressed blood calcium compared with controls. Knapp (1939), Feldman (1950), and Stansbury (1948) did not find, however, that administration of calcium and vitamins (especially vitamin D) arrested the progress of myopia. There may be other reasons than diet for the children's low blood calcium.

Some endocrinological and metabolic relationships have been investigated. Botham (1931) determined that the basal metabolism rate in myopes was somewhat below normal, indicating hypofunction of the thyroid. Linder (1939) concluded that the greater metabolic demand of near work (reading) produced abnormal composition of nourishing fluids, softening the sclera. DeVreis (1950) also concluded that low thyroid was implicated in myopia. Lijo (1939) implicated the pars intermedia of the pituitary because of the association of pigment epithelium changes of the retina. Filatov (1940) also postulated hormonal influence in myopia and reported increased acuity in subjects given 10 percent saline intravenously. Borrello (1951) implicated hyposecretion of the adrenal cortex. Tasaka (1951) reported labile galvanic skin response in myopes. Temporary increases in myopia from one to six diopters due to the side effects of certain drugs have been found by several investigators (Dellaporta, 1942; Kramb, 1951; Stern, 1955; Back, 1956; Halpern, 1959; Galin, 1962). The drugs implicated included sulfanomides, corticotropin, carbonic anhydrase inhibitors, and autonomic blocking agents. The condition disappears within a few days after cessation of use of the drug.

<u>Conditions of Use Theory</u>: Studies have been made which attempt to show that there is a positive correlation between myopia and near work, reading, profession, urban dwelling (vs. rural), and intelligence (Borish, 1954; Kelly, 1958, 1971; Baldwin, 1964; Young, 1966). These studies generally, but not exclusively, showed a positive correlation, but it has remained difficult to say whether the conditions of civilization caused the myopia or whether myopes gravitate toward civilized conditions of living.

The facts supporting the use theory relate to the increase of myopia from a very low one percent in the under five-year-old group, 8.6 percent in the five to ten year-old group, 19 percent in the 10-15 year group, and 24.17 percent in the 15-20 year-old group (Tassman,1932). That there are other factors in the school environment which might be more relevant to the incidence of myopia are evident from a work in progress by Streff (1974). He indicates a very significant decrease in myopia in an elementary school which is designed to reduce stress and anxiety as compared with a control school.

The incidence of myopia is markedly lower among peasants or farmers than among highly educated and professional people (Kephart, 1953). But again, other factors than near work may be causal agents, including the combined predilection towards reading and less active pursuits with an undetermined third factor which is also related to myopia (Baldwin, 1964).

Young (1961) confined monkeys in chairs enclosed in plywood boxes, limiting their far point vision to 18 inches. The animals were kept confined nearly full time for the period of one year. Two control groups were also measured. One group was not confined; the other was confined to chairs in their cages. Young found an increase in myopia of 1.10 diopter for the experimental monkeys as compared with an increase of 0.19 diopter for the animals kept in chairs but not in boxes.

Young also studied three levels of illumination with caged and hooded monkeys, and found that the very low level lighting produced an increase in myopia of 0.124 diopter, the animals in the medium level showed a 0.75 diopter change but the high level of illumination was associated with a 0.25 diopter increase. He concluded as did Luclish (1939), in an early study on humans, that light levels were an important factor in the development of myopia. Young (1966) also found that wild monkeys had a significantly lower incidence than the laboratory monkeys. Again, because of the many uncontrolled factors which exist in such studies, the specific causal elements are not clear.

Despite the existence of these many studies, very little in the field is actually established. The research is marked by inconsistencies and much confusion. Because of the lack of conclusion and the feeling that little could be done about it, the causes of refractive error are scarcely mentioned in educational experiences and the students are left with the impression that, like Topsy, refractive conditions "just growed."

Normal Biological Variation Theory: This view states that refractive errors are due to normal variations present in all biological systems such as height, weight, finger length, leg length, etc. If height, for example, is measured over the total sample of adults in the world, and if this data is displayed in a graph, the curve would have a bell-like shape. This is referred to as a normal curve. Normal curves are descriptive of situations which have random causal factors.

However, if refractive errors are plotted against the number of people having a particular prescription, the resulting curve is not bell shaped. The peak, which is slightly farsighted, shows a heavy excess. Far more people are essentially emmetropic than would be expected if refraction were due to random growth factors. Some 75 percent of the population have essentially no refractive error (Sorsby, 1964). If the components of refraction are plotted individually against the number of eyes in the population, each component does seem to have a norm distribution. This has led to the conclusion that refractive emmetropia is produced by some active mechanism which correlates the various ocular components leading to clear focus at distance. This mechanism is called emmetropization. In cases of refractive error (ametropia) it is not the ocular components but the correlation of these components which is at fault. The mechanism which produces this coordination is considered to be automatic. Sorsby (1967) has stated:

> There is no free association of the axial length and cornea. There is instead a highly coordinated mechanism involving the correlation of four normally varying components: axial length, corneal power, lens power, and depth of the anterior chamber. The characteristic of the eye as an optical system is its marked correlation of these four components. It is this correlation which generally produces emmetropic and near emmetropic eyes. Generally the abnormal component is the axial length.

In 90 percent of the cases the axial length does tend to be short in farsightedness (Sorsby, 1967).

The mechanism producing self-focusing in the eye is considered to be the possible result of regulation through feedback between the fovea and cortical and subcortical control systems of the brain (Van Alphen, 1967).

Psychological, Personality, Emotion Theory: Kelly (1971), in a clinical but not experimental observation, described refractive error in Reichian body energy concepts. Using Bates' idea that myopia was caused by the co-contraction of the oblique muscles of the eyes, he assumed that this related to a flexor action and that, therefore, the energy flow is inward, contractive, toward the self. Hyperopia is caused by the rectus muscles and related to a kind of extension attitude, the reverse of myopia,i.e., outward, expansive, away from the self. The armoring posture of the myope is an attitude of blocking the feeling and expression of fear, and that of the hyperope is blocked rage.

Again, from clinical observation, Kelly described basic behaviorial and personality characteristics of myopes. He directed his attention to body structure and function and described the appearance of the eyes. The myope tended to be:

> Inward, introjective, self-oriented, shy and withdrawn as a child, "good" in school, child-hood temper tantrums rare, stubborn, emotionally inflexible, more at home with self, uncomfortable with others, often "off in day dreams", subvocal thought, comfortable with eyes closed, and retreats from visual perception inward. (p. 48)

In the myope, structure and function of the body tended to be:

> Underactive, often sedentary, body soft, sometimes flabby, throat, high chest, jaws, back of neck, scalp--chronically tense, jaw rotated forward, forehead back, shoulders forward, disconnected from feet up in the head, centered but poorly grounded, voice often breathy or husky, becomes hoarse easily, chest often depressed, breathing blocks on inspiration, fearful, blocking terror. (p. 49)

Kelly described myopic eyes as:

> usually large-looking, open, very little local armoring around eyes, squint, fusion problems not common, unusual to have pain, eye headache, eyes lack sparkle, brightness, eyes look down or away in anger. (p. 49)

Kelly was quick to state that these are the deeper layers of the myopic traits. Such fundamental armoring patterns are often covered over by more superficial compensating patterns of behavior and armoring, with maturity and experience covering to some extent the deeper tendencies:

> Although the myopic posture is fearful, it is not often yielding or acquiescent. There is stubbornness and determination expressed in the stiff neck and tense jaw. It expresses a layer of anger present in most myopes that must be freed before the more fundamental fearfulness becomes accesssible. Occasionally an angry myope is found, with a high stiff chest. This anger is superficial, easily accessible compared with the deep fear underneath. (p. 53)

Lanyon and Giddings (1974) grouped the clinical observation and speculation of others concerning myopic psychological characteristics. They supplied a list which includes such descriptive phrases as:

> shy, introverted, socially awkward, having relatively few friends, tending toward dogmatism and self-centered personality development. (p. 273-274)

The use of psychological testing of myopes in comparison with normals and with hyperopes has generally supported the observations of Kelley, et. al. Using the Bernreuter Personality Inventory, Mull (1948) found myopic college students to be more introverted. Inertia, over-control of the emotions, disinclination for motor movement, inhibited disposition, and strong need for social dominance were indicated for myopes in a study by Schapero and Hirsch (1952) using the Guilford-Martin Temperament Test. Rosanes (1966) interpreted results from the Rorschach test to demonstrate that myopes tend to have a high tolerance for anxiety; exhibit a "wait and see" attitude in stress situations; be cautious, doubting and compliant; and avoid confrontation. Young (1955) supported the hypothesis that distinct personality differences do exist between myopes and non-myopes. Myopic students scored significantly lower in need for exhibition and need for change on the Edwards Personal Preference Schedule. Stevens and Wolff (1965) measured the cognitive style of myopes as tending to pay attention to the differences between things rather than looking for their similarities.

The above studies were correlational, relying on univariant techniques. However, Young, Singer, and Foster (1975) changed the analysis from "t" tests and analysis of variance to stepwise discriminant analysis, followed by a factor analysis of the variables selected on the discriminant analysis. They examined 163 male myopes and 160 male non-myopes entering a military institute, using College Entrance Examination Scores; the Alport, Vernon, Lendzey Study of Values Test (SOV); the Edwards Personal Blank (SVIB). By their methods they could correctly classify 76 percent of their population. Consistent with the above studies, the myopes preferred high status, academically oriented occupations, and those which appeal to an introverted, accepting person.

Palmer (1966) examined the relationship between visual acuity and personality. It is well known that the error of optical refraction is not in an absolute relationship with visual acuity, and that although average visual acuity does increase in a regular way with refractive error in myopia, there is a spread of acuities for any refractive error. For example, a one diopter myope usually has 20/50 acuity, but people with one diopter myopia could range between 20/50 to 20/200 (Hirsch, 1945). This is generally known in the vision-care professions, but little notice is paid to these individual variations. Palmer found that poor acuity subjects (20/200 or worse) have more inward orientation and are less sensitive to external stimuli than the high acuity (20/20 - 20/40) group. Palmer concluded that myopia develops as a result of attempts to reduce one's contact with the external environment:

> For some individuals, unrestricted visual imput leads to painfully high levels of excitement, and...these individuals develop a myopic norm of vision or other visual impediment as a means of "gating," controlling or reducing stimulus input, to avoid being overwhelmed with large quantities of unmastered excitation. (p. 370)

Zeiger (1976) examined the relationship between personality and vision in terms of both the refractive error and the visual acuity. She attempted to differentiate myopes as to characteristic style, mode or being in the world. Her data on college students revealed that there were not significant differences between emmetropes and myopes when all myopes from low to high were taken together. When she divided the low, moderate, and high refraction myopes, and the high, medium, and low acuity subjects, she found significant differences for the students with moderate levels of acuity and refractive error. Applying a stepwise discriminant analysis to her data, she was able to predict 86.5 percent of the moderate myopes. Moderate myopes were seen to view the world as repugnant; they reject it and attempt to withdraw from it by creating a conceptual buffer and staying internal. The world view of the low myopes is like that of the moderate myopes, only low myopes show an even stronger aversion to the world. Their coping strategy is to be actively alert and active in challenging the noxious and irrational world.

High myopes looked generally more like emmetropes than did moderate or low myopes, implying a successful defense. Zeiger presents a very interesting conclusion:

> The low and moderate myopes show the problems and attitudes myopes have and the high myopes show solutions that myopes have. (p. 86)

This review of the possible causal elements which might contribute to refractive error has shown a wide variety of approaches to the problem. In most cases the results remain inconclusive. There are isolated facts scattered here and there, but there are no final conclusions. One factor does remain clear, however. The evidence existing in the scientific literature, while not mentioning Bates except in a very few psychological studies, generally does not contradict his thinking, and in some cases offers direct support. This will be shown in the next section, which develops a model of brain function compatible with much of what has been presented in this review.

Summary of Bates' Concepts of Etiology of Myopia

Bates made some important observations about the psychophysiological factors which contribute to myopia. An inspection of his ideas reveals a holistic approach which is surprisingly contemporary in its tone. The following summary is based on his 1920 publication, The Cure of Imperfect Sight by Treatment Without Glasses.*

Bates (1920) believed that vision problems are most likely functional responses to an unhealthy environment. These become long-term habitual responses to stress and are ingrained in the behavior of the visual-mental system.

He was aware that some conditions imposed on people living in modern cultures are unhealthy. In education, for example, where children are required to sit for hours at a time, conditions are produced which lead to "mental strain" (p. 256). Contributing to this strain is the influence of teachers who are "too often themselves nervous and irritable" (p. 256). Bates felt that the process of learning to learn was the purpose of education, but the emphasis in the school is too often upon grades and prizes. When the information in schools is presented in uninteresting, non-relevant ways, when the object of such prolonged attention has no inherent motivating interest, the student must develop a means of controlling the mind and body, compelling each by will to do its master's bidding. Some

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*This book is not generally available. Better Sight Without Glasses, published in 1940, (nine years after his death) is not the same as his 1920 book. It was reworked by his widow and lacks the magnitude of The Cure of Imperfect Sight Without Glasses.

children developing under these conditions can endure better than others, but some cannot stand the strain; "thus, the schools become the hotbed not only of myopia, but of all other errors of refraction." (p. 256)

Modern civilization forces individuals to exist under continual strain, worried, lost in thought, reviewing memoirs of past experiences which filter out present experience. It is only within the last decade that popular attention has begun to focus on the production of stress-related illnesses, a relationship which Bates pointed out over six decades ago in conjunction with his studies of refractive anomaly.

Refractive errors are produced by a strain or effort to see. But for Bates the act of vision is passive, just as taste and touch are passive. The letters on a visual test card are there, perfectly distinct, just waiting to be recognized. But when we make an effort, when we try to force the eye to see, the effort sends impulses to the eye and to the extraocular muscles which tense abnormally and distort the shape of the eyeball.

At the same time the eyeball loses its ability to aim and coordinate its movement as intended. Bates felt that the visual impairment is seldom due to a faulty construction of the eyeball itself, but rather to more central errors of functioning. The basic problem lies in "wrong habits of thought" (p. 106). Our culture, our activities, lead to the faulty mental habits which become normal ways of operating in the world. Patients must be taught to let the mind rest, to let the eyes become passive robots.

Only then will the visual system respond naturally and spontaneously to the exigencies of the environment.

Bates pinpointed the cause of refractive errors in the way the eyes are used, and hypothesized that it is in one's mental habits and attitudes that the fault lies. He related vision problems to temporary and habitual emotional attitudes. The anxieties of fear, of lying, or of being in a strange environment, cause the eyes to move in a myopic (nearsighted) direction. It was his philosopny that in an atmosphere of increasing anxiety myopia becomes epidemic, a contagious disease. The causes, then, as Bates saw them, are holistic, and they relate to effort and strain, mental habits which influence the perceptual and anatomical functioning of the eyes.

Development of the Model

A description of recent neurophysiological evidence follows which provides a model for understanding the mechanisms which underlie Bates' observations. The literature of neurology has continued to add new information about the process of vision. The technology of scientific inquiry has allowed us to get closer to some basic aspects of brain and muscle function than was possible fifty years ago. Perhaps Bates' evidence would receive greater substantiation in today's scientific community.

If mechanisms are found which explain how mental strain can cause the extraocular muscles to change the refractive state of the eye, and if the model can relate to the literature reviewed in the first section of this chapter, the questions of remediation and prevention would be more accessible to future scientific study. Such a model would also help to extablish Bates' credibility with the professional community and might also change the present paradigm of refractive treatment.

The scientist whose work appears to have the most relevance to this topic is Karl Pribram. His contributions to neurological thinking attempt to amalgamate the fields of neurology, physiology, and the behavioral sciences. The model developed in this section relies heavily upon his book Languages of the Brain (Pribram, 1971).

Pribram's approach to neurophysiology is unique in the field. In fact, he calls his area of research "neuropsychology" (Pribram, 1971) which is the multidisciplinary approach to research.

> ...my experiments, to a large extent, deal with determining by behavioral analysis the function of various systems of neural structures that make up the brain. This "systems" neuropsychology furnishes a halfway house between neurophysiology: the electrical and chemical study of the functions of nerve cells (and their parts), and experimental psychology: the behavioral analysis of functions of the organism-as-a-whole.
> The systems neuropsychologist perforce, therefore, listens to--and relates his investigations to--disciplines that have encountered their own concepts and styles to deal with these problems.

Pribram (1975) calls for a more comprehensive view of psychological processes to establish a system of what he calls "scientific psychology" which concerns problems of consciousness, perception, imagining and attention.

> ...paradox was encountered in experimental results that puzzled because they departed from those predicted and thus made suspect the predictive value of currently held views about how the brain was supposed to work. So new theories and theses were developed. (Pribram, 1971)

> At this stage, the theory must of necessity be primarily inductive, relying on a systematization of available data and drawing upon metaphor and analogy from more advanced knowledge concerning other physical, biological and social organizations for initial model construction. (Pribram, 1975)

Pribram is considered a pioneer in this area, and has been suggested as a possible Einstein of an emerging paradigm of consciousness (Ferguson, 1977). His grander ideas concerning the merging of "spirit and science" are beyond the scope of the dissertation, his

> research and theory encompass the whole spectrum of human consciousness: learning and learning disorders, imagination, meaning, perception, intention, paradoxes of brain function. (p. 2)

> The new theory has awesome implications in terms of the individual's potential to affect his life—his reality—and impressive power to unify disparate discoveries in consciousness research. (p. 3)

> Pribram's theory has gained increasing support and has not been seriously challenged. (p. 3)

This dissertation has drawn from only a small portion of Pribram's work. An attempt has been made to include information which would be accepted by more moderate investigators in the fields of brain and vision research. The adaptation of systems neuropsychology or scientific psychology to the practical problems in optometry and ophthalmology has not been attempted before now with the possible exception of Bates' (1921) and Huxley's (1942) writing.

Mental Control of Vision

In order to more easily understand the information presented in this chapter a descriptive model of sensory-motor organization has been created. There are different ways an organism can organize itself in its interaction with the environment. Perhaps the following example will illustrate what is meant by sensory-motor organization:

If we examine the normal behavior of a police force in a city, we see that the officers in squad cars (which are analogous to the sensory receptor systems of an organism) travel around the city looking for meaningful situations. They look for people who are breaking laws—who are running red lights, fighting in bars, being disorderly, behaving obscenely, selling or using illegal drugs, speeding, etc. When such a situation is perceived the parties are cited, arrested, reprimanded, or handled in some routine automatic manner. Information is recorded and filed, usually reported to the police headquarters, and, in turn, recorded in some government computer. In addition, the computer might be searched for past records which could be meaningful to the current situation. The police chief and administrative staff are usually unconcerned or unaware of any specific details. They only care that the level of activity is proceeding normally. No analysis of the activity is carried out, and the police chief can be speaking to the Lions Club or the PTA, golfing, or having lunch with the mayor, or filling the abstract, higher order, or future needs of the police department.

But if one of the patrol officers is wounded at the scene of a bank robbery, and has reported to headquarters that the bandits have escaped in a red Ford automobile, then the behavior and organization of the police department changes rapidly. Calls go out to all available patrol cars; the chief is summoned from his dinner; the central radio control operators are alerted to attention and stand ready to relay information to the chief; news media people converge to the scene, etc. The patrol cars now turn on their sirens and rush to the bank, ignoring any petty misdemeanors which occur along the way. The information of interest becomes all important as all the police look for the same thing: the telltale red Ford. At each sighting of a red Ford the information is transmitted to headquarters and then to the chief who analyzes the input, plots it on a map, and alerts and directs the other patrol members according to the emerging pattern. This feedback loop is continued until the pattern becomes predictive and a feedforward plan is plotted out on the central map: the red Ford is going west on Highway 1, will arrive at the bridge in nine minutes, patrol cars and officers are directed to seal off all exits to block off the bridge, and a helicopter covers the scene until the offenders are apprehended. The all-clear is given and patrol cars are again on the lookout for shoplifters, flashers, and student protesters. The novel episode has been properly integrated into the records of the police files, and the police chief can return to his dinner or playing cards with the newspaper reporters.

This is an example of the simple reciprocal operational organization of a peripheral-central sensory-motor response system. If the red Ford silently disappeared or if the bandits took over a school bus full of children as hostages, attached and commandeered a police car, or went to the local airport with a large bomb, the process would become more complicated and pressures within the department would be greater. The officers on patrol would become more nervous and trigger-happy and the chief might lose his job. As long as the situation persists, the department cannot return to normal functioning, yet neither can it maintain its vigilant state indefinitely. Thus the distinction between the two modes of police organization becomes less clear, with the result that the system comes under increased pressure to develop new levels of control to cope with the confusion and uncertainty of the situation.

The brain is constantly reorganizing itself according to its needs and according to forces in the external world. In the above model, the police officers in their squad cars correspond to the sensory receptors. The police radios represent the neurological transmitting elements which communicate information from the receptors to the appropriate brain stations and from the brain to the receptors. There is two-way communication. The police headquarters and police chief correspond to the brain.

In dealing with the situation brought about by the bank robbery and wounding of the police officer, the process of reorganizing the various parts of the police force represents a model of how individuals can reorganize themselves. An extreme event can alert the brain to bring about changes in sensory organization. The organism attends only to pertinent aspects of the environment; it ignores the rest. Instead of merely receiving and recording data from the outside world, the brain begins to reason and to plan, and to control the action of the total organism in more goal-dependent ways. If the situation resolves itself quickly, the system recovers its original organization. If the situation persists, the organism continues to alter its function, constantly changing, vigilantly directing and controlling its action according to new data. A sufficiently stressful situation, or one prolonged for too long, can bring about chronic changes in the organism (Pribram, 1971; Bates, 1920).

Neurophysiological mechanisms and models have been discovered and conceptualized which can account for such behavior in humans. There is evidence that brain centers have direct control over visual input even at the retinal level.

<u>Central Control of Visual Process</u>

Evidence describing central control over sensory input has been produced by several experiments (Pribram, 1971). In one experiment a tiny electrode is inserted into a lateral geniculate nerve cell. The lateral geniculate is located in the subcortical brain and is the next step in the visual processing pathway after the retina. The electrode measures tiny electrical nerve discharges in the nerve cell as it responds to visual stimulation through the eye. By presenting visual targets at various places in the visual field, the response characteristics of the nerve cell can be measured and mapped. In some locations the visual targets will cause the cell to alter its electrical discharge rate, in other locations there is no change in discharge rate.

In the geniculate and retinal cell experiments the receptive fields are generally round in shape and usually have a central area which, when stimulated, causes the cell to fire more rapidly. Surrounding this central area is a peripheral area which inhibits the firing of the cell. Such receptive fields are said to have an on-center and an off-surround. Pribram (1971, 1974) found that the size of the central area of the receptive field did not always stay the same. The size of the central area changes if specific brain areas are electrically stimulated while a receptive field is being mapped for a given nerve cell in the lateral geniculate.

Two areas of cerebral cortex have been shown to influence the neural organization of visual input (Pribram, 1971). One is in the inferior posterior temporal lobe cortex (also known as the visual association area). The other is in the frontal lobe cortex (also known as the frontal, frontal cortex, or frontal limbic). See Figure 6. If the visual association cortex is electrically stimulated, the receptive field central area measures markedly smaller than when there was no stimulation of cortical brain areas. If the frontal cortex is stimulated instead, and the receptive field is again replotted, the reverse effect is recorded; the receptive field center now plots larger than before. The size of the visual-spacial organization is changed by stimulating selected areas of the brains cortex.

Evidence for central influence on the retinal organization is obtained when the intensity of electrical discharges in the optic nerve is compared during stimulation of these same brain centers. The discharges measured in the optic nerve are visual responses to two light flashes which stimulate the retina. One light flash is followed quickly by the second. If the electrical nerve discharge to the second flash is less than it was for the first flash, we know that the second response was affected by the first and that the retina had not recovered from the effects of the first flash. When the association cortex is stimulated and the experiment is run, it takes a longer time for the retina to recover from the first flash (ie., the flashes have to be separated by a longer time interval for equal discharge), and a shorter time when the frontal cortex is stimulated (Pribram, 1971). This is direct evidence of the two-part control that the brain has over the visual system at the retinal level. In addition, non-visual input (such as tapping the paw or auditory clicks) changed the electrical activity of the retina in cats (Pribram, 1971).

Brain Organization for Two Types of Focusing Attention

If a rabbit notices a potential predator, it will become alert, set up an internal plan of action (flight) and implement the plan. If its response pattern is intact, it will run quickly

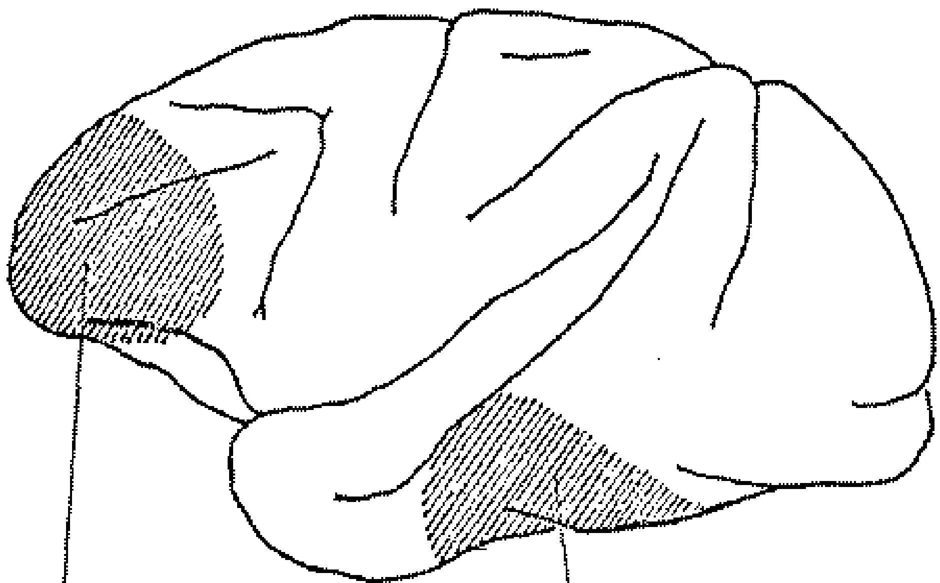

Figure 6 Schematic view of the brain

Shows the approximate locations of the frontal lobe cortex and the inferior posterior temporal lobe cortex. Based on Pribram, 1971.

to cover and will ignore any appetizing berries it comes across along its path. It thus selects which aspects of the environment to attend—the internal plan, or the external stimulation. Once it reaches safety and the danger has passed, it will again search the environment for potential food, sex, fight, or flight stimulation. Thus, it can selectively open itself up to the external environment or close itself down.

Posterior Organization

The brain is essentially a decision-making mechanism. The organism must be aware of complexities of input which lead to actions. It must attend to information relevant to decisions. It must recognize the familiar and distinguish the novel. The association areas of the posterior cortex, in conjunction with lower brain centers, are involved with search processes. It is involved in organizing and preparing for motor actions such as voluntary saccadic eye movement (see definition of terms). It attends to overall, broad perspective input and is concerned with making decisions about what to do about what is perceived (Pribram, 1971). Its action is analogous to the routine situation in the police department model. Police are moving about the total environment searching, acting, and handling isolated events without much direction from headquarters. The situations are routine; they are recorded in the log book and then forgotten.

This is the function of the association complex of organization: making matches between outside events and long-term knowledge, seeing much, but not stopping to analyze deeply what is there. There is no episodic sense or temporal continuity. Each event is a relatively isolated, acted upon, and then dismissed experience. In reading, for example, some children are very adept at naming the letters or calling the words but at the end of a paragraph they cannot tell you what they just read. There is no sense of continuity, no context, just a series of unrelated events matched to long-term memory. A person can flow along, moving from one experience to another, attaching no meaning to the experience. This seems to be the style of the association are (Pribram, 1971).

Frontal Organization

The frontal cortex and its lower brain connection serve a different function. The frontal system centers on specific details in the environment. It organizes sensory input in order to categorize, record, and identify surprising or unique input. It shuts down awareness of the larger aspects of the environment in order to concentrate on and identify smaller details. It provides a context and a meaning for the input.

When the bandit robbed the bank and shot the officer, the police headquarters was alerted and the police chief was aroused. The police chief is analogous to the frontal cortex. The chief alerted the patrol officers and altered their action, gathered and organized the incoming information and finally created a context for meaningful action. The frontal system seems to be involved in arousal and discrimination tasks; it works to make the unfamiliar familiar. It closes the organism down with respect to awareness of the greater environment, and it curtails motor action (Pribram, 1971). Thus, the mental system of apprehending the world and acting on it is seen to be a product of two major brain organizing systems—the frontal and the posterior—and a third system in the limbic area of the brain, the hippocampus, which controls and coordinates the other two, Figure 7. These changes in configuration of brain organization include the peripheral sense organs themselves.

Central Control of Visual Acuity

In the case of the organization of the eye, the size of the central area of receptive fields recorded from retinal ganglion cells changes depending upon cortical stimulation. Frontal stimulation causes an expansion, and posterior temporal stimulation a shrinking of the receptive field center. These changes in spacial organization are due to lateral inhibition or contrast enhancing mechanisms which are abundant in the nervous system (Pribram, 1971). The area of a receptive field is large compared with the area of a photoreceptor (rod or cone); individual rods and cones connect with many ganglion cells and each ganglion cell receives connections from many rods and/or cones, Figure 8. Any given area of retina does not belong to any one particular ganglion cell but instead, many ganglion receptive fields overlap the area. The receptive field center is surrounded by an inhibitory border area (i.e. instead of causing the ganglion cell to fire more often, stimulation of this portion of the receptive field results in a decreased

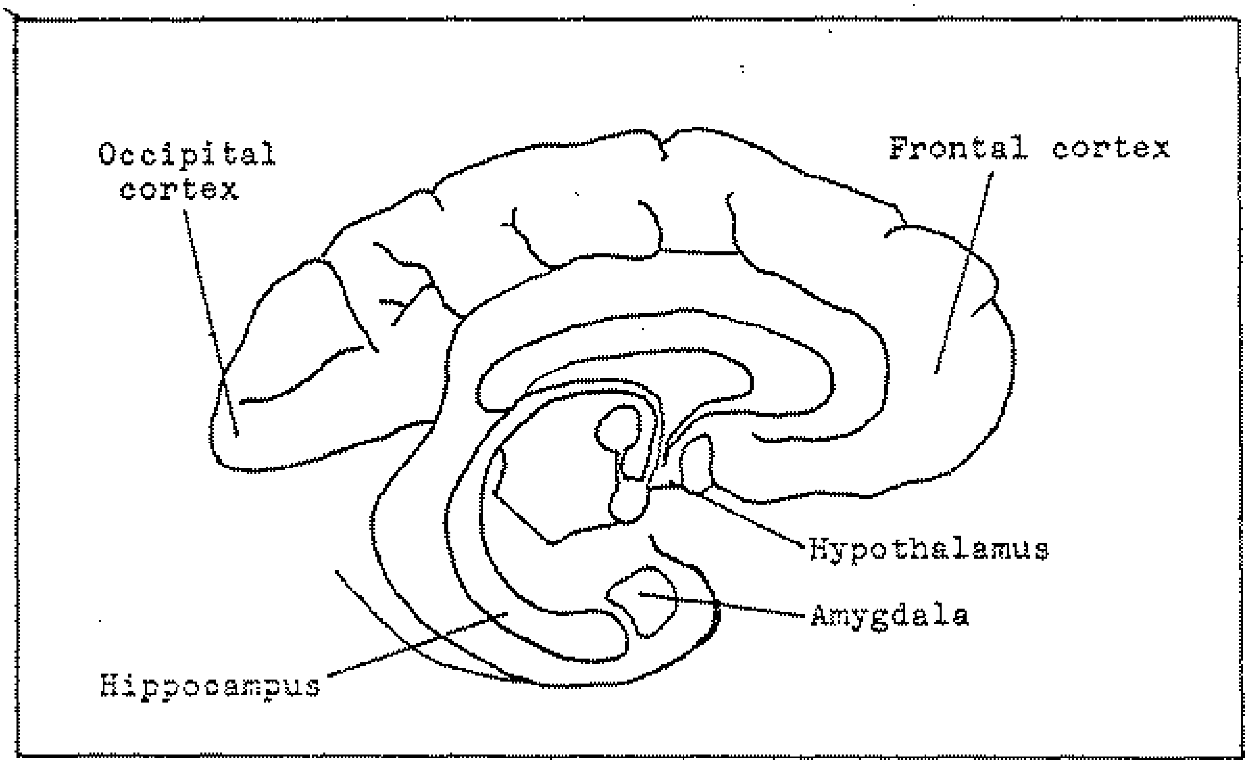

Figure 7 Schematic cross section of the brain

Shows the locations of the hypothalamus, amygdala, and the hippocampus.

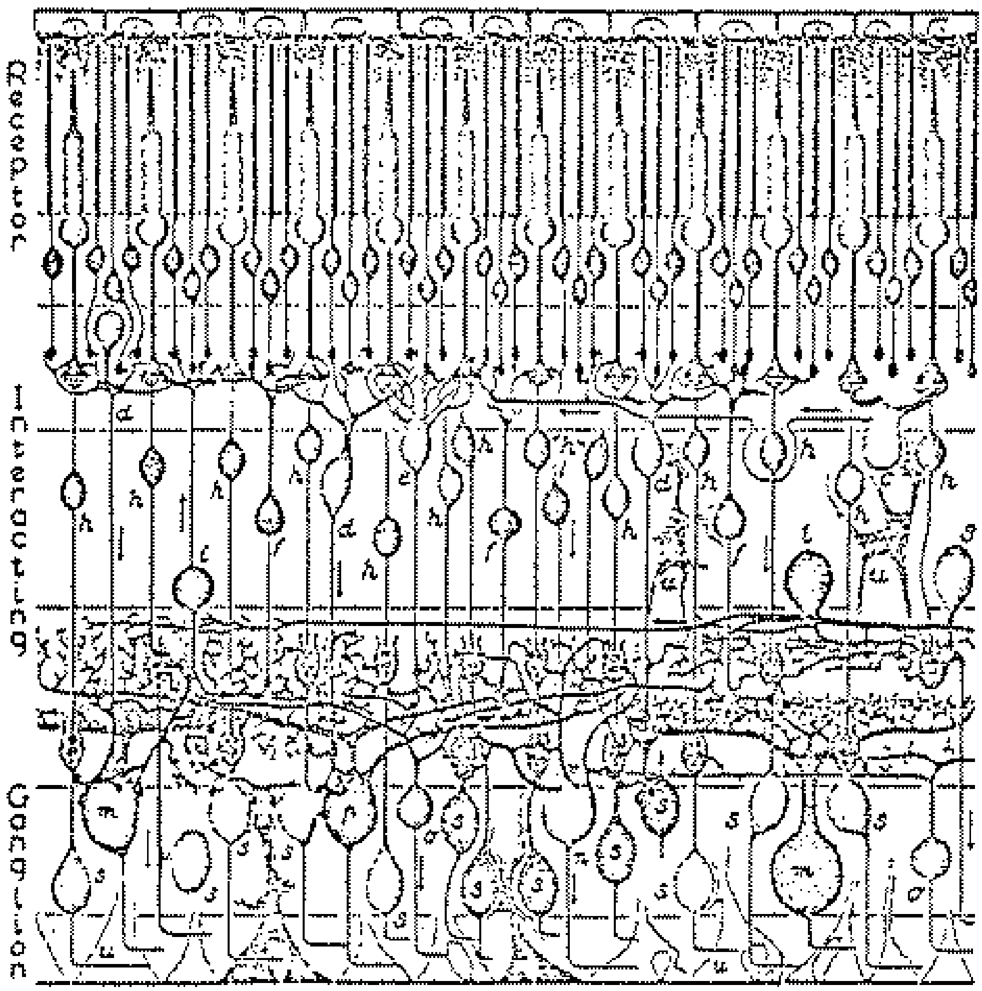

Figure 8 Scheme of the primate retina

Rods and cones connect with many ganglion cells and each ganglion cell receives connecions from many receptors. From Polyak, 1941.

firing well below the spontaneous rate for that ganglion cell) (Pribram, 1971). Stimulation of one area of the retina leads to inhibitory interactions among adjacent neurons (ganglion cells). This facilitates the sharpening of spatial patterns.

Activation of the frontal brain organization acts to increase the contrast between adjacent areas of the field. This increases the resolution of details and, thereby, increases the acuity of the visual system. Posterior association cortex activation works in a reciprocal manner; resolution of detail is decreased and, therefore, visual acuity is reduced.

Changes in visual acuity are thus dependent upon brain and retinal states as well as on the focus characteristics of the optical system of the eye. The frontal and posterior reciprocity and its effect upon contrast enhancing mechanisms provides a much needed explanation for the variability in the relationship between visual acuity and refractive error. It also explains how acuity can improve without a corresponding change in refractive error as reported by Kelley (1958), Zeiger (1976) and others.

In summary, Bates (1920) suggested that the underlying cause for refractive error was mental strain or loss of mental control and clarity which, in turn, is caused by emotional, intellectual, and social factors. The information from the neurophysiological studies presented above provides a basis for understanding what might be happening in the brain and sensory systems and tends to support Bates' seventy-year-old concepts. The above information also provides a neuropsychological explanation for much of the psychological literature on near-sightedness.

Emotions, Mental Strain, and Vision

Kelley (1958) found that the threat of electrical shock created a myopic response in eight out of ten normally emmetropic boys. Bates (1920) reported an instance of a girl whose myopia increased while she was telling a lie. Others (see Chapter Two) have reported some chronic personality and anxiety patterns correlated with myopia. This section will describe this relationship of vision to emotion in neurological terms.

The Arousal System

The frontal system of neuro-sensory organization works in conjunction with other areas of the brain. These include the amygdala and the reticular system of the hypothalmus and brain stem (Pribram, 1971). This frontal system is intimately related to the arousal-orienting response reactions of the organism. Whem an animal is alerted by a novel situation the frontal system is engaged and the visceral-autonomic centers in the core brain are stimulated. Changes occur in breathing, heart rate, blood flow, pupil size, skin resistance, etc., and the motor system orients (turns towards the action and then freezes). There are also changes in electro encephalographic measurements; the brain wave rhythm increases in frequency and becomes desynchronized. If the stimulus is especially strong, surprising, or appears especially dangerous, the reactions of fight or flight take place.

In the example of the police department, the novel situation stimulated the wounded officer to alert headquarters and arouse the police chief, which action, in turn, changed the sensitivity and reaction of the entire police force. In the brain, novel stimulation changes brain function in an analogous way through the arousal system. The amydgala and hypothalmic structures are the control and activation centers of the arousal response. If the frontal cortex and/or the amygdala is eliminated from the brain (through accidental brain trauma or through experimental tampering) the visceral-autonomic aspects of the arousal response disappear, but the behavioral-motor and electro-encephalic reactions remain intact, often continuing to react for longer periods of time than under normal, intact brain conditions (Pribram, 1971). The amygdala and hypothalamus are commonly known to be centers for emotional reactions (Bard, 1961)(See Figure 7). Thus the brain organizes itself according to the stimulus-response demands of the situation and part of this reorganization involves the emotional-motivational centers of the brain.

Motivation and Emotion

According to Pribram's (1971) model, motivation and emotion are reciprocally connected and are expressions of the relationship between perception and action. When information is familiar to the organism it is immediately meaningful and is recognized and acted upon without effort expended to classify or understand it. The response pattern in this case is mainly motor (action) with little need for the autonomic changes which an especially novel environment stimulates through the arousal reaction.

If the information is not familiar and is confusing, threatening, or overwhelming to the organism, a different brain process is engaged which includes arousal, frontal organization and vigilance (i.e. the information will be processed until it is understood).

Suppose the rabbit, in our previous example, were involved in an emergency wherein the environmental stimulation overwhelmed the rabbit's ability to act in a meaningful way. For example, if a dog came running towards the rabbit from the left, the rabbit would alert, go into its flight reaction and run for cover to the right (motivation leading to action). If another dog suddenly appeared coming from this new direction, the rabbit would freeze. It would be at a loss to make a decision about where to run (emotion and inaction). it could make a break for possible cover in a new direction or it could remain frozen in position. But the situation would no longer be automatic and the rabbit would have to organize itself to cope with its uncertainty.

According to Pribram (1971), the organism has two ways to internally adjust to its uncertainty. It can increase the rate at which it processes information (frontal organization) or it can decrease that rate (posterior organizing action). It can cope by opening to external input through enhancing its monitoring of the external environment, or it can restrict input by minimizing the external and focusing on internal configurations. The first way implies motion or motivation, the second emotion. When the variety of perceptions exceeds to some considerable extent the repertory of action available to the organism, it feels "interested" and is motivated to (i.e. attempts to) extend this repertory. Whenever this attempt fails, is nonreinforced, frustrated or interrupted, the organism feels emotional, (i.e. the coping mechanisms of self-regulation and self-control come into play). Furthermore, emotion is likely to occur when the probability of reinforcement from action is deemed low. Pribram (1971) states:

> The suggestion is that ordinarily interests, feelings of motivation and emotion, occur when the organism attempts to extend his control to the limits of what he perceives. To the extent that this attempt appears (on the basis of trials or experience) feasible at any moment, the organism is motivated; to the extent that the attempt appears infeasible at any moment, the organism becomes, of necessity, emotional. (p. 212)

Since the frontal system is so intimately involved with the arousal system, and the arousal system is an autonomic-visceral brain system dependent upon the homeostatic balances in the body, it is in this system that we have such a close tie with emotions and nutritional and metabolic balance.

Vigilant Attention

An area of the forebrain called the hippocampus seems to be responsible for controlling or prolonging attention (Pribram and McGuinness, 1975). The ability to voluntarily prolong states of attention is interfered with when the hippocampus is lesioned. In experimental animals, with hippocampus lesions, voluntary control over brain organization decreases. They are left at the mercy of involuntary reactions, and either sensory input or motor output dominates behavior. The voluntary control operations are absent (Pribram and McGuinness, 1975).

In higher order tasks, such as categorizing and reasoning, a prolongation of the states of arousal and readiness for action is maintained voluntarily to allow for the internal rehearsal necessary to organize the perception or response pattern. Such tasks are called vigilance tasks and they require the voluntary disruption of the stimulus-response pathways in the brain organization. These tasks might be termed the "What is it?" (categorizing) and the "What is to be done?" (reasoning) modes of behavior. In the case of the rabbit, for example, when the predator was noticed, the defense reaction was fully automatic, the sensory organization closed down to external cues and focused upon internal plans of action.

Categorizing Tasks and Movement

In categorization there are autonomic as well as muscular changes in behavior. In studies of heart rate and muscular movement (Pribram and McGuinness, 1975) ability of children to match photographic slides from memory (vigilant attention to categorize) was accompanied by heart decleration and decreased motor response. The longer and more decelerated the heart rate, and the more the reduction of movement, the more likely the children were to make a correct match. A similar relationship was found with I.Q. and heart and muscle changes. The ability for the brain to organize itself for this skill (vigilant attention for categorization accompanied by autonomic and motor changes) seems to be developmental and occurs earlier in girls than in boys. The ability increases linearly with age for both sexes. This means that the ability to maintain attention to outside stimuli, while at the same time retaining awareness of recently perceived events which are now stored in memory (short-term memory) is related to a brain organization which produces a decrease in heart rate, an inhibition of motor activity (including the muscles of breathing) and other physiological changes.

> When the organism prolongs attention to the complexity of input in a categorizing discrimination task, he reduces extraneous noise by eliminating random movement. Heart rate then adjusts to the reduced demands of the system reflecting characteristics of the somatomotor system (Pribram and McGuinness, 1975)

Reasoning Tasks and Isometric Contraction

Reasoning also requires vigilant attention but it is not the same as categorizing. In categorization processes, external information is attended for prolonged periods of time. Arousal precedes action. Reasoning, on the other hand, seems to be more involved with processing alternatives for action; motor readiness for action is internally rehearsed until a solution is found and then the action takes place (either externally as behavior, or internally as imagery or imagination) which is now monitored by the sensory apparatus. In reasoning tasks action precedes arousal. Categorization, the discriminating and registering of small details of the external world, seems to be related to frontal organization and arousal; reasoning (internally rehearsed alternatives to action) appears related to the posterior cortex control systems.

Reasoning seems to involve the activation of a special form of muscular and metabolic activity which is related to sympathetic nervous control. Oxygen uptake in the muscles and blood flow to the muscles decreases to much lower levels than in usual somatomotor activity. Muscle force increases but "the muscles 'work' under the special conditions of isometric contraction" (Pribram and McGuinness, 1975). An example of this is the common practice of holding the eyebrows close together in an isometric contraction during reasoning tasks. In addition, optometrists are aware of changes in the eyeball during reasoning tasks such as math problems (e.g. Apell and Lowry, 1959).

Cognitive State and Refractive Error

Gesell (1949) provides an in depth description of changes in refraction (including myopic, hyperopic, and astigmatic variations) and retinal characteristics (the color and brightness of light reflected off the retina) observed during categorizing and reasoning behavior. These changes were observed during retinoscopic examination of children while performing various tasks. They (Gesell, et.al., 1949) note that:

> The variations which are observed in a single session in a single child are not random, but are correlated with variations in his visual acts....The reflex showed a definite against (myopic) motion when the child fixated the examiner's face. Similarly, the reflex brightened and showed an against motion when an interesting toy was proffered. As the infant's hand came in, there was a with (hyperopic) motion, followed by brightening as the hand grasped the toy. During tactile-visual exploration of the toy, there was a succession of against, with and against motion. The slowness of the motion suggested a wide range of oculocortical manipulations. (p. 176-177)

They further state:

> The eye, like the hand (to say nothing of the mouth), is an organ of manipulation, and in higher adjustments each is separably, and both are conjointly, governed by the cortical brain. In the last analysis, it is the brain which appropriates the outer world, whether manually, orally, or ocularly. It does so by a projective process, but this is a two-way, reciprocating process—a directional process which emanates from within the self, goes out, and then returns within. Thus projection both externalizes and internalizes. These two distinguishable phases have their counterparts in the plus-minus (myopic-hyperopic) and minus-plus adjustments of the oculo-manual prehensory apparatus. Skeletal, visceral, and cortical factors are simultaneously involved, but the manifestations are not fortuitous. They are lawfully correlated with the functional and maturity status of the action system. (p. 177)

It is this author's contention that the retinoscopic changes observed and described above are due to the isometric muscular and the metabolic changes which occur during categorizing and reasoning tasks. This is certainly in concert with Bates' ideas about the development of myopia (and other visual problems), which Bates (1920) related to peripheral manifestations of mental strain: "Every thought of effort in the mind, of whatever sort, transmits a motor impulse to the eye; and every such impulse causes a deviation from the normal in the shape of the eyeball." Bates held that refractive problems are due to habits of thought which develop as a result of the unhealthy conditions imposed upon individuals in educational and vocational activity. The cure, he felt, must reside in finding ways to change these faulty habits which lead to loss of mental control and to poor vision.

Bates (1920) claimed that even the circulation of the blood in the eyes and other parts of the brain was influenced by habits of thought. Confirmation of this idea has been indicated by studies of local differences in cerebral blood flow related to effortful problem solving behavior (Pribram and McGuinness, 1975).

According to the model of brain organization described above:

> ...physiological (including muscular) responding during stimulus intake will depend entirely upon how a task is constructed and whether it is primarily a categorizing or reasoning problem (Pribram and McGuinness, 1975).

In situations where attention is maintained (categorizing) while an organism is involved with problem solving (reasoning), metabolic and muscular changes occur. If these conditions are maintained for long periods of time, they may become structured into the response patterns of the organism.

The task variables which affect arousal and activation, and the effort required to retain information during categorizing and reasoning include the information content of the relevant stimuli and the degree of concentration required, i.e., the "cognitive effort." Cognitive effort is defined as the measure of attention paid to increase or maintain the efficiency of a communication channel (Pribram and McGuinness, 1975). This cognitive effort arises through voluntary restrictions placed upon one's response patterns in an attempt to obtain a goal.

The reading task which has so often been related to myopia (Chapter II) certainly falls into the category of skills which require simultaneous categorization and reasoning processing. The reader must search and discriminate words and letters, register the information, digest its meaning and at the same time vigorously forstall the fading of recently acquired information (delay closure). Retinoscopic fluctuations in brightness and color of the light reflected from the retina, and changes in refraction in myopic and hyperopic directions and in astigmatism accompany the level of interest or disinterest, familiarity or unfamiliarity, and complexity of simplicity of the reading process (Getman, 1960). Myopic changes are commensurate with interested reading or unfamiliar or complex material.

Interacting with the everyday environment in many ways is similar to reading, and research exists which supports the notion that myopes are involved in a continual effort to see and to organize their perception of the world. Stimulation from the environment is categorized (what is it?) and actions are rehearsed (what is to be done?) for most people most of the time. But when an individual has high self-expectation and is motivated to act "correctly" ("...myopes are good children," Kelley, 1971) and to achieve high success (Young, 1967) the world-out-there must be read constantly and with great cognitive effort in order to conform to the self-directed (and externally imposed) goals. This is expecially true when the goals are unrealistic.

Eye Movement and Mental Strain

Bates observed the characteristic eye movement behavior of people with good, natural vision and compared it to the behavior of people whose vision is poor. He found that those with poor vision tend to hold their eyes in one position for prolonged periods. "If an eye with poor vision cannot see a particular point it stays there trying to make it out by staring at it" (Bates, 1920). An eye with good vision will shift its fixation, moving around looking from point to point until enough of the context is known for the image to become clear. It does not try to bring out the detail by staring at it, "...which is what the eye with poor vision does all the time" (Bates, 1920).

The eye movement patterns characteristic of poor vision are similar to those of experimental subjects who are involved in situations of visual overload. Mackworth (1976) used sophisticated eye movement measuring devices to record the visual characteristics of subjects in visual tasks at various levels of difficulty. He described the adjustments made by the visual motor system to conditions of visual overload. The major adjustment was seen to be a narrowing of the size of the useful field of view. This was true not only during the active search of too much material in too short a time, but was also true during tasks requiring vigilance, or waiting for a visual stimulus event to occur.

He also found that the size of movements was reduced and became more stereotyped; despite the decrease in useful field of view, the subject tried to include more stimuli in each fixation. The visual fixation time was lengthened to account for the increased number of items encompassed in a single fixation indicating the increased cognitive difficulty in processing complex visual material. Finally, there was a breakdown or failure of adjustment to increasing complexity under visual overload.

If the world appeared to be too complex for the individual to easily handle, we might expect the visual motor system to become habitually adjusted to behave in a manner described by Bates (1920), Mackworth (1976) and predicted by Pribram's model as described in this chapter.

Mackworth (1976) supports the idea that people have different habits of viewing the world. He states that the useful field of view (the amount of peripheral vision available to an individual) varies in size between different types of tasks as well as between different kinds of people. Some people can attend to specific details and then quickly take a broader view when understanding of the general situation is necessary. Others seem caught up in one steady middle-distance look.

> The brain initiates the physiological mechanisms of attention rather than waits for the environmental input to set these mechanisms in action. The interaction between brain and the environment is two-way, and the set or motivation of

> the subject is as important as the physical input in determining the physiological responses. For instance, the pupil contracts reflexly when light falls on it, but it also changes according to the cognitive state of the brain. Similarly, the useful field of view sharply constricts when there is high density of detail to be processed by eye and brain. Both behavioral changes are attempts to prevent the processing mechanisms from being overloaded. (Mackworth, 1976)

Myopia, Posture and Cognitive Effort

Prolonged and chronic involvement in such tasks as reading, or situations which are demanding but difficult to understand (e.g., family or peer group situations in which there is a demand to act "correctly" in conformity to a reality structure which the individual does not understand) can lead to chronic isometric muscle patterns and metabolic changes. It is the thesis of this paper that myopia is one possible outcome of this behavior. The situation of a rabbit frozen between two charging, barking dogs if repeated for a period of weeks or months would likely lead to siometric muscle contraction and metabolic changes in the rabbit which become structured into the brain and body.

Humans exhibit chronic isometric muscle contraction patterns in various places in their bodies even to the extent that they grossly distort their physical postures. Lowen (1968) contends that severe chronic isometric constriction patterns are evident in the posture adopted by the majority of people in our culture. Darwin (1965) classified emotional expression (and suppression) according to isometric muscle contraction patterns. Reich (1949) analyzed character and personality types on the basis of patterns of postural contraction. Alexander (1969), Feldenkrais (1972), Lowen (1958), and Reich (1949) have developed forms of psychomotor therapy to deal with this very type of muscle contraction. Lowen, who studied with Reich and later developed his own form of therapy called bioenergetics, has found myopia to be so common among his patients that the considers it abnormal if they are not myopic. With regard to his experience and observations Lowen (1964) states:

> In my opinion myopia is a functional eye disorder that has become structured in the body as a distortion of the eyeball. It does not differ from other bodily distortions that are the result of chronic muscular tensions. In many cases these distortions are significantly reduced as the tensions are released. I have seen considerable changes produced in people's eyes by bioenergenetic exercises and therapy. And I know one person who completely overcame his myopic conditon through the Bates method. One of the difficulties in working with the myopic eyes is that the tense ocular muscles are not accessible to palpation and pressure. (p. 11)

Bates (1920) attributed myopia directly to isometric contraction in the extraocular muscles. These are the muscles which attach to the outside of the eyeball and are considered to be responsible for moving the eye in its socket (Alpern, 1962). The extraocular muscles comprise the physical mechanism which is responsible for manipulating eyeball length. If the oblique muscles of the eyeball (Figure 9) both contract simultaneously they can increase the corneal-retinal distance. The focus of an optical system such as the eye depends upon the refractive power of optical elements in the system, and it depends upon the distance of the optical elements from the focusing screen (the retina in the eye). If the corneal-retinal distance increases too much, the rays of light entering the eye will focus between the cornea and the retina and not on the retina itself. This condition is defined as myopia. This is perhaps Bates' most controversial concept.

The general dicta of physiological optics only ascribes a movement function to the extraocular muscles and rejects the idea that they might also be responsible for changes in eyeball length (Huxley, 1942). Physiological optics does not conceive that the process of emmetropization involves active mechanisms which coordinate the ocular components of refraction, regulated by extraocular isometric contraction patterns involving oblique and rectus muscles.

What is the evidence which supports this idea? Bates (1920) reports experiments which he conducted on fish and mammals (including humans) which led him to believe that the extraocular muscles were responsible for refractive changes. In many varieties of sea creatures, it is known that the extraocular muscles are responsible for changing the focus of the eyes dynamically to see clearly objects at near and far distances. The focus of the fish's eye is controlled by the relative tension of the oblique muscles in comparison to the rectus muscles. The same mechanism was found to exist in rabbits, cats, dogs, and humans (Bates, 1920).

Further evidence that pressures on the globe of the eye can produce changes in eyeball length, leading to refractive changes, exists in recent literature:

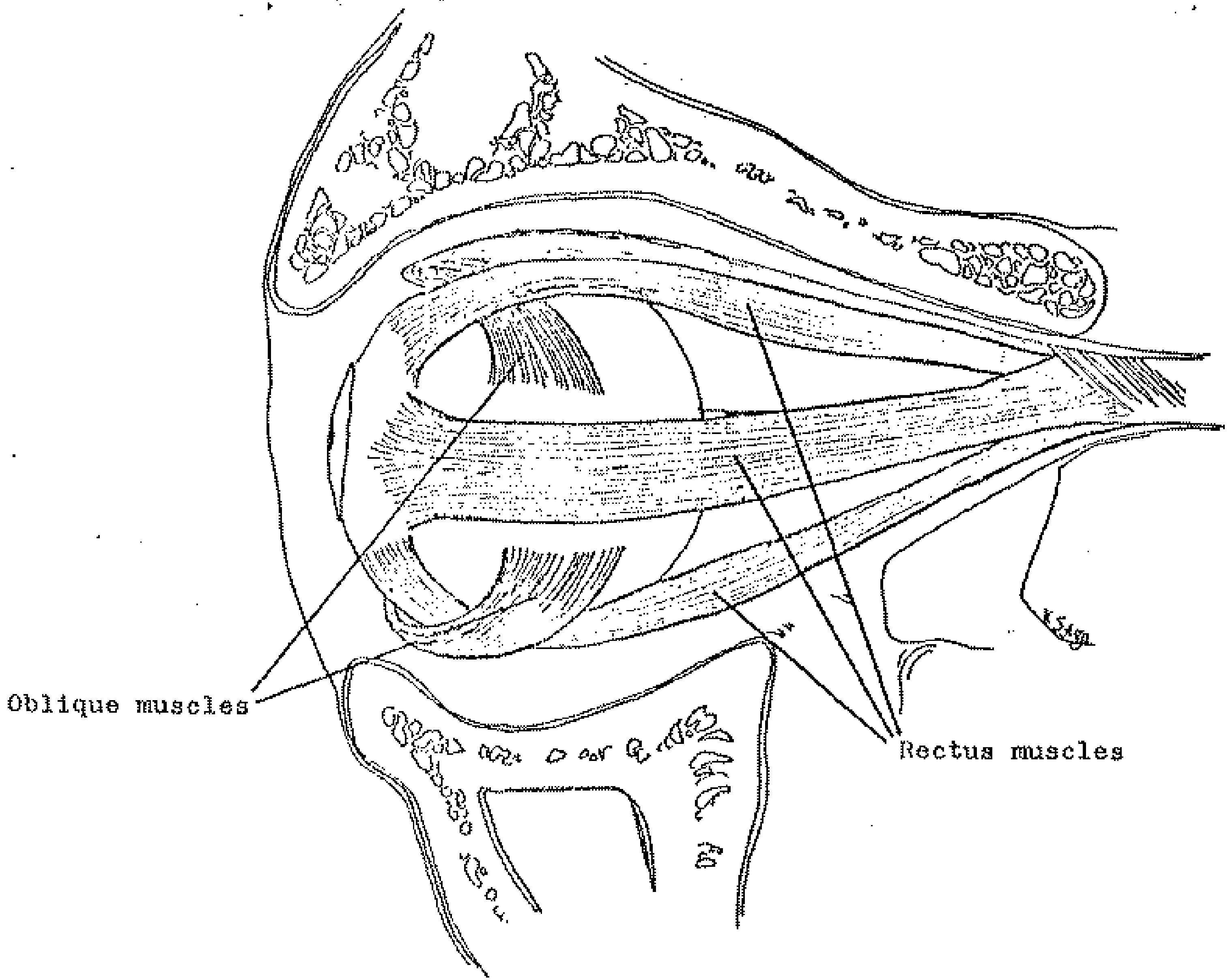

Figure 9 Side view of the eyeball and its extraocular muscles

> Succinylcholine-induced co-contracture of the four rectus and two oblique muscles in cats produced enophthalmos and up to 0.4 mm of globe-shortening as measured by strain gauges. Concomitant hyperopic refractive changes of up to 2 diopters were also noted in cats, and similar hyperopic refractive changes were noted in two human subjects (Bach-y-Rita, 1968).

Two types of muscle fibers and control systems exist in the extraocular muscles. These muscle systems are "quite distinct motor systems", one quick acting, the other more primitive and slower to act. The quick acting system is responsible for "rapid and wide movements of the eyeball, while the tonic system provides for slow, small movements and fixations" (Matyushkin, 1964). Succinylcholine is related to sympathetic neural transmitter chemicals which Pribram and McGuinness (1975) have implicated in isometric and metabolic alternation of muscle action during cognitive effort in reasoning tasks. The experiment by Bach-y-Rita, et.al. quoted above, is similar to the ones reported by Bates (1920); both arrived at similar conclusions.

Additional evidence that pressure around the equator of the eyeball can lead to myopic changes comes from the inadvertent discovery

> ...that, when silicone bands are placed about the equator and tightened to reduce vitreous traction in retinal detachment work, the eyeball becomes longer axially and thereby increases myopia.... (Rubin, 1966)

Tentative support for the existence of extraocular muscle influence on refractive error is suggested by Fry (1966), who recommended that the tension on the eye by the tonus of the extraocular muscles should be investigated as a possible cause of refractive error; and by Ogle (1966), who advised that studies be made as to the possible effects on the corneal curvatures of surgical procedures on the extraocular muscles.

Van Alphen (1966) proposed that the eye is self-adjusting, focuses itself to emmetropia through cortical and subcortical control of the tonus or ocular muscles, and that ametropia is produced by factors which interfere with that mechanism. Ametropization as well as emmetropization may be active, ongoing processes in brain organization. He also stated his belief that the ocular muscular control centers in the brain stem and the reticular activating system are so intimately related that "psychological factors, stress and emotion, and extreme autonomic endowment" might very well affect the activity of these centers. He (Van Alphen, 1966) stated:

> I have found some evidence for psychological differences between emmetropes and myopes, including indications that psychological factors may facilitate the development of myopia and not vice versa: I have emphasized the stress situation in the so-called school myopia; and I have also the clinical impression that many myopic children are distinctly nervous. If such factors interfere with the emmetropization mechanism at a subcortical level, one might expect imbalance in the ammetropic eye. Indeed, there are differences in pupil size in myopes and hypermetropes.... Admittedly, the extraocular muscles may well contribute to the origin of ametropia. (p. 31)

Summary of the Model

A neurological, neuropsychological model has been presented which supports the notion that myopia results from habits of mental focusing (habitual ways of organizing mental process in order to pay attention) which can lead to chronic isometric contraction of the extraocular muscles which lengthen the eyeball and lead to myopia. Voluntary attention involves mechanisms which prolong readiness for action and discrimination. The attention involved is voluntary in the sense that it is initiated by the organism rather than by some input event. Such tasks have been designated as categorization and reasoning. Categorization delays the process of closure (i.e. prolongs readiness for discrimination) when the stimulus situation is unfamiliar or confusing to the organism. Selective attention to external details must be maintained until enough appropriate information can be detected and categorized. Such processes involve the frontal and arousal systems of brain action. Reasoning involves the internal rehearsal of potential solutions (actions) just as categorization involves the internal rehearsal of potential perceptions. In reasoning tasks the response is delayed until the solution is internally experienced (e.g., in mental arithmetic or in playing chess). Reasoning demands the uncoupling of attention from the immediate input variables and involves the posterior temporal (association) cortex.

Special forms of muscular effort involved in problem solving while categorizing or reasoning have been discussed. These have been implicated as the source of the chronic isometric muscle contractions linked to psychologically related postural distortions and to the extraocular muscle contraction which leads to myopia.

Electrophysiological evidence has been cited indicating that the posterior and frontal cortex contribute opposing controls on sensory channels. This evidence is based on changes produced in the recovery cycles of the visual system (the speed with which the system recovers to its full capacity after a sudden, intense stimulus) and the alterations produced in the shape of visual receptive fields. This has been implicated as a probable explanation for fluctuations in visual acuity which are known to exist in the absence of changes in refraction.

Emotions occur as a result of involuntary self-control mechanisms triggered by environmental stimulation which is beyond the ability of the organism to deal with effectively. Mechanisms similar to those of categorization and reasoning are involved in emotional responses due to the decoupling of arousal and action. Emotional reaction implies inaction and can result from direct environmental stimulation or from projected inability to cope with potential environmental situations on the basis of previous failure or frustration in similar situations.

Emotions are related to arousal and therefore to frontal system organization. The organism is motivated to seek pertinent information in the stimulus situation, but is inhibited from doing so by the over-reaction of the arousal mechanisms. This causes the organism to close down prematurely from external stimulation by triggering emotional reactions (fight or flight).

> ...The organism's nervous system is temporarily swamped by the arousing input and reacts defensively to shut out all further input and thus leads to automatisms (Pribram and McGuinness, 1975).

Mental strain prolongs muscular strain. Chronic involvement in emotional and/or categorizing-reasoning situations leads to muscular and metabolic changes in the organism. These become patterned into the mental response systems;

> It is thus plausible that the neuromuscular processes demanding effort are to a large extent initially peripheral in their origin and manifestation. But as problem-solving progresses and problem-solving skill develops, the effort becomes more and more a concomitant of the brain processes involved—apart from, or only reflected in, the peripheral manifestations—and thus becomes truly cognitive (Pribram and McGuinness, 1975)

That is to say, they become habits of mental strain which manifest throughout the body, including the retina and the extraocular muscles. If an individual is continually involved in situations which are unclear or not easily resolved (searching while problem-solving), changes in sensory-motor, metabolic, and brain organization occur which can lead to myopia.

If an individual has been successful in coping in certain situations through internal control mechanisms (i.e., cognitive effort), the habit can become established even in less demanding situations. Darwin (1872) observed that

> Actions which have often been of direct or indirect service, under certain states of the mind, in order to gratify or relieve certain sensations, desires, etc., are still performed under analogous circumstances through mere habit although of no service. Even when these and other emotions or sensations are aroused in a very feeble manner, there will still be a tendency to similar actions, owing to the force of long-associated habit; and those actions which are least under voluntary control will generally be longest retained. (p. 81-82)

Actions which are least voluntary (such as co-contracture of the oblique extraocular muscles) may be altered when they are brought under voluntary control.

Conclusion of the Chapter

Bates (1920) concluded:

> Primarily the strain to see is a strain of the mind, and, as in all cases in which there is a strain of the mind, there is a loss of mental control.... These facts appear sufficient to explain why visual acuity declines as civilization advances. Under the conditions of civilized life men's minds are under continual strain. They have more things to worry them than uncivilized man had, and they are not obliged to keep cool and collected in order that they may see and do other things upon which existence depends. If he allowed himself to get nervous, primitive man was promptly eliminated; but civilized man survives and transmits his mental characteristics to posterity. (p. 98)

The etiological model which has been developed here serves to integrate the work of Bates with recent psychophysiological findings and provides for the expansion of our notions of visual impairment and its possible cure.

What emerges here is a portrait of myopia as not merely a problem of refractive error but as a posture which the myope has adopted to deal with life.

It is the author's clinical observation, supported by the current study, that myopia is caused by some crisis in reality wherein an individual is compulsively searching for clues, continually attempting to discriminate details of the environment in order to figure out how to act, to make the best choice, to achieve the most success, to get the most meaning out of the story, etc.

It is clearly indicated that the work of Bates, so long ignored by the scientific and clinical communities, needs to be reexamined and tested in an open-minded, scientific manner.

A comparison of this model with the evidence about myopia presented in the literature review and the conclusions and further implications derived from this chapter will be presented in the final Chapter of the dissertation. The following two chapters describe a pilot study of myopic patients.

CHAPTER III: METHODS AND PROCEDURES

This study has been an effort to learn more about the nature of myopia. Of primary concern was the development of a method of measuring refractive change in a sample of young adult myopes. This study was designed as a retrospective investigation, not an experiment, and was based on records collected over the past six years (1971-1977). The author was interested in learning the extent to which myopia is a fixed or flexible condition. But before meaningful statements can be made about myopic change, the relevent variables must be isolated. Factors such as age, gender, amount of initial refractive error, or the speed with which the refractive error is changing, are important to explore. If a method of analysis can provide meaningful ways of comparing myopic behavior then further studies can be conducted to test for relationships and for the effects of remedial vision therapy. This chapter describes research questions, subject, method of data collection, and procedures used in data analysis.

Research Questions

1) What are the most important variables to consider in analyzing changes in refractive error?

2) What are the most sensitive methods of measuring refractive change?

3) Do the results tend to support Bates and the conclusions of Chapter Two?

4) Are future studies of dynamic change in refractive error worthwhile?

5) Have baseline data been established which can be used in future studies concerning variables which influence changes in refractive error?

Description of Subjects

The control subjects were selected from record cards of three optometric offices in Santa Rosa, California. All patients were between the ages of twenty and thirty, were nearsighted and had less than two diopters of astigmatism (see Definition of Terms). Contact lens patients, i.e., any patient who had worn contact lenses at any time, were excluded from the sample because contact lenses often lead to changes in the optical properties of the cornea. Wearers often experience great, unpredictable fluctuations in vision and refraction after switching back to regular spectacles.

All patients from three optometric offices who met the criteria were included in the control population. There were 442 patients from Gottlieb's office, 211 patients from the records of Campbell, and 99 patients from Shipley. The distribution of refractive errors for the three control populations was compared with the distribution of refractive errors of the study population from Gottlieb's office to insure that the study population was not unusual.

A study population was selected from Gottlieb's records. The patients who met the criteria stated above, and who returned to the office for a second examination, were included in this study population. Normal optometric procedures of the office include the collection of data on each patient. This study was a search through the data which have been collected over the last six years (1971-1977).

The size of the sample was determined by the number of patients who fit the required description and were recorded in the files. There were fifty-two subjects (or 104 eyes) in the sample. The numerical adequacy will be discussed under statistical methods.

The frequency distribution for refractive error is displayed in Figure 10. Data for the control samples is also plotted in the Figure.

The age of the subjects was recorded at the time of the initial refraction. Since the interval between the first and second refraction was as much as 68 months, some of the patients were over thirty at the time of the second examination.

All the patients were caucasian.

There were 28 females and 24 males in the study. Female and male subjects were analyzed separately and in combination.

<u>Special Characteristics of the Sample</u>

Sixty-five percent of the subjects in the study sample were medically indigent, and were on Medicaid. The statewide percentage of Medicaid is fifteen percent (Campbell, 1977). This unusually high percentage indicates the uniqueness in the characteristics of patients in the sample.

Most of the patients in this study were exploring "alternative life styles", i.e., they tended to use marijuana and LSD, had sexually "open" attitudes, worked and lived in low-pressure situations, and tended to be interested in growth-oriented activities such as yoga, meditation, massage, group and individual psychotherapy, "natural foods", etc. The patients had been exposed to ideas and methods of vision improvement (such as Bates) and/or came to the office for advice because they knew of the examiner's interest in Bates and vision improvement. Generally they came expecting to be counselled on vision improvement.

No data was available to distinguish between patients so involved and patients who were not involved. The number of patients who fell into this category is not known.

Research Instrumentation

Equipment

Refractive information and patient history was recorded on a standard optometric form.

An American optical 590 minus cylinder phoropter was used to aid in determining the prescription. This instrument contains 14,000,000 different combination of lenses.

Variables Measured

Date. Date of exam was recorded.

Patient History. Age, gender, and contact lens history were ascertained.

Refractive Error. Data were recorded for each eye separately. The prescription was determined using common techniques of refraction (Borish, 1954). In determining the lens power for any patient, there is a choice of prescriptions available. The optometrist can prescribe the least power lens which allows the patient to see 20/20 size letters on the distance test chart (see Definition of Terms). A maximum acuity prescription also can be measured by asking the patient which lens power gives the maximum sense of clearness. The range of lens power from minimum 20/20 to maximum clarity is usually 0.75 diopter (D) (Hirsch, 1963). This range varies among different patients. The patients who practiced the Bates' exercises often had a range of 1.50 to 2.00 or more between minimum 20/20 and maximum clarity.

Some vision professionals give the maximum clarity lenses routinely, others give the slightly weaker prescription, i.e., 0.25 D less than maximum. This latter procedure is the most common because patients will often experience strain with the strongest prescription (Hirsch, 1963). Some patients demand the strongest and others demand the weakest lens power to give 20/20 acuity.

The maximum acuity lens were chosen in all cases in all three offices including both exams of the study sample. This procedure was considered necessary by the examiner since it was not known whether the previous practitioner used the maximum or the slightly reduced prescription for the patient's lenses. The maximum acuity lens tended to bias the data in the direction of an apparent increase in myopia but this was the only procedure which was guaranteed not to prejudice the results in favor of supporting Bates. Therefore, the examiner assumed it was the proper choice to make.

The actual prescription was modified in some cases where there was an astigmatic component to the myopia. There is a standard formula which converts the astigmatic component into what is known as the equivalent sphere (Borish, 1952). In this modified form the prescription represents the average amount of myopia present and was much easier to use in comparing eyes and in computing the data.

The following is an example of the procedure for obtaining the average refractive error for each subject. For an eye with 1.00 diopter of myopia combined with 0.50 diopter of myopic astigmatism, the spherical equivalent was determined as follows: one half the astigmatism is considered to be equal to the average spherical refractive error, hence, $0.50/2=0.25$ diopters of myopia. This is then added to the existing myopia, $1.00 + 0.25 = 1.25$

diopters of myopia (equivalent sphere) for the eye.

Refractive Drugs

No ophthalmic drugs were used in the examination. This included cycloplegics which are often used in refraction to expand the pupil and eliminate accomodation. The literature comparing cycloplegic with noncycloplegic data for adults show no difference in refraction (Baldwin, 1964).

Sample Time

The patients returned from five to sixty-eight months later for a second examination as they felt the need for it. The average interval was twenty-four months. Some returned to obtain a new frame or because they had broken a lens or lost their glasses. Some came because they felt their glasses were too strong, others because they felt too weak. Thus, sample time was determined by the patient. Since that dates of each examination were recorded, the sample time was easily obtainable.

Methods of Administration of Testing

Standard Testing Procedures

Eye examinations last approximately one hour. Standard directions and methods of testing were used which are similar to those used by most optometrists and which have been described in detail by Borish (1953). Using the phoropter (see Research Instrumentation), the spherical and astigmatic components of the prescription are determined for each eye separately. Both eyes are then examined simultaneously for proper balance. A routine examination progresses through various steps using objective measures and psychophysical techniques until the prescription is determined.

Variations in Procedures

The mechanics of determining the refractive error were equivalent to the standard procedures used by other optometrists. However, Gottlieb's manner of conducting the examination does differ somewhat from the typical eye examination. This difference is essentially one of style and it is in keeping with the characteristics of the alternate style of life of many of the patients. The atmosphere in the office is casual, relaxed, and non-authoritarian. There is an emphasis upon patient responsibility and the information found in the examination is discussed openly with the patient so that the determination of the final prescription power of lenses is a mutual decision. Because of the orientation towards humanistic health care (i.e., that the whole patient is being examined and not just the eyes and that the emotional state of the patient is an important factor in the determination of the refractive error). Gottlieb is especially sensitive to the feelings and level of relaxation of the patient. An eye examination requires a close scrutinization of the patient and some patients experience great anxiety during an examination for that reason. The manner and procedure is often altered in order to allow the patient to be comfortable so that a valid measurement could be obtained. Fluctuations of over one diopter on many occasions have been observed as the patient changed moods during an examination. Since the style of examination did not change during the time of the experiment, the internal consistency of the data for each examination (the first and second) was not affected.

Variables not Considered

Data were not recorded to differentiate between those who did or did not practice self-improvement or vision improvement methods. Attempts to gather these data were made and later abandoned because of the wide variety of factors involved. Some patients choose to go without their glasses or to wear them as little as possible. Some wear their glasses all the time. Some prefer to do vision improvement exercises routinely every morning or evening for a set number of minutes; some do exercises only a few days each week; others do little formal exercise but remember to be aware of their breathing and eye relaxation—and the association between these processes and improved vision. Many individuals had done little or no work on their eyes, others had read books or had even attended classes with Bates teachers.

Some patients were involved in a variety of psychological, physical, nutritional, spiritual, or other therapies; others took no interest in such procedures. Some patients did not work, others held full-time jobs, and some were students.

Recording data on such a variety of items seemed impossible, and isolating any one factor would have yielded only fragmented, meaningless information of the existing state of knowledge and methods of analysis. It seemed more reasonable to group all patients together, the interested and the disinclined, the four-eyed with the near blind, the private-payers and the welfare patients, the meditators, and the yogis.

At the time of the initial examination those who were interested received counseling on vision and health awareness, with an emphasis on breathing. They were also given instructions in regard to Bates' exercises (see Appendix One for a handout given to most patients). Data on who did or did not participate in this procedure were not recorded in a way useful for this study.

The prescription which the patient received was generally less than the maximum which could have been given. This was due to the author's observation that patients who received weakened prescriptions tended to get better more easily than patients who received stronger lenses.

Treatment of the Data

Synthetic Procedures

In order to cover as many aspects of analysis as possible, the treatment method is a hybrid of parametric statistical as well as dynamic analysis (visual curve fitting). Correlation coefficients and tests of significance were computed.

Analysis Model

The development of a method of analyzing data for populations of subjects such as the one in this study is a major interest of the author. Several studies which review methods of data analysis have been presented in Chapter Two. These studies show refractive changes over time. The methods of analyzing the data allow for a visual interpretation of refractive trends. Dynamic changes in refractive error are obtained in the studies which plot the refractive velocity (Bucklers, 1953 and Hofstetter, 1953) and the rate of change of the refractive velocity over time (Slataper, 1950). These methods of analysis are especially valuable for small sample populations which are being used as probes for directing the course of ongoing research. Small changes over relatively short periods of time are amplified and the dynamics of the changes can be directly inferred from the graphs. The data in the present study will be analyzed according to the methods described.

Reliability

Standard equipment and standard techniques were used in the examination and the tester was educated at an accredited school of optometry and holds a license to practice optometry in the State of California. This, by definition, establishes the reliability of the data.

Validity

Neither the tester nor the patient was concerned with the current study because it was done retrospectively. Since the style of the examination and the instrumentation was the same in the first and second examination, any uniqueness of the data due to unusual attitudes or examination style would tend to be deemphasized. On the basis of these considerations the findings are considered valid.

It must be noted at this point, however, that peculiarities of professional and of patient population characteristics such as those which have been described in this study make it important that the data base established in this study be considered as unique. The data base is designed to be used only in assessing further research with a similar population and in comparing this population with others.

CHAPTER IV: RESULTS OF DATA ANALYSIS

The emphasis of this study was on developing a method of analysis for use in future research and to examine the changes in refraction for a sample of young adult myopes. The findings will be presented in visual form based on canonical precedent. Interaction between the variables and dynamic tendencies will be inferred from a visual analysis of the graphs and from statistical analysis. This form of presentation also allows the opportunity to compare these results with results from past research in the field.

Analysis Model

First the histograms of the distribution of refractive error of the three optometric populations and the subgroup sample will be compared to establish the credibility of the sample used in the study. Next, the data for the study sample will be displayed. The variables in this study include: age, refractive error (first refraction), refractive error (second refraction), and the interval between the data points. These will be displayed for the total population as well as for males and females separately. These results will be compared in several ways, i.e., for refractive change, dioptric velocity and degree of refractive error, dioptric velocity and age, and dioptric velocity over time. When appropriate, means, standard deviations, tests, and correlations will be computed. These results will also be compared with the historical data. The raw data is presented in Appendix Two.

Summary Data

Figure 10 depicts the distribution of refractive error for three optometric populations of myopes and for the sub-group used in the study. The refractive error histogram is composed of 442 data points (patients) contributed by Gottlieb, of which 52 constitute the sample studied for refractive error changes, 211 data points contributed by Campbell, and 99 data points contributed by Shipley. The mean of Gottlieb's large sample was -2.83 ± 1.75 diopters, for the sub-sample -2.65 ±1.73 diopters, for Campbell -2.40 ±1.75 diopters, and for Shipley -2.33 ±1.63 diopters. Analysis of the graph shows that there is little difference in the distribution of refractive error between the groups. This is interpreted to mean that the data base is not unusual and the sample is assumed to be a normal sub-group of the population of myopes at large.

Figure 11 is a histogram of the age distribution of the sample. Female, male, and combined sample populations are all plotted. Distribution for each group is similar, the female mean is 25.28 ± 3.00, the male mean is 25.70 ± 2.79, and the combined mean is 25.49 ± 2.90 years.

Figure 12 displays the length of time between the first and second refraction for males, females, and combined sample. There is little difference between the groups. The mean interval for females is 24.21 ±11.84, for males is 22.67 ±17.09, and for the combined sample is 23.96 ±14.01 months. The average is nearly two years.

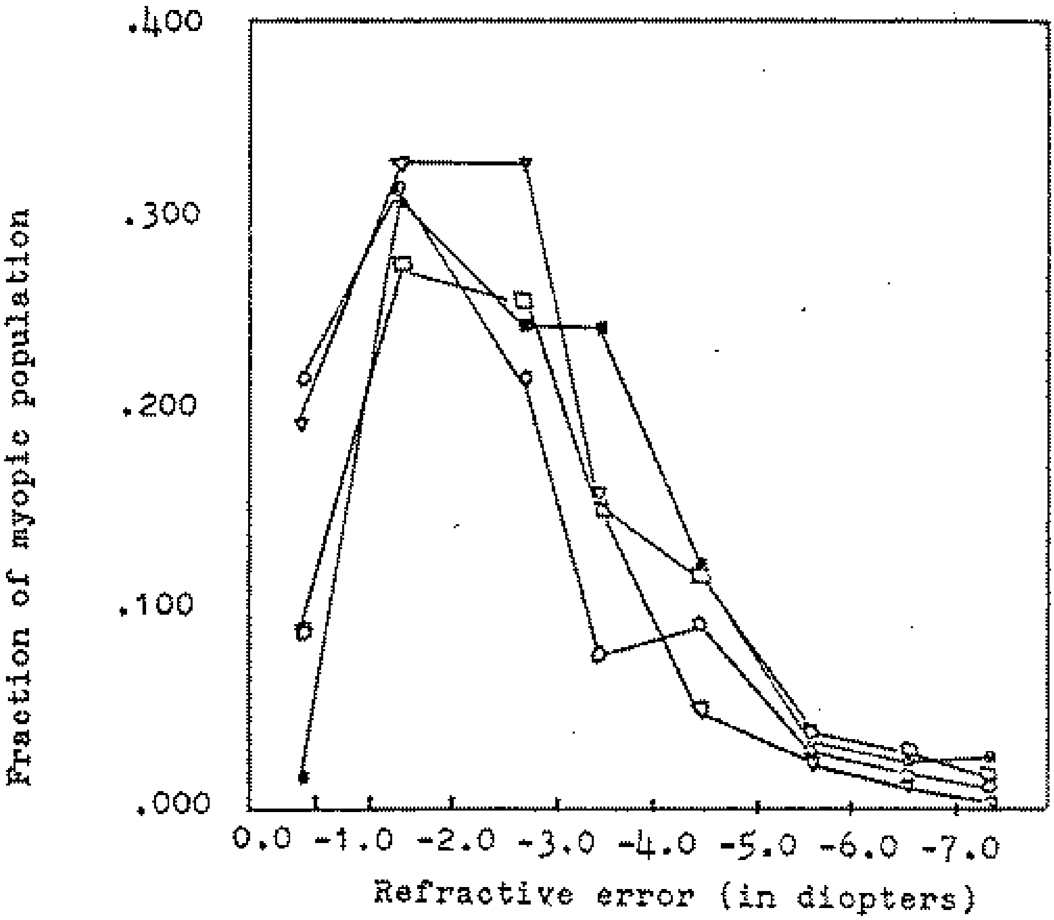

Figure 10 Graphic Comparison of the histograms of the contributing optometrist's myopic population.

□ Gottlieb n=442, mean = -2.93 diopters, s.d. = 1.75
• Gottlieb n=52, mean = -2.65 diopters, s.d. = 1.73
○ Campbell n=211, mean = -2.40 diopters, s.d. = 1.75
▿ Shipley n=99, mean = -2.33 diopters, s.d. = 1.62

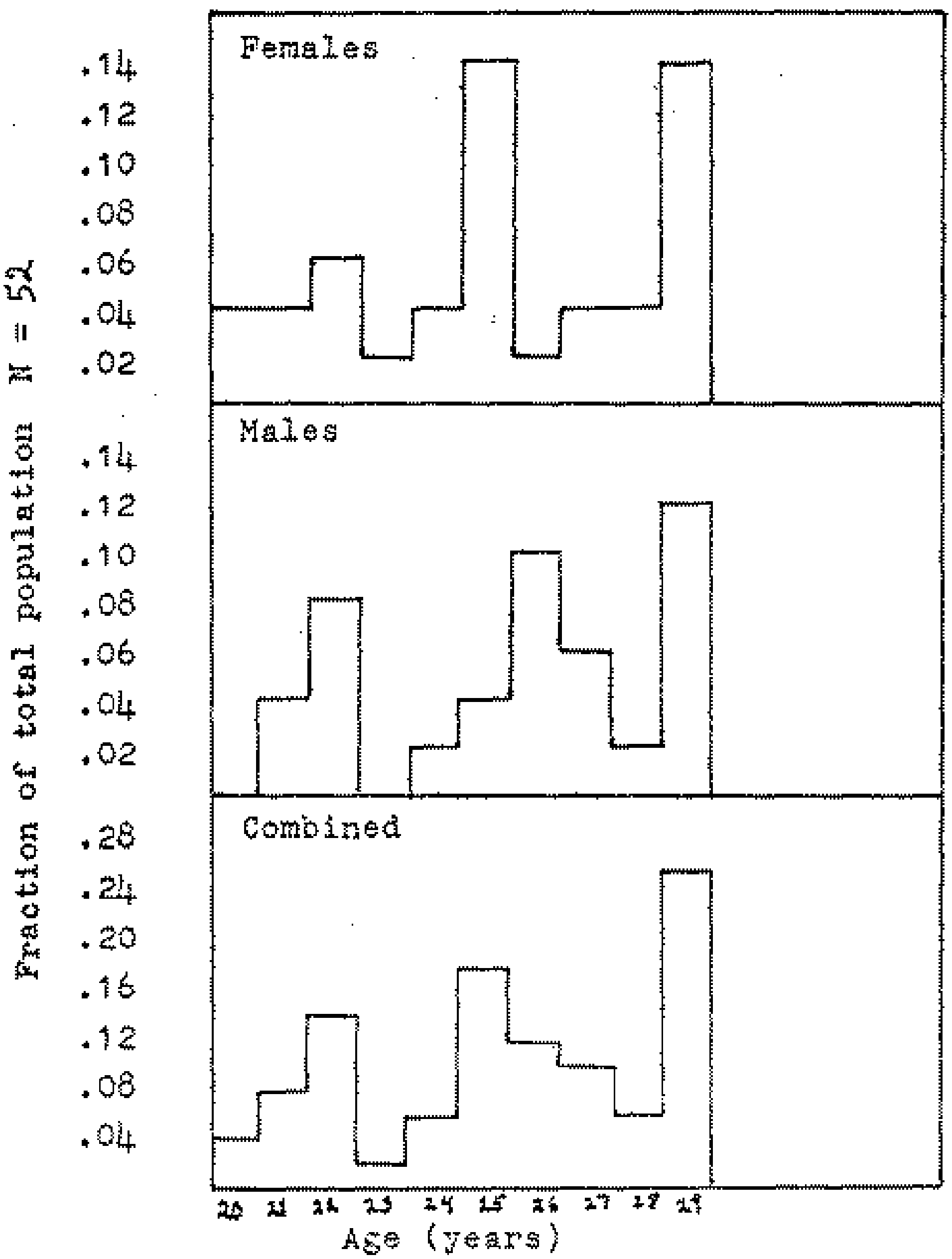

Figure 11 Age distribution of the sample

Histograms of female, male, and combined study population. For females: mean = 25.28 years, s.d. = 3.00, males: mean = 25.70 years, s.d. = 2.79, combined: mean = 25.49 years, s.d. = 2.90.

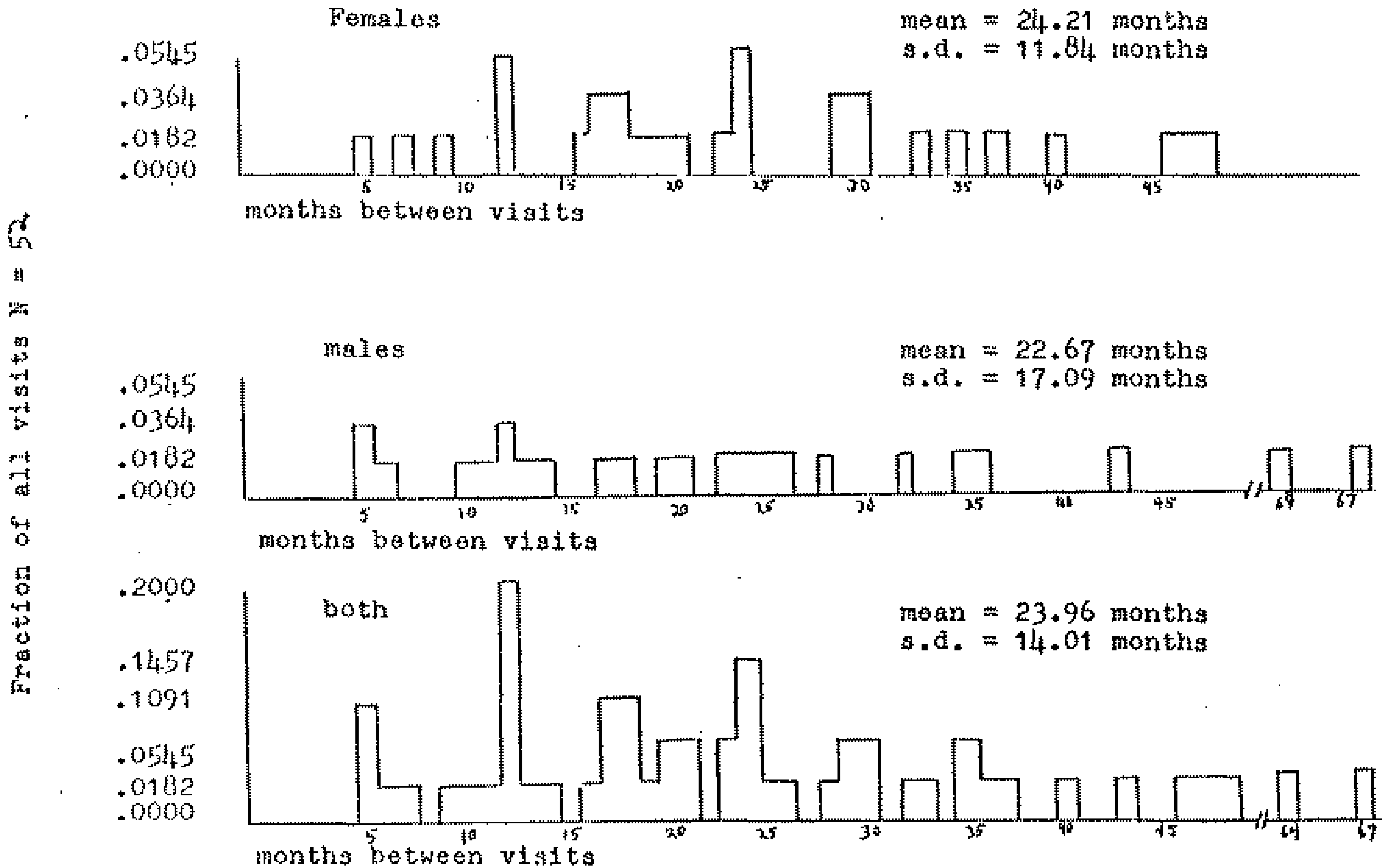

Figure 12 Interval in months between first and second refraction.

Histogram shows the frequency distribution of the months between refractions for female, male, and combined sample. The distribution is similar for all three groupings. The approximate average is nearly two years.

Figure 13 is a histogram of the frequency distribution of the refractive error for females and males for the first and second eye examination. The female mean for the first data point was -2.28 ±1.26, for the second data point -1.99 ±1.31, for the first male data point -3.09 ±2.09, and for the second -2.86 ±2.71 diopters. The refractive error mean for females was lowered (less myopia) by 0.29 and for males by 0.23 diopters. Figure 14 is a similar graph for the total group. The mean for the first refraction was -2.65 ±1.73 and for the second was -2.39 ±1.80 diopters. The difference between the two means showed a decrease in myopia by 0.26 diopters over an average time interval of twenty-four months.

Inferential Data

The following data will show trends in refractive changes and interactions among the variables studied.

The frequency breakdown for refractive difference between the first and second refraction for male, female, and combined samples is displayed in Figure 15. There was no significant difference between the means of the females and males. If the means are compared with a dioptric change of zero (Hirsch, 1963) there is a significant difference at the .001 level of confidence. For females the mean was 0.29 ±0.49 diopters ($t = 4.35$, p .001), for males the mean was 0.23 ±0.48 diopters ($t = 3.80$, p .001), and for the total group the mean was 0.26 ±0.47 diopters of change ($t = 5.76$, p .001).

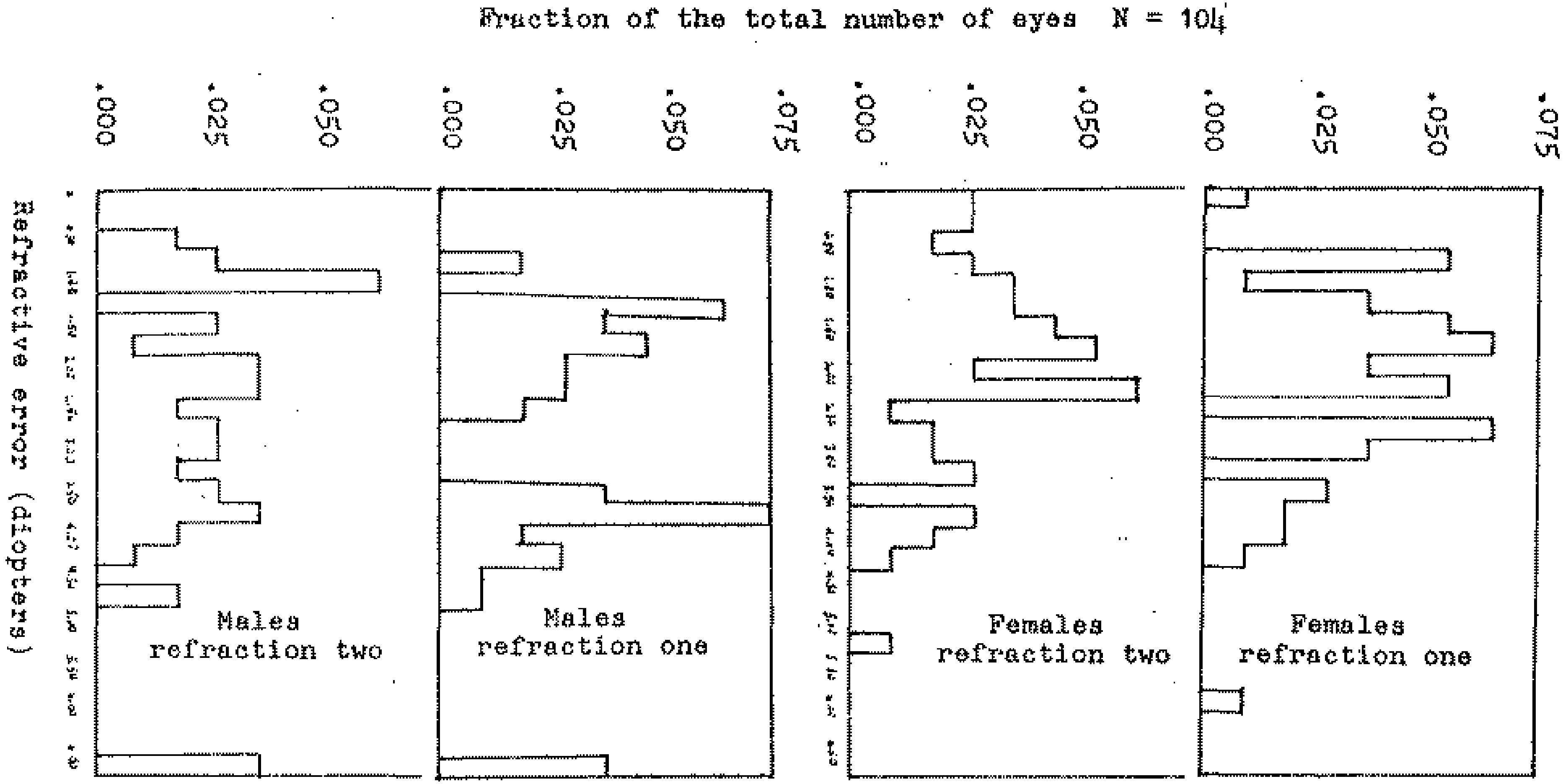

Figure 13 Distribution of first and second refraction by gender

Histograms of refractive error, refraction one and two for females and males. The mean refractive error was lowered between the second and first refraction by 0.29 diopters and 0.23 diopters for females and males respectively. First female mean = 2.28 , s.d. = 1.26 , second mean = 1.99 , s.d. = 1.31 . First male mean = 3.09 , s.d. = 2.09, second mean = 2.86 , s.d. = 2.17.

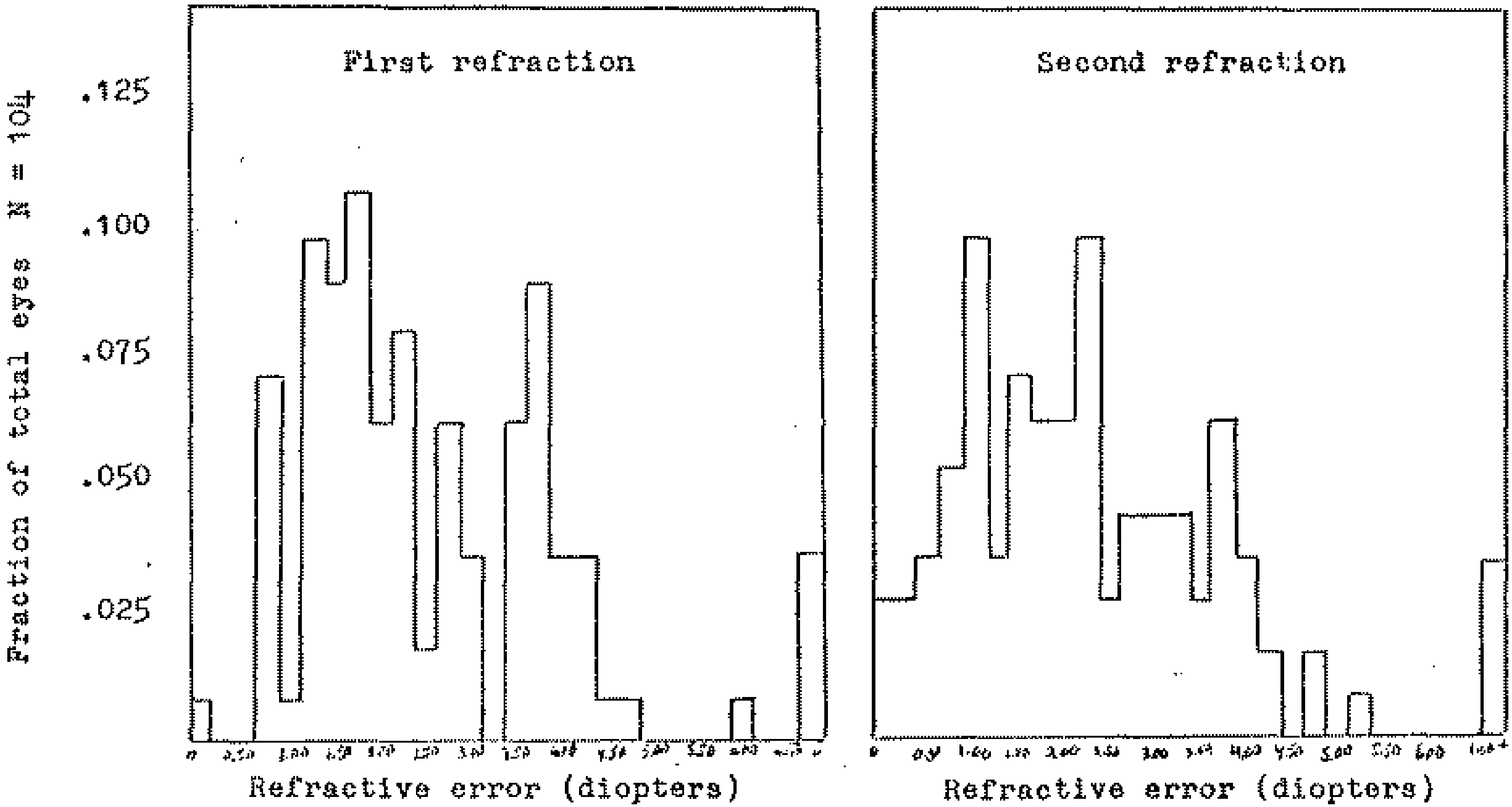

Figure 14 Distribution of first and second refraction for the total sample

The mean refractive error on the first visit was 2.65 diopters, s.d. = 1.73, and 2.39 diopters, s.d. = 1.80 on the second visit. There was a decrease in myopia by 0.26 diopter over an average time interval of twenty four months.

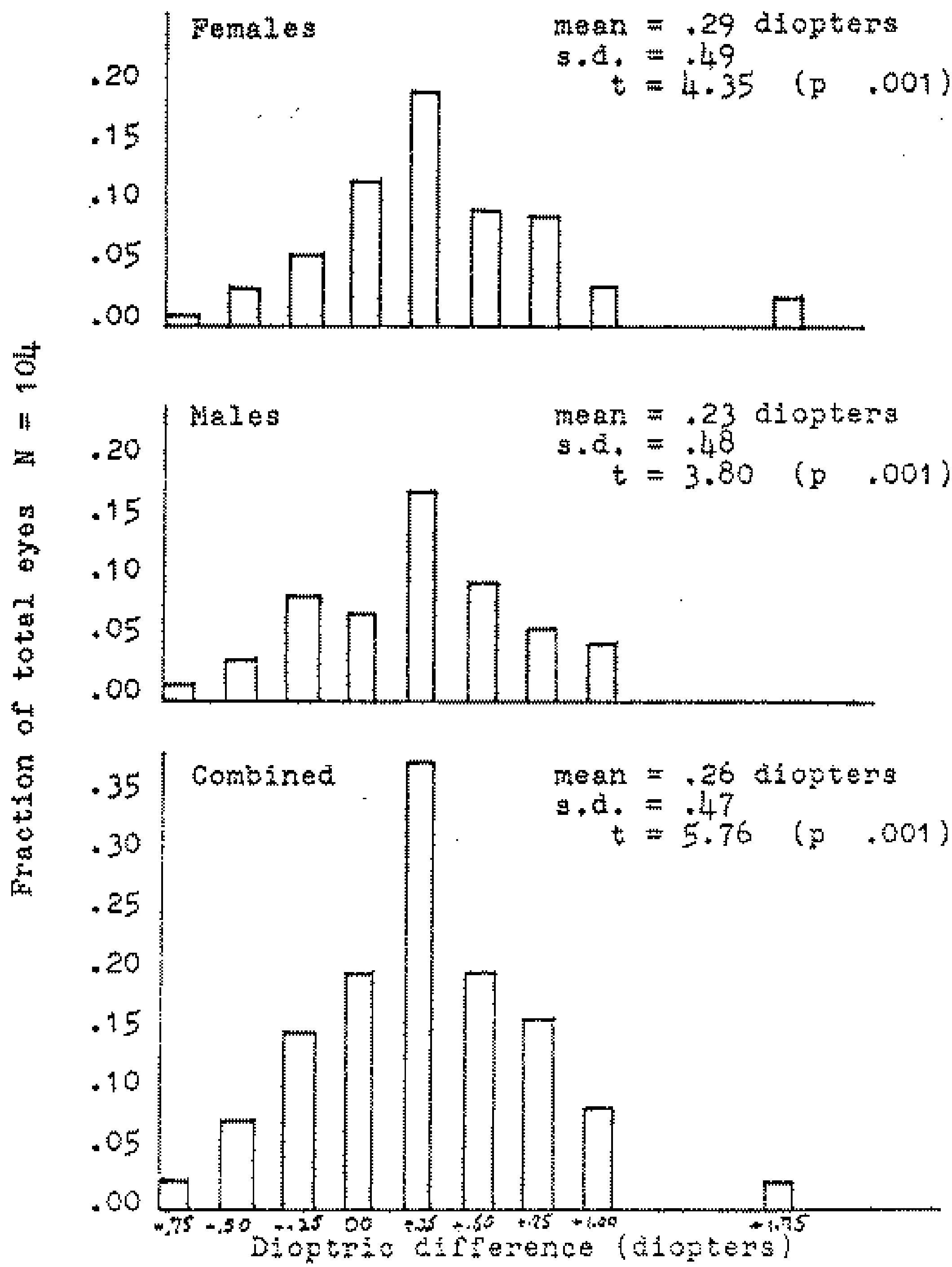

Figure 15 Frequency distribution of dioptric difference between first and second refractions

Histograms display male, female, and combined frequency breakdown for dioptric change. Negative direction indicates increase in myopia, positive indicates decrease in myopia. All means are significantly different from zero (p .001). There was no significant difference between males and females.

Dioptric velocity, or refractive velocity, is a dynamic measure of the change in refractive error per time (months). This is a valuable means of specifying refractive change because individuals or groups can be compared with each other or with control data after relatively short periods of time. This could be useful, for example, in experiments concerned with specific remedial techniques where it would be inefficient to wait for long periods of time for results. The rate of dioptric change for a given patient in routine refractions could also be compared with the expected velocity at the same age which might be useful in providing preventive or remedial information for patient counselling. The remainder of this chapter will explore dioptric velocity and its interaction with the variables of age, degree of refractive error, and the interval of time between eye examinations.

Figure 16 is a histogram displaying the dioptric velocity for the female, male, and total samples. The means for each group will be compared with a refractive mean of zero rate of change. The mean for females was 0.018 ±0.033 diopters/month ($t = 4.02$, p .001), for males 0.019 ±0.038 diopters/month ($t = 3.58$, p .001), and for all 0.018 ±0.034 diopters/month ($t = 5.38$, p .001). All groups were changing toward decreased myopia. There was no significant difference between males and females.

The relationship between patient age at the time of the first refraction and dioptric velocity is visible in the scatterplot in Figure 17. The grouping of data points appears

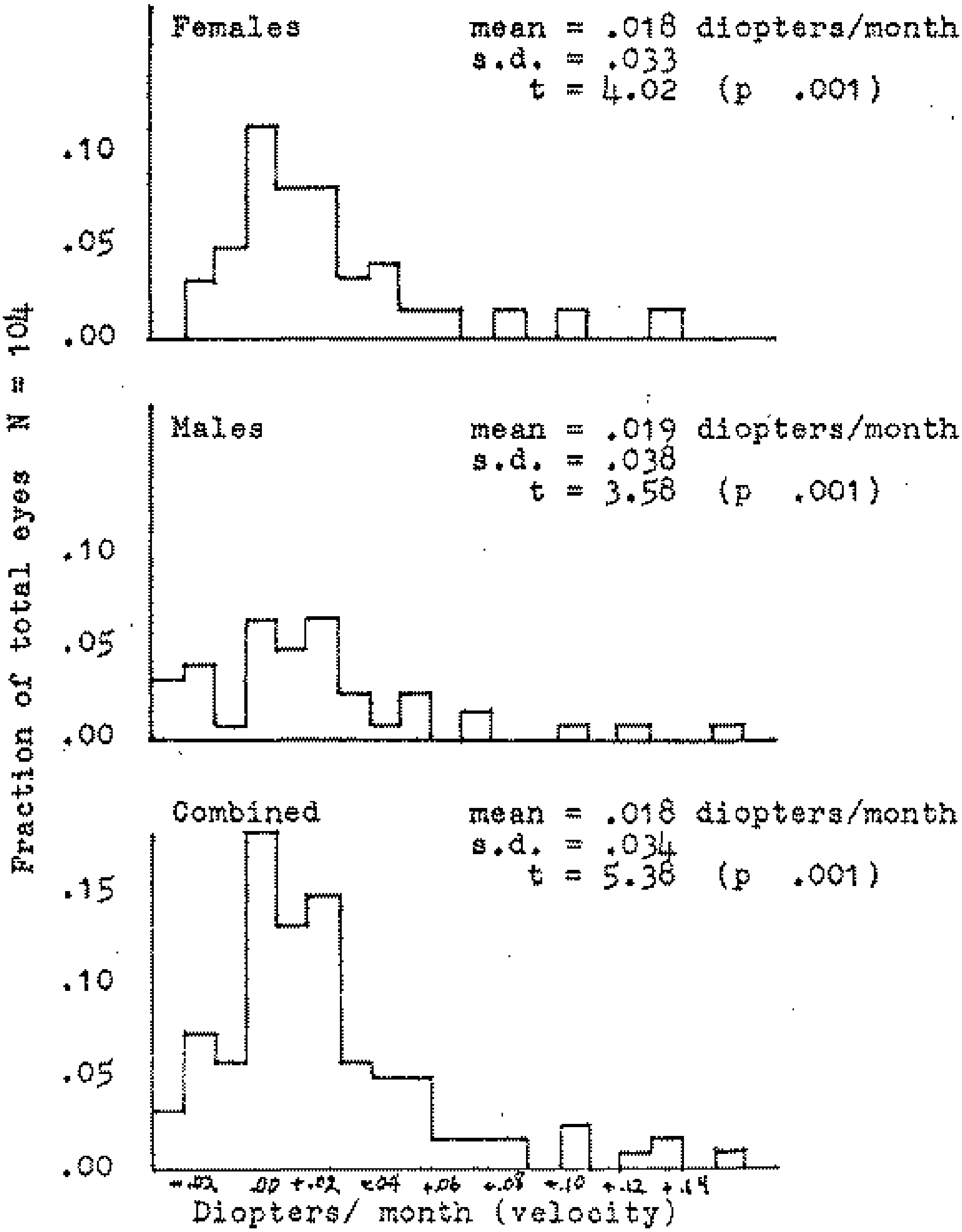

Figure 16 Frequency distribution of dioptric velocity

The histograms show the distribution of the refractive error change per month between the first and second refractions. Negative diopters indicate increase in myopia, positive indicate decreasing myopia. Comparison of the means for males and females showed no significant difference, but all groups were significantly different from zero change at the .001 level of confidence (t test).

nearly random for female, male, and combined groups, with only a slight suggestion of an increase in velocity with increasing age. The correlation is not significant (correlation = .056).

The interaction between the magnitude of the refractive error (first refraction) and velocity is more apparent as suggested in Figure 18 and Figure 19. Dioptric velocity increases (toward decreased myopia) with increasing refractive error, but only moderately. The correlation of .64 is significant only at the .07 level of confidence for the total group.

Figure 20, for females and males, and Figure 21, for the total sample, are scatterplots showing the relationship between the interval of time (months) between the first and the second refractive examination and the kioptric velocity. It is apparent from the graphs that the largest velocity (decrease in myopia) happened within the period of time just following the first refractive examination. The correlation of .22 is significant (p .05) for the combined group appear similar, the velocity approaches zero at about two years and seems to be most rapid before ten months.

In the last two graphs the trajectory of each eye of all the patients is plotted. The trajectory is a line drawn between the data point for the refractive error at the age of the patient at the time of the first examination and the data point for the second examination. The male and female characteristics are plotted in Figure 22 for the total sample in Figure 23. These graphs show the information contained in all of the other Figures in this Chapter. Visual inspection of the trajectories shows

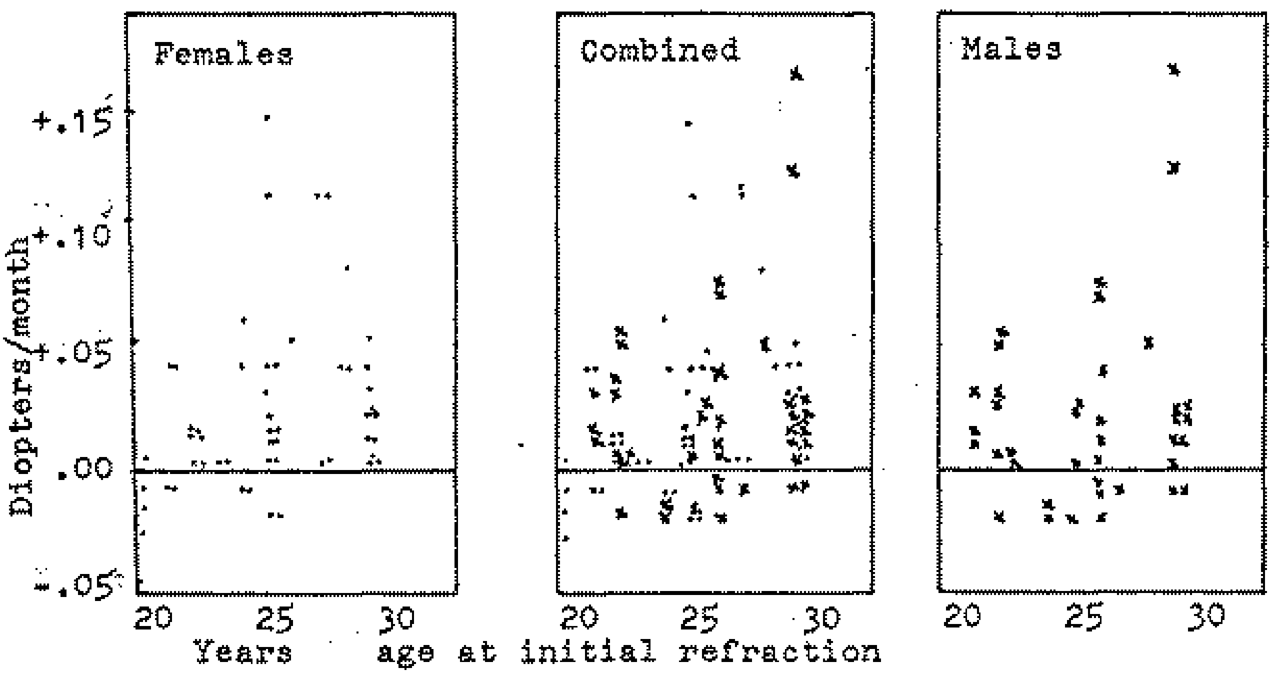

Figure 17 Dioptric velocity and age

The dioptric velocity, change in diopters per month, is shown for females, males, and combined samples, as it compares with the patient's age at the time of the initial refraction. Minus velocity indicates increasing myopia, positive indicates decreasing myopia. Visual inspection of the scatterplots suggests that the older the patient, the more positive the velocity. The relationship was only moderate, however, correlation = .056, not significant.

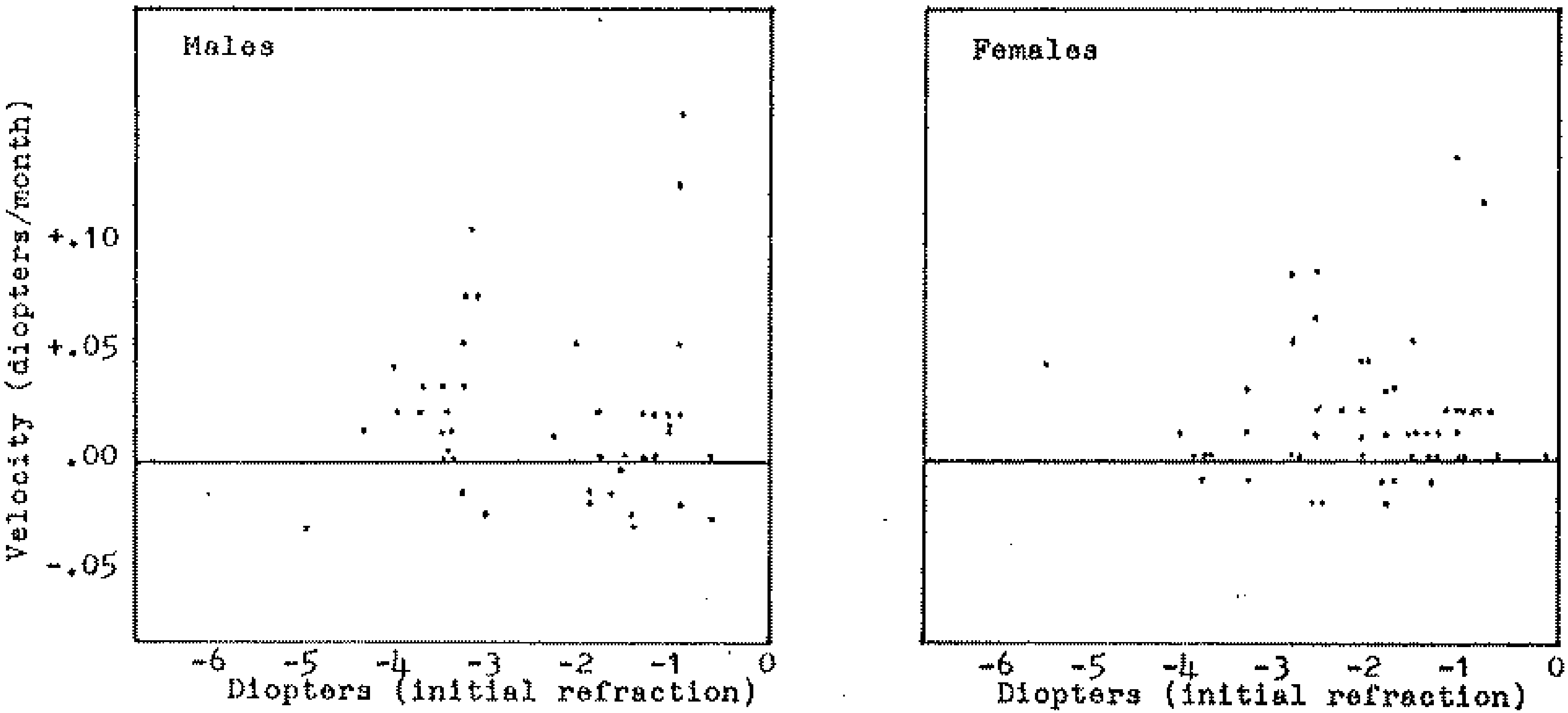

Figure 18 Relationship between dioptric velocity and refractive error (gender)

The refractive error measured at the first examination is plotted with respect to the dioptric velocity for males and females. Positive velocity indicates decreasing myopia, negative indicates increasing myopia. Each dot represents one eye.

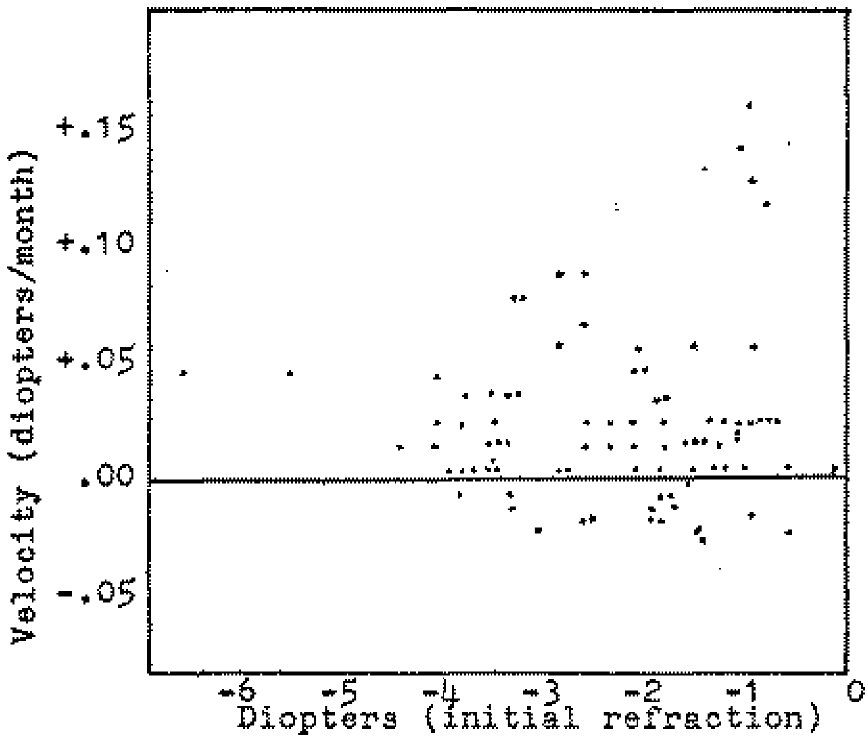

Figure 19 Relationship between dioptric velocity and refractive error (total group)

Scatterplot of the total group suggests that the larger the initial refraction, the greater the velocity towards decreased myopia. The correlation is moderate, correlation = .64, significant at the p = .07 level. Negative indicates increasing myopia, positive decreasing myopia. Each dot represents one eye.

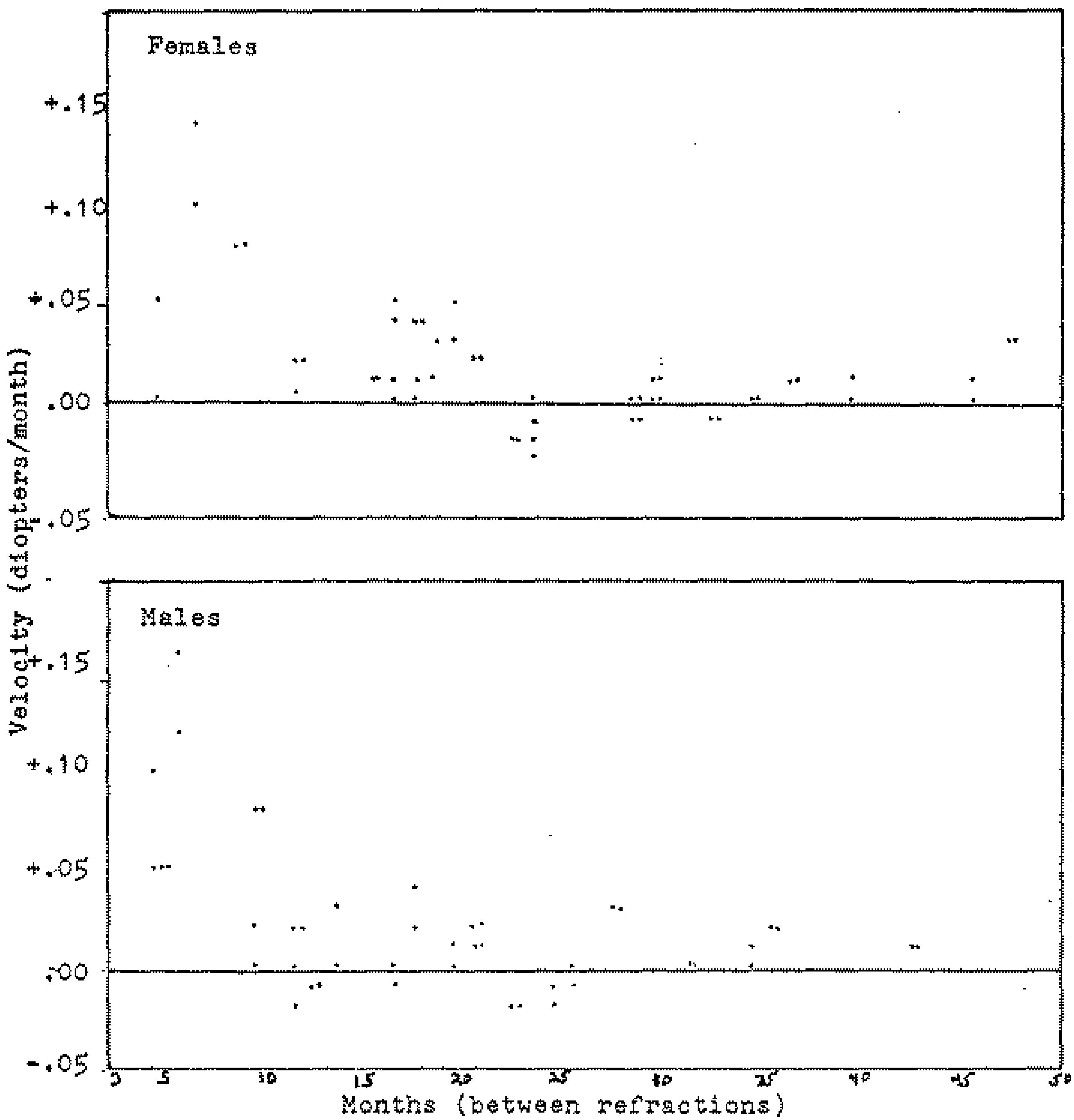

Figure 20 Dioptric velocity related to interval between refractions for males and females

The change in diopters per month is plotted with respect to the time, in months, between the first and second refraction. Each point represents one eye. The minus velocity represents increasing myopia, plus velocity represents decreasing velocity.

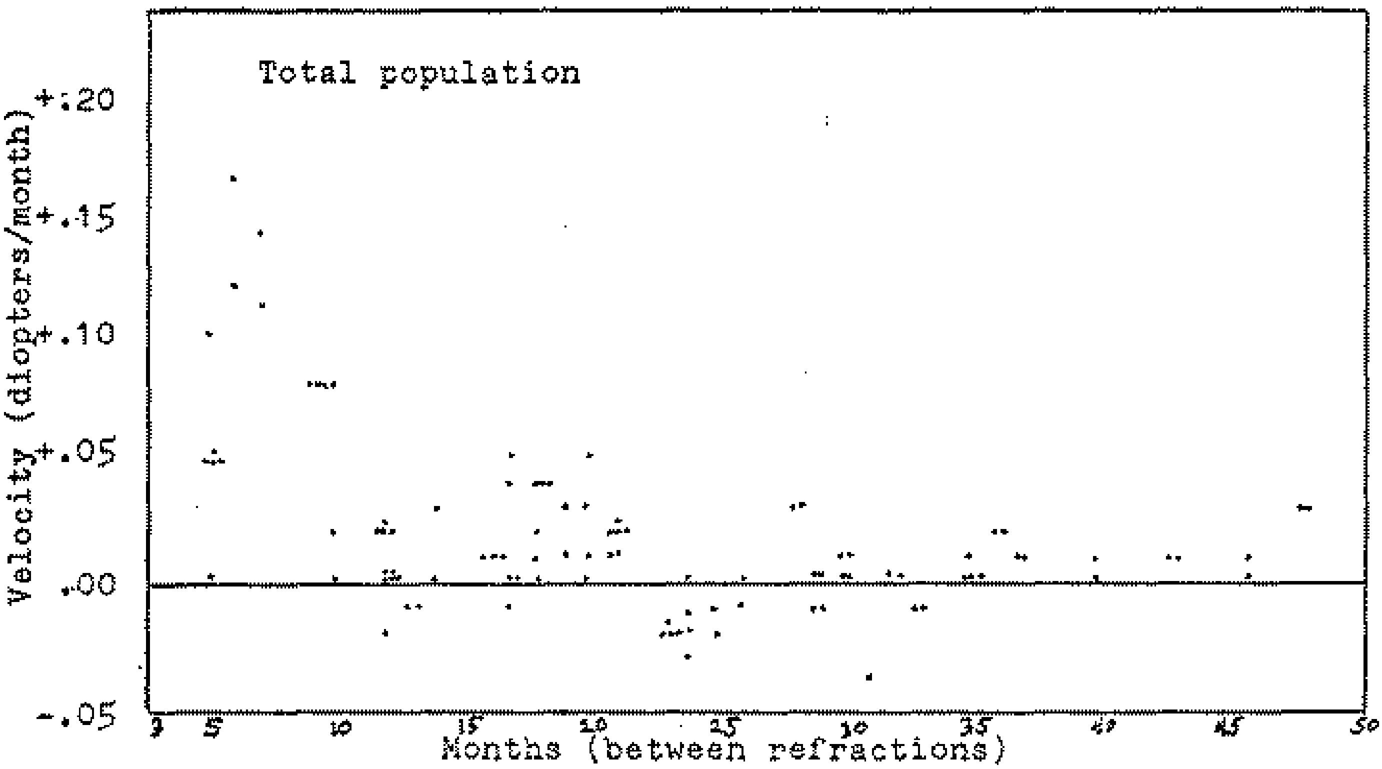

Figure 21 Dioptric velocity related to interval between refractions, total group

The change in diopters per month is plotted with respect to the time, in months, between the first and second refraction. Each point represents one eye. Minus velocity represents increasing myopia, plus represents decreasing velocity.

Visual inspection suggests that the greatest change takes place in the beginning months after refraction. The correlation is .22 significant at p .05.

the number of patients at each age, the average and dispersion of the initial and subsequent refractive error for the samples, the decrease in myopia, the refractive velocity (slope of the lines), the velocity compared with age, the velocity compared with the amount of refractive error, and the velocity with respect to interval (horizontal distance between data points). In addition, the relationship between the two eyes for each patient can be observed. When two trajectory lines start at the same age and end at the same age, they represent two eyes for one patient. Some trajectories are parallel and close together indicating that both eyes were of similar refractive error and changed in a similar way. In some cases one eye has a much greater refractive error than its partner, but both change in a parallel fashion. In other cases the pair of lines for a given patient diverge away or converge towards each other with time, indicating that the eyes were becoming less or more similar respectively. Some patients' eyes are widely different, others only slightly different from each other.

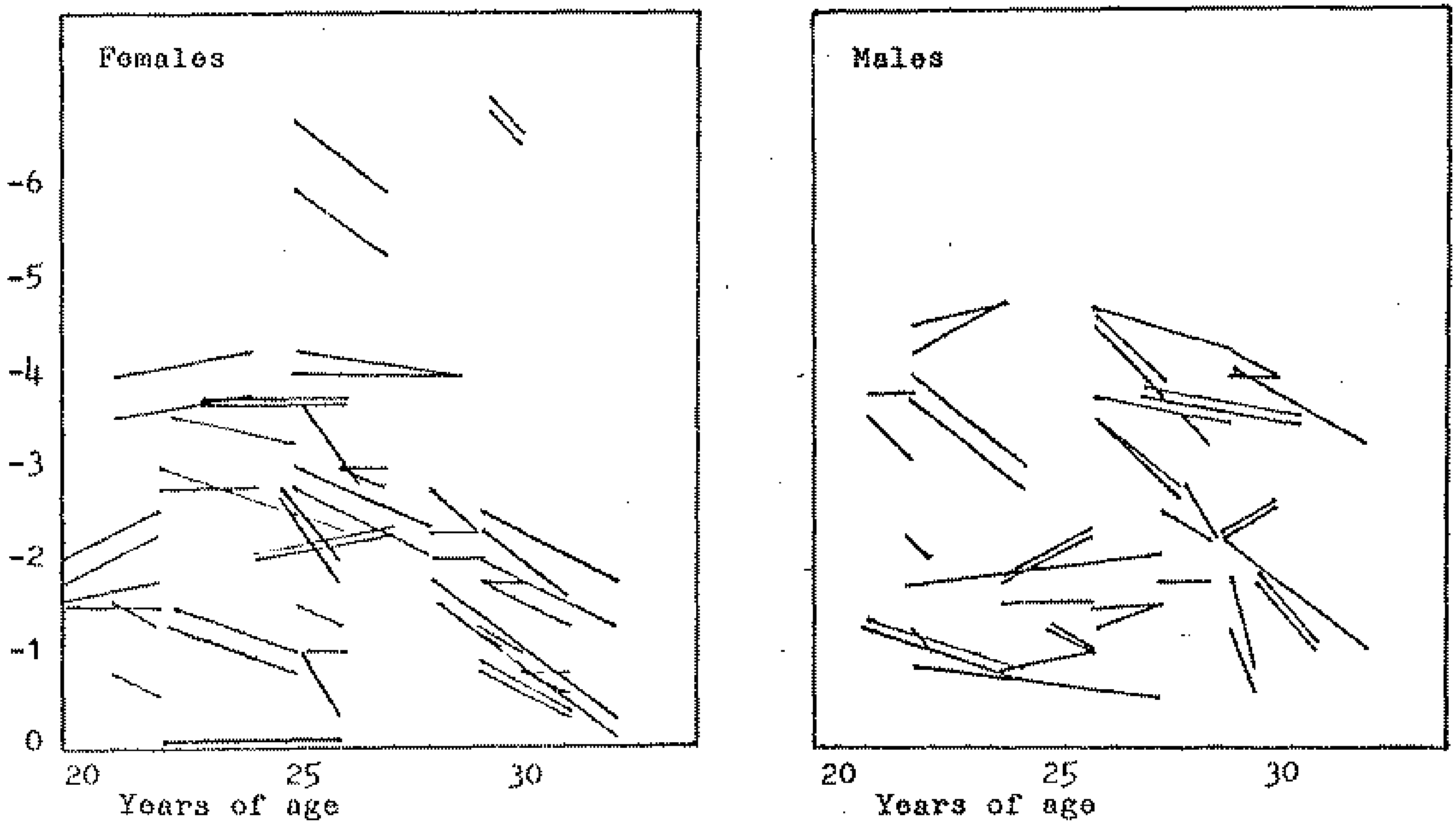

Figure 22 Trajectories of refractive error at age for males and females

Each eye at each age (at the time of refraction) is plotted for refractive error and the two points for each eye are then joined with a line.

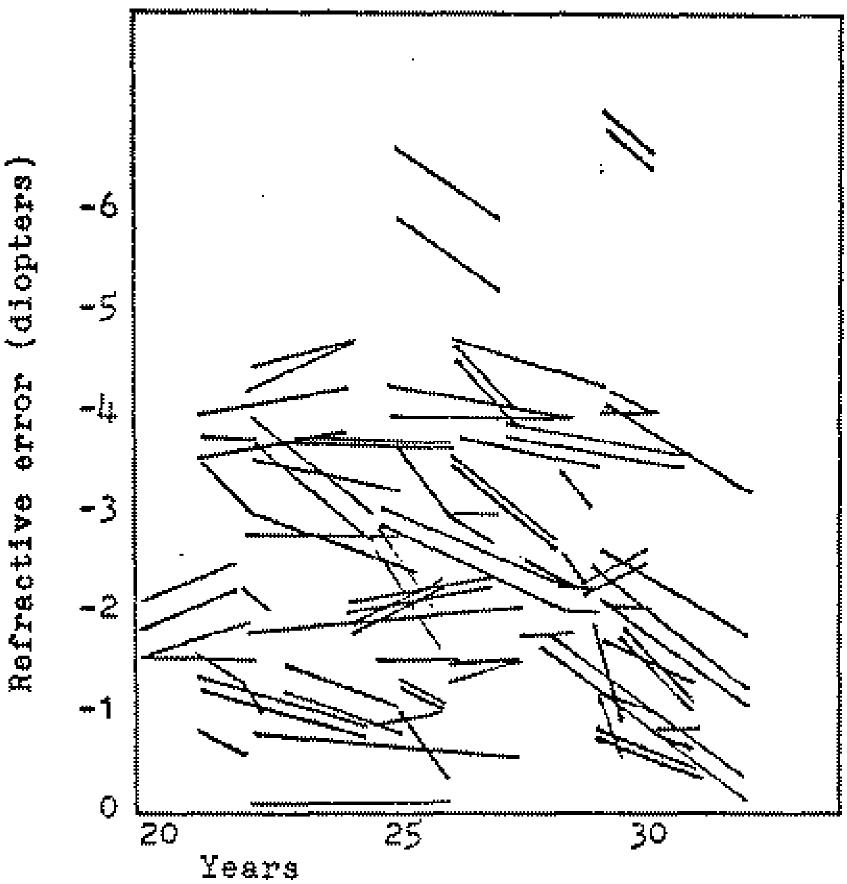

Figure 23 Trajectories of refractive error at age total group

Each eye at each age (at the time of refraction) is plotted for refractive error and the two points for each eye are then joined with a line.

Summary of the Findings

A comparison of the frequency distribution of refractive errors for the study sample with those of other samples showed that there was a similar distribution of refractive errors for all the populations studied. This established the credibility of the study sample. Summary data showed little difference between males and females. Average age for the total sample was 25.49 ±2.90 years. Average interval between the first and second refractions was 23.96 ±14.01 months. The mean refractive error for females was -2.28 ±1.26, for males was -3.09 ±2.09, and for the total was -2.65 ±1.73 diopters.

Inferential data showing the trends in refractive changes and interactions among the variables was examined next. There was little difference between the genders. The average refractive error changed towards less myopia by 0.26 ±0.47 diopters. A test comparing the mean changes with zero change was significant at the .001 level of confidence. The rate of change per month (dioptric velocity) for the sample was 0.018 ±0.034 diopters/month, which was significantly different from zero rate of change (p .001). The correlation between dioptric velocity and age was not significant, but the rate was slightly higher with increase in age. Dioptric velocity correlated at the .64 level with amount of refractive error, but the significance was only .07. The greater the refractive error, the greater was the rate of decrease in myopia. The interval (time between exams) was correlated (.22, p .05) with dioptric velocity. The greatest rate of change occurred within the first ten months following the initial refraction. Inspection of trajectory lines plotted for each sample group showed the relationships between the variables already mentioned and the similarities and differences between the two eyes of each patient. A variety of responses were described.

The implications of these findings and the use of this method of analysis will be discussed further in Chapter Five.

CHAPTER V: REVIEW, CONCLUSIONS, DISCUSSION AND SUGGESTIONS

This dissertation consisted of two major sections. The first was an examination of the credibility of Bates' ideas and the development of a model of myopia based on recent psychophysiological research. The second was a pilot study of myopes to examine trends in refractive error change and to determine the practical implications of future research in the field.

A model was developed through a synthesis of concepts in the field of neuropsycnology which supports Bates' ideas. On the basis of the model, myopia is explained as a cognitive behavior style which relates to Bates' concept of mental strain and to Pribram's concept of cognitive stress. The physiological manifestations of mental strain were explained in terms of autonomic and muscular changes in the body which lead to hyperconstriction of the extraocular muscles which lengthen the eyeball and produces myopia.

The second part of the dissertation is related to the first since it outlined a possible method of analysis, described a potential control sample, and examined refractive error changes in a sample of myopes. Results of the study showed that females and males were similar with respect to the refractive data. The patients in the sample reduced their myopia. The speed of refractive change was faster in the initial period following refraction but was not statistically related to patient age or refractive magnitude. This was a pilot study of changes in a particular group of patients; it was not an experiment of methods of curing myopia. The fifty-two patients in the study had been examined by the author in his optometric office on two occasions, were myopic, were in their twenties, and had never worn contact lenses. The method of data analysis was by parametric statistics and by visual inspection of graphs.

The Model Compared with Previous Studies

Returning to the literature reviewed earlier on the etiology of myopia, the genetic, metabolic, conditions of use, and the psychological factors must be examined in terms of the information presented here.

Genetic Theory

What is it that is inherited by the myope? Not necessarily the specific anatomical curvatures, thicknesses, or distances in the eye which develop to form the myopia. Potential styles of brain functioning or propensity for over or underreaction of autonomic response (fight or flight) systems might be the common factor. It is indeed difficult to separate genetic factors from environmental causes since the cognitive style of a child results from the ways in which he or she has been exposed to learning environments and the specific demands which are placed upon the situation. For example:

> ...Physiological responding during stimulus intake depends entirely upon how a task is constructed and whether it is primarily a categorizing or reasoning problem (Pribram and McGuinness, 1975)

Myopia might be "contagious" and passed on unwittingly by parents and teachers (Bates, 1920). Indeed, myopia seems to be

> ...precipitated by conflicts involving discipline, poor grades, incongenial associates, unsympathetic supervisors, and other factors indigenous to the educational world (Burch, 1954, p. 17)

The nature-nurture question is beyond the scope of this paper, but the evidence contained herein suggests that the issue be considered in a broader light than it has been. That there may exist a genetic factor does not eliminate the possibility of preventing or curing myopia, insofar as it may be the functional reaction, not the anatomical structure, which is inherited (Darwin, 1965/1872).

Metabolic Theory

The model which the experimenter has proposed would account for differences in metabolic characteristics between myopes vs. nonmyopes. These metabolic differences were found by Bothman (1931), and others (see p. 19); a reexamination of the problem is indicated in light of this new information. Wood (1927) and others found that young myopes have depressed levels of free ionic calcium (Ca^{++}) in the blood compared with controls. Low calcium leads to muscle tetany and hyperexcitability of nerve and muscle, especially sympathetic nervous system transmitter chemicals which have been implicated in the special type of isometric contraction referred to above. (Information concerning Ca^{++}, Pco_2*, blood alkalinity, breathing, etc., comes from

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*Pco_2 (also written pCO_2) is the partial pressure of carbon dioxide. In blood the principal gasses are oxygen and carbon dioxide. The relationship between these gases determines the pH (acidity or alkalinity) of the blood. Gases in a mixture exert pressure (i.e., tendency to go into solution), each gas exerting part of that pressure (partial pressure).

Bard, 1961, unless referenced otherwise). Feldman (1950) and others found that the administration of calcium and vitamins did not arrest the progress of myopia, however. Since it is the ratio of bound to free ionic calcium that is important in hyperexcitability of nervous and muscle tissue, and not the overall amount of calcium in the body, it is not surprising that changes in diet did nothing to change refraction. If it is not dietary, what might be causing the decreased blood levels of Ca^{++}?

The Ca^{++} level in the blood is related to blood pH which is determined by the Pco_2 in the blood. When the blood is alkaline, the Pco_2 is low and the Ca^{++} is low as well. Blood alkalinity and Pco_2 are also related to respiration, which has been reported to be abnormal in individuals suffering chronic isometric muscle tension (Reich, 1949). The author has observed clinically that myopes exhibit Biot's breathing (deep breathing for one or two breaths, followed by prolonged breath-holding). It is interesting to note that low Pco_2 is related to hyperventilation, which is the opposite of what one would expect in patients with chronic Biot's breathing. The common factor which relates these two conditions may be explained as follows: "during tasks which involve vigilance and cognitive effort, uncontrolled somatomotor movement is minimized and the sympathetically dominated isometric muscle contraction increases (this form of tonic muscle contraction is anaerobic, whereas the somatomotor muscle contraction is aerobic) (Pribram and McGuinness, 1975). This means that less oxygen is consumed in the metabolic processing taking place in the body, which would lead to a decrease of P_{CO_2} in the blood. The decreased breathing (Biot's breathing) might be a response mechanism designed to increase the blood P_{CO_2} through respiratory control. Watson (1972) reports a mental disorder syndrome in which the patient is continually setting high self-expectancy goals which are rarely met and which keep the patient in a constant state of effort and anxiety in attempting their fulfillment. Pertinent to this discussion, these patients were found to metabolize a deficient amount of oxygen and to have decreased P_{CO_2} levels.

Kelley's (1971) description of body characteristics of myopes included an increase in muscle tension at the base of the skull. (This observation has been confirmed in clinical experience). This type of muscle tension at the base of the skull is known to decrease blood circulation to the brain and head (Jones, 1976). It is interesting to note that one of the medical treatments for Biot's breathing is to decrease blood circulation to the brain (Bard, 1961). The chronic tension at the base of the skull may be a compensatory mechanism to deal with the decreased P_{CO_2} levels in the blood.

Therefore, if the body is chronically using oxygen during habitual cognitive efforting, it is possible that depressed breathing can exist with low P_{CO_2} and low Ca^{++} blood levels. (The incidence of myopia has been related to the incidence of dental caries) (Hirsch and Levin, 1973) which might also relate to calcium level and factors just discussed).

The information offered in the above discussion is conjectural, but has been included to emphasize the importance of broadening the bases of investigations of factors related to myopia. Further investigation of the relationships between myopia and the physiological factors discussed could yield important practical information about the myopic response.

Conditions of Use Theory

Some past studies (Young, 1963) have indicated that the major cause of nearsightedness is reading. The model developed in this chapter would predict that reading is a causal factor in myopia. The process of reading has been described earlier as a vigilance task requiring cognitive effort. It has been suggested that the physiological changes which accompany categorizing, while reasoning, lead to a type of visual motor contraction which can result in myopia.

There must be more factors than just reading involved in the production of myopia, because not all chronic readers become myopic. The psychophysiological model presented suggests some possible factors which might resolve the apparent paradox. One possible difference between the myopic and the non-myopic readers concerns the relationship between the arousal response and frontal organization. A low threshold of arousal (a hyper-reactivity of arousal) might require more cognitive effort to maintain the brain organization for reading. Evidence supporting this possibility is the enlarged pupil which is so characteristic of myopes. Another possibility might include the calcium level in the blood. It has been indicated that low ionic calcium causes hyper-reaction in nerve, muscle synapses, and increases the responsiveness of the sympathetic nervous system. The factors relating to calcium level are varied and include blood alkalinity, Pco_2, breathing, digestion and diet. The psychophysiological model broadens the perspectives for investigating previously isolated relationships and invites research which might lead to remedial and preventive approaches to the problem.

Studies which show a positive relationship of myopia with intelligence, profession and city living have been reported by Borish (1954) and others. These can all be related to aspects of life which encourage the brain organization patterns of self-control and cognitive stress. Farmers for example are not usually in situations which demand the kind of vigilant mental attention which students or highly stressed professionals are used to. Their reality structure is rarely in question. The research by Streff (1974) in which he reported a decrease in expected myopia in a stress and anxiety reduced school environment adds support for the model. If learning can be structured in more meaningful ways, the need for habitual vigilant mental control can be reduced which may lead to the reduced incidence of myopia.

Young's (1961) work with monkeys who were confined for one year in boxes eighteen inches from their eyes produced myopia. This result is not incompatible with the model since the many variables introduced by this procedure could include emotional and physiological reactions besides the limitation of visual fixation distance. The fact that monkeys held in chairs (with longer fixation distances) and monkeys in captivity have a greater amount of myopia than do wild monkeys in further evidence against the mere reduction of viewing distance. The casual elements are not clear. Why lighting levels should influence the development of nearsightedness (Luclish, 1939 and Young, 1966) is not clear. This evidence does indicate a possible physiological effect and is not incompatible with this model.

Biological Variation Theory

This theory is refuted by the evidence that ametropia is not a random affair (e.g., Sorsby, 1964). It has been suggested by Van Alphen (1967) and others that an active process involving cortical and subcortical brain centers works to keep the images clear on the retina. When this process is interfered with in some way, ametropia is produced.

The model developed here suggests that extraocular muscle tension can change the refractive state by changing eye length and this might be the mechanism which correlates the ocular components to bring about emmetropization. Other research concludes that eyeball length is highly correlated to ametropia (e.g., Baldwin, 1964). Cognitive states of brain organization have been implicated as causal factors in chronic muscle tensions of the extraocular muscles and cognitive mental states have been shown to influence refraction (Gesell, 1949). Thus, the evidence which refutes the theory that myopia developes due to normal random variation of anatomical structures also is quite compatible with the proposed model.

Psychological Theory

A problem basic to the studies of personality and its relationship to myopia is that most studies are done after the fact, that is, the myopes are measured many years after the onset of the myopia. This is suggested by Zeiger's (1976) finding that low and medium (under two diopters) myopes measured differently on psychological tests than high myopes who measured more like emmetropes. She conjectured that personality and attitudes of myopes progress through stages as they become more myopic. Low myopes showed a strong aversion to the world which is seen as noxious and irrational. Moderate myopes maintained a similar view of the world but their aversion to it was more moderate. Low myopes were seen to be alert and active in challenging the world, moderate myopes became internal, withdrawing from it by rejection.

Palmer (1966) compared low and high acuity myopes and found that low acuity myopes were more inward and less sensitive to external stimuli than were high acuity patients. His testing involved acuity and not refractive error. His model explains how acuity can change irrespective of refractive error through organization of the contrast enhancement mechanisms of the retina and visual system mediated by the frontal system. If the frontal system were suppressed, awareness of external cues would be reduced and the internal processing mechanisms (posterior system) of reasoning (internally performed actions) would dominate. Palmer (1966) goes on to postulate that myopia is a coping response designed to avoid being overwhelmed by visual overload.

This is consistent with the model in that an over-reaction of the arousal mechanism will cause an emotional reaction which would prevent the individual from seeking information from the environment. Thus a person would tend to avoid situations of uncertainty if possible. Zeiger (1976), however, has found that myopes tend to view the world as uncertain which would tend to lock them into patterns of neurological behavior. They would at first actively attempt to reduce the uncertainty by cognitive effort with the accompanying muscular and metabolic reactions (isometric contraction). Once the pattern had become established the peripheral changes would be involuntary and would be maintained in the posture structure, for example, as myopia, even if the overwhelming aspects of the world have been resolved.

Until the more acute aspects of the struggle to establish certainty in the world had been resolved, the myope would be engrossed in active efforts to understand as much information from a disorganized environment as possible. The individual would attempt to categorize, vigilantly maintaining attention as much of the time as possible. This is compatible with the finding of Stevens and Wolff (1965) that myopic cognitive style is that of sharpeners, tending to categorize rather than to synthesize external cues.

An individual who has been brought up in an atmosphere of uncertainty and unrealistic expectations who is eager to succeed and win approval from authority figures would tend to try harder to understand an overwhelming environment. Such individuals would tend to fall into the categories of psychological tendencies indicated for myopes by various researchers. They would tend to be dependent on approval from external sources rather than from self. Such traits as shyness, introversion, social awkwardness, emotional inflexibility, need for approval, avoiding confrontation, cautious with a high tolerance for anxiety, over-control of emotions, low desire for change, and high need to be good, approved of, and to succeed in high status activities, have been consistently reported in the research (e.g., Lanyon and Giddings, 1964). Myopes were also found to have reduced inclination for motor movement (Mull, 1948) and chronic isometric muscle tension (e.g. in the upper neck, jaws and throat) and distorted posture (Kelley, 1971). This is predicted by the model since cognitive effort requires reduction of motor responses and increases sympathetically dominated isometric contraction of the muscles.

The literature on emotion, personality and psychology thus supports the model. Huxley (1942) summarized the inter-relatedness of psychology with vision.

> That a function so intimately related to our psychological life as vision should remain unaffected by tensions having their origin in the conscious "I" is inconceivable. (p. 39)

The Pilot Study Compared with Previous Research

The assumption of this dissertation is in agreement with the statement of Newell and Hirsch (1967) that good vision is important and that it is desirable to increase the state of our knowledge regarding the refractive anomalies of the eye. But it disagrees with Hirsch (1963) when he urges professionals to deemphasize the possibility of preventing or remediating refractive error. Such an attitude closes us into the present paradigm and fogs our perception of possible evidence to the contrary. There is also disagreement with Hirsch's (1963) statement that refractive error does not change between the ages of twenty and forty. The data of Slataper (1950), Jackson (1934) and Tassman (1932) also contradict Hirsch.

Figure 1 shows the fraction of people with myopia at various ages. There is a noticeable decrease in the percentage of myopes in the age group from about twenty to about age forty-five. This is an indication that myopia must have improved in at least some of the patients. Figures 2 and 3 indicate data points for individual patients. It is clear that some patients change in the direction of less myopia. Examination of the data from the sample study indicate concordance with the existing information. Figure 3 compares the mean dioptric velocity of the present study with the results of Hoffstetter's (1953) study. The data point in this study falls within the general cluster of data points. Figure 4 shows the rate of change of dioptric velocity compared over time (age level). The mean from the present study shows an intersting relationship to the other points. It is as if they lie on a continuation of the direction established in the late teens. This relationship, if valid, could be interpreted in terms of the altered life style of the sample, i.e., if the alternative life style represents a withdrawal from a culture dominated by cognitive effort, then the disposing factors leading to myopia as discussed in Chapter Two, would be minimized for the myopes in this study. This could allow the continuation of the trend established in the late teens. This is highly conjectural, but does indicate an interesting application of this method of data analysis.

The data in this study agree with Tassman's (1932) that myopia improves in the twenties. Bucklers (1952), Hofstetter (1954), and Slataper (1950) all found improvement in some patients. The conclusion, that some patients reduce their myopia, is supported by the historical literature.

Research Questions

There are three questions concerning the first part of the study which relate to Bates, the etiology, and the psychophysiology of myopia.

1) Does recent psychophysiological evidence tend to support Bates? The information presented in Chapter Two indicates that Bates' notions are quite consistent with recently gathered psychophysiological data.

2) Can an etiological model be developed on the basis of Bates' ideas and psychophysiological concepts which is compatible with the literature on nearsightedness? The model developed in this study predicts the literature and integrates information which previously had been considered separately from other information. It also suggests the existence of clues to aid our understanding of the problem of myopia.

3) Should future research be conducted on the basis of Bates' conceptions? The purpose and value of Chapter Two has been based on the assumption that Bates made an important contribution to our understanding of vision and refractive problems. The soundness of this assumption is suggested withing the presentation of the material and in the predictive value of the model. The time is ripe for considering Bates as a major contributor to this field. Technology now exists for examining the details of his statements. Further research should be directed toward this end.

The research questions for the second part of the dissertation, the pilot study, will now be considered.

1) What are the most important variables to consider in analyzing changes in refractive error? The variables considered in this study were age, amount of refractive error, gender, and time after refraction. The mean rate of change and the amount of change was similar for males and females. The amount of change was not compared with the variables since the interval between refractions was not the same for all patients (the interval ranged from five to sixty-four months). The rate of change varied widely according to age in past studies of children and adults (Slataper, 1950). For the relatively narrow range (twenty to thirty years) investigated in this sample, the velocity (change toward less myopia) was slightly greater for the older patients but was only mildly statistically significant. The rate of reduction of myopia increased slightly with increasing refractive error but was not statistically important.

Most rapid change took place within the first ten months following the first examination. This is important to know since it implies that patients should be examined and the prescription reduced more often than suspected.

Of those considered, the most important variable in analyzing refractive change is age according to past studies of a large range of ages.

Some patients in the present study improved rather rapidly (up to 0.167 diopters per month) while others did not change at all. This suggests that other variables which were not considered in this pilot study are important. The psychophysiological investigation of myopia presented in Chapter Two could increase an understanding what the most important factors are. Future research with this model recommended.

2) What are the most sensitive methods of measuring refractive change? On the basis of this investigation the author concluded that computing the dioptric velocity will allow the most dynamic interpretation of the data. This is true not only for investigation of samples of patients but, once a data base can be established, it is also true when working with individual patients. Emphasizing the dynamic aspect of refractive change (velocity) allows for examination of trends over short periods of time. Otherwise, the patient and the practitioner might have to wait for years to prove that refractive error has changed more than an expected amount. The fact that most change takes place in a relatively short period of time following a new prescription (Figure 21) suggests that frequent refractions could implement increased improvement in myopia. The effectiveness of this strategy can be measured by determining the velocity at each interval.

3) Will the results of the second study refute or support Bates' ideas as expressed in the first study? What is at issue here is whether myopia is a fixed anatomical condition (like finger length). If it can be shown that myopia can be improved, then Bates' concepts are supported. If myopia is fixed, then the converse is true. The results of this study indicate that myopia is a flexible condition and does reduce in magnitude (for some individuals as much as 1.75 diopters). The mean change for the total group was a reduction of 0.26 ±0.47 diopters, signifi-

cant at p .001. The conclusion is, therefore, that the data do support Bates' observation that myopia is not a fixed anatomican condition.

4) Can baseline data be established that will be useful in future studies concerning variables which influence changes in refractive error? The data collected in this study represent an historical statement about psychophysiological changes taking place in a sample of young adults in Sonoma County, California in the mid-1970's. The trends which are suggested in the analysis of the data have established a point of departure for future studies. It is important to consider the possibility of spontaneous remission of the ametropia at the age level under consideration (or at any age level for that matter). This fact must be considered when testing for the effects of manipulating specific variables (e.g., diet, remedial techniques, underprescribing, lens therapy, psychotheraputic experience, drugs, life style changes, etc.). The research conducted in this field has been plagued by just such problems in experimental design. Studies using control groups would be a more powerful approach. However, this is time consuming and impractical for private practitioners and it would be suspect for small sample sizes because of individual variation. Definitive statements about results in studies of this kind are not deduced easily. The establishment of baseline data represents a more practical way of attacking the problem. The pilot study of this sample has been conducted in order to define the difficulties and to aid in the design of future research.

Because of the lack of data about aspects of personality, life style, and other variables which might influence refractive changes, the usefulness of this study as baseline data is limited. Nevertheless, it serves a useful purpose in producing certain provocative findings as well as indicating the direction in which future investigation could proceed.

Discussion

Although the model developed here is convincing, there are some aspects of it that are founded more on a synthesis of concepts rather than specific research data. Pribram's concepts are in fact theories about how things might work. They do not represent the typical thinking in the field. Pribram tends to work intuitively and is involved in establishing a more inclusive paradigm than has been offered in the past. He tends to revise his ideas as new information extends or conflicts with his ideas. This could, of course, reduce the validity of the model developed herein but it is a more far-reaching, more inclusive model than has been developed until now. It fills in an important link between the observed anatomical, behavioral, and theoretical thinking about myopia and it calls attention to the thinking of Bates whose ideas have so long been ignored.

There are questions which the model does not reach, for example, why one eye can be so different from another and why some people differ so greatly from others in refractive responses. There is need to develop measures of the physiological and psychological variables and to measure more precisely the dynamic aspects of the eye's anatomy.

Questions as to the scientific basis of methods of treatment of myopia have not been discussed. It will be interesting to examine these in conjunction with the psychophysiological evidence and to measure just how far refractive error can change. There may be different types of myopias which may or may not be compatible with the ideas suggested in this research. Nor did the dissertation consider the other types of refractive anomalies which Bates claimed had similar causes (i.e., mental strain due to environmental stresses).

When considering the possible importance of this work within the framework of humanistic psychology, the author would first point out myopia as indicating an adaptation to an environment which is less than healthy. Myopia represents a constriction in the flexibility of the perceptual, adaptive, and action systems of the organism and therefore, restricts the potential of an individual. If it is true that our ways of seeing determine what we see, what we know, and how we think, then the occurence of myopia has important ramifications in terms of the more general problem of the effects on humans of modern civilization. The dramatic increase in myopia among the Eskimos in a two to three generation time span (Young, 1969), and the two to three times increase of myopia in Japan over a twenty-five year period which came at a time of industrialization and westernization (Sato, 1964), are certainly grounds for considering myopia an epidemic condition of our time. The study of myopia as a social phenomena offers a clue to understanding the unhealthiness of many cultural developments.

Recently the paradigm of health care has been called to public attention. Pelletier (1977) emphasizes that personal health is a personal responsibility and that normal stresses imposed upon us by our institutions may be severely affecting our health. He sums up part of the situation as follows:

> Both chronic and acute illnesses have been linked to psychological and environmental factors. Psychosomatic disorders due to psychosocial stresses have been in evidence since at least 500 B. C., when Socrates stated "there is no illness of the body apart from the mind." And yet, despite the pervasiveness of the view that such a connection exists, the precise causal links remain obscure. They seem to involve the entire life style of the afflicted individuals. Each civilization has its own kind of pestilence and can control it only by reforming itself...just as the great epidemics of the nineteenth century were precipitated by environmental factors which favored the activities of pathogenic microorganisms, so many of the diseases characteristic of our times have their origin in some faulty factor of the modern environment. Perhaps the most important of these faulty factors is excessive, free-floating stress which remains unabated and eventually induces psychological, neurophysiological, and endocrine disruption. (p. 156-157)

He describes syndromes of personality style which proceed various diseases common in our culture and recommends that individuals can learn to change themselves through self-awareness and change in life style which are reminiscent of the approach and thinking of Bates.

In the best sense of the words, Bates was a humanistic psychologist. He was interested in the full development of human potential. He was not satisfied with what seemed to be natural and normal—the increasing dependency on artificial devices to cover up psychophysiological indicators of malfunction in the body. His observation was similar to that of Maslow (1967)

> We tend then to get into the situation...in which normalcy from the descriptive point of view, from the value-free science point of view—that this is the best we can expect, and that therefore we should be content with it. From the point of view outlined, normalcy would be rather the kind of sickness or crippling or stunting that we share with everybody else and therefore don't notice. (p. 155)

Bates (1920) was not content even with what is commonly considered good vision and he described people who could perform amazing acts of outstanding vision such as seeing 20/3 vision, and seeing stars during daylight. He stressed the virtues of perfect vision which included superior memory and highly developed imagination, he formulated a theraputic approach to problems of vision and perception that resembles contemporary holistic approaches to health. He investigated people who had better than normal vision rather than exclusively studying people with vision problems. He examined the behavioral characteristics of these individuals and compared his findings to those who were less fortunate. His therapeutic methods were designed to teach patients to develop healthy habits of seeing and perceiving.

Bates looked for causes, not just within the realm of visual activities, but with regard for the total environment. He was interested in both the individual and the cultural constraints of our society. His observations about the assumptions and methods of our educational institutions are only recently becoming popular in the thinking and literature of humanistic psychology (Harman, 1967).

That Bates has been so maligned and misunderstood is a gross injustice which has impeded our investigation of important problems in the world of health. It is time we take another look at Bates, it is time we stopped paying "lip service" to the ideals of health and prevention; it is time that we seriously investigate concepts and approaches to developing what Teilhard de Chardin (1941) called

> ...ever more perfect eyes within a cosmos in which there is always something more to see. (p. 226)

Implications for Future Research

This dissertation hopes to establish the beginnings of a new paradigm for understanding and treating problems of the eyes. The concepts expressed here need to be filled in with further investigation of the neurophychological aspects which explain more of the variables involved with development, not only of myopia, but with the whole etiology and treatment of all disorders of the eyes.

There is need to measure more precisely the various autonomic functions which might relate to refractive problems. We must expand our viewpoint in seeking the variables which relate to vision. There is need to investigate the validity of the ideas expressed here especially in regard to children.

There exists great opportunity to learn more about the influences of improperly administered educational methods which might lead to problems of vision and the constriction of consciousness which seems to manifest in so many of our children. If a study can show the effects of mental strain on school children (as measured by refractive changes) perhaps it could lead to improvement in the paradigm which dominates our educational institutions. The work of Streff (1974) mentioned earlier represents a good start in this direction.

There exists a great data pool in the offices of vision professionals. Information about sociological and anthropological influences as measured by refractive conditions can lead to better understanding of the influences of modern civilization on the health of humans. Research is rarely conducted by individual practitioners in the field. Perhaps the pilot study reported herein can lead to more work on small samples of patients and to the establishment of baseline data for future understanding of refractive changes in our population in terms of life style, cultural shifts, educational methods, and perhaps the improvement and prevention of vision problems. Larger clinics such as those at colleges of optometry could investigate these matters and have a great potential for establishing procedures for improving and preventing myopia.

There is a need to investigate methods of eliminating refractive problems by the use of psychological, nutritional, biofeedback and other approaches to health. Specific techniques already exist (such as Bates') which have received little energy by the established research centers in vision. Other approaches such as the use of biofeedback, various body therapies, acupuncture, and color have been mentioned by individuals interested in improving their vision.

In the author's work, the information contained in this paper has added greatly to future investigation of the problems. The present pilot study was severely limited due to a lack of data on psychological and social aspects of the patients. The examiner understands enough background about the relationship of nutrition, breathing, and myopia to formulate meaningful research questions and to open the possibility of including a nutritional element in his practice.

The pilot study will be used to design future research on psychological and life style effects on refractive variations. The author is in the process of designing a questionnaire to be completed by his patients and the patients of other optometrists which will allow him to research various demographic and sociologic factors. The questionnaire is being designed to test not only the possibility of improving vision, but will allow the assessment of the practicality and validity of the psychophysiological model developed here. Research projects on his therapy groups will be conducted with greater elegance and will lead him to develop more effective therapy techniques.

From the perspective of the examiner the possible applications of the model are profound. A model, of course, differs from a theory for its intention is to clarify questions, not to settle them. This is an important distinction, for as Bates (1920) pointed out:

> ...I have never been able to formulate a theory that would withstand the test of facts either in my possession at the time, or accumulated later. The same is true of the theories of every other man, for a theory is only a guess, and you cannot guess or imagine the truth. No one has ever satisfactorily answered the question, "Why?" as most scientific men are well aware, and I did not feel that I could do better than others who had tried and failed. One cannot even draw conclusions safely from facts, because a conclusion is very much like a theory, and may be disproved or modified by facts accumulated later. In the science of

> ophthalmology, theories, often stated as facts, have served to obscure the truth and throttle investigation for more than a hundred years. The explanations of the phenomena of sight put forward by Young, von Graffe, Helmholtz and Donders have caused us to ignore or explain away a multitude of facts which otherwise would have led to the discovery of the truth about errors of refraction and the consequent prevention of an incalculable amount of human misery. (preface)

The field of humanistic psychology would do well to remember this line of reasoning.

Appendix I

THE BATES SYSTEM OF BETTER EYESIGHT WITHOUT GLASSES

It is important for you to become self-aware of the ways in which you overtense your eyes in order to try to see. It is important that you free your body - your potential mechanism. The places to look for tension mostly include: the back of the upper neck; the upper back; between the shoulders; the hands and feet; the shoulders; the pelvis; the chest; and the stomach. Yoga, meditation, massage, Feldenkrais, Alexander, Rolfing, polarity, dancing, running, breathing, swimming, etc. are all excellent adjuncts to Bates' system. It is important to learn to take your glasses off, especially in non-demanding, non-threatening situations. You are not blind, and though you can't see what you think you are supposed to see, you can see what you can see, so pay attention to that which is there for you. Everyone experiences emotional factors when they change to no glasses.

The Four Basic Exercises: (To be done when they feel good - ten minutes or thirty seconds - the more often and the longer, the better.)

Palming: Eyes covered by palms (no pressure on eyes); fingertips at hairline; fingers overlapped to allow breathing room for your nose. Elbows resting on table, chairback, pillow, etc. Relax, feel your eyes give up the tension of trying to see. Let yourself go as much as you can. Let go into what you may be seeing; keep breathing. Memorize the feeling of palming. To be done especially before doing a visual task such as reading. EYES CLOSED.

Swinging: Rotate your body from left to right and back. Eyes, torso and head move together. Turning mostly around your waist. Don't look at anything as you swing; be aware of movement mainly. Let your eyes go, let your consciousness stay in front of you while you turn. Make sure to keep breathing.

Sunning: Face the sun, eyes closed. I repeat: EYES CLOSED. Allow the warmth of the sun to penetrate deeply into your eyes and forehead.. Relaxedly turn your head from side to side. Keep breathing. Feel the position of the sun.

Blinking and Breathing: Beware of the stare. We lock ourselves into a stare, eyes immobile and breath stopped. Spaced. Blink your eyes rapidly as you take two big breaths whenever you become aware of your eyes or breath.

Other exercises and more complete descriptions are to be found in the following:...

M. Corbett: Help Yourself to Better Sight

W. Bates: Better Eyesight Without Glasses

A. Huxley: The Art of Seeing

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APPENDIX II

RAW DATA

FEMALES	AGE	D_1	D_2	D_2-D_1	t_2-t_1 MONS.	D_2-D_1/t_2-t_1
	20	-1.50	-1.50	.00	24	.000
	20	-1.75	-2.25	- .75	24	.031-
	20	-1.50	-1.75	- .25	24	.010-
		-2.00	-2.50	- .50	24	.021-
	21	-1.50	-1.25	+ .25	12	.021+
		- .75	- .50	+ .25	12	.021+
	21	-3.50	-3.75	- .25	29	.009-
		-4.00	-4.25	- .25	29	.009-
	22	.00	.00	.00	46	.000
		-2.75	-2.25	+ .50	46	.011+
	22	1.50	-1.25	+ .25	35	.007+
		-1.25	-1.00	+ .25	35	.007+
	22	-3.50	-3.25	+ .25	30	.008+
		-3.00	-3.00	.00	30	.000
	23	-3.75	-2.75	.00	29	.000
		-3.75	-3.75	.00	29	.000
	24	-2.00	-2.25	- .25	33	.008-
		-2.00	-2.25	- .25	33	.008-
	24	-2.75	-2.00	+ .75	17	.044+
		-2.75	-1.75	+1.00	17	.059+
	25	-3.50	-2.75	+ .75	24	.031+
		-2.75	-2.25	+ .50	24	.021+
	25	-2.00	-1.75	+ .25	37	.007+
		-2.25	-1.75	+ .50	37	.014+
	25	-1.50	-1.25	+ .25	17	.015+
		-1.00	-1.00	.00	17	.000
	25	-5.00	-5.25	+ .75	18	.042+
		-6.75	-6.00	+ .75	18	.042+
	25	-2.75	-3.25	- .50	23	.022-
		-2.75	-3.25	- .50	23	.022-
	25	-4.00	-4.00	.00	40	.000
		-4.25	-4.00	+ .25	40	.006+
	26	-3.00	-2.75	+ .25	5	.050+
		-3.00	-3.00	.00	5	.000
	25	-1.25	- .25	+1.00	7	.143+
		- .75	.00	+ .75	7	.107+
	29	-1.75	-1.50	+ .25	18	.104+
		- .75	- .75	.00	18	.000
	27	-1.75	-1.75	.00	12	.000
		-2.25	-2.25	.00	12	.000
	28	-2.75	-2.00	+ .75	9	.083+
		-3.00	-2.25	+ .75	9	.083+
	28	-1.75	.00	+1.75	48	.036+
		-2.25	- .50	+1.75	48	.036+
	29	-2.25	-1.50	+ .75	20	.038+
		-1.75	- .75	+1.00	20	.050+
	29	-1.25	-1.00	+ .25	16	.016+
		-1.25	-1.00	+ .25	16	.016+
	29	-2.50	-2.00	+ .50	30	.017+
		-2.25	-1.75	+ .50	30	.017+
	29	- .75	- .25	+ .50	21	.024-
		- .75	- .25	+ .50	21	.024+
	29	-1.50	-1.50	.00	12	.000
		- .75	- .75	.00	12	.000
	29	-1.75	-1.50	+ .25	19	.013+
		-1.75	-1.25	+ .50	19	.026+

APPENDIX II
RAW DATA

MALES

Age	D_1	Age_2	D_2	D_2-D_1	t_2-t_1	D_2-D_1/t_2-t_1
21	-3.75	22	-3.75	.00	14	.0000
	-3.50	22	-3.00	+ .50	14	+.0357
21	-1.25	24.5	- .75	+ .50	43	+.0116
	-1.25	24.5	- .75	+ .50	43	+.0116
22	-3.75	24.5	-2.75	+1.00	28	+.0357
	-4.00	24.5	-3.00	+1.00	28	+.0357
22	-1.25	22.5	-1.00	+ .25	5	+.0500
	-2.25	22.5	-2.00	+ .25	5	+.0500
22	-1.75	27.5	-2.00	- .25	68	-.0037
	- .75	27.5	- .50	+ .25	68	+.0037
22	-4.50	24	-4.75	- .25	25	-.0100
	-4.25	24	-4.75	- .50	25	-.0200
24	-1.75	26	-3.25	- .50	23	-.0217
	-1.75	26	-2.25	- .50	23	-.0217
25	-1.50	26	-1.50	.00	12	.0000
	- .75	26	-1.00	- .25	12	-.0208
25	-1.25	26	-1.00	+ .25	12	+.0208
	-1.25	26	-1.00	+ .25	12	+.0208
26	-4.75	29	-4.25	+ .50	35	+.0143
	-3.75	29	-3.50	+ .25	35	+.0071
26	-1.50	27.5	-1.50	.00	17	.0000
	-1.25	27.5	-1.50	- .25	17	-.0147
26	-3.50	28	-2.75	+ .75	10	+.0750
	-3.50	28	-2.75	+ .75	10	+.0750
26	-8.75	31.5	-9.00	- .25	64	-.0039
	-8.25	31.5	-9.00	- .75	64	-.0117
27	-3.75	30.5	-3.50	+ .25	32	+.0078
	-3.75	30.5	-3.50	+ .25	32	+.0078
27	-2.50	28.5	-2.25	+ .25	20	+.0125
	-1.75	28.5	-1.75	.00	20	.0000
27	-2.00	29	-2.00	.00	26	.0000
	-2.00	29	-2.25	- .25	26	-.0096
26	-4.50	27.5	-3.75	+ .75	18	+.0417
	-4.50	27.5	-4.00	+ .50	18	+.0278
28	-3.50	28.5	-3.25	+ .25	5	+.0500
	-2.50	28.5	-2.00	+ .50	5	+.1000
29	-3.75	30	-3.75	.00	11	.0000
	-4.00	30	-3.75	+ .25	11	+.0227
29	-7.50	31	-7.25	+ .25	24	+.0104
	-10.25	31	-10.00	+ .25	24	+.0104
29	-2.25	30	-2.50	- .25	13	-.0192
	-2.25	30	-2.50	- .25	13	-.0142
29	-3.75	32	-3.00	+ .75	36	+.0208
	-2.00	32	-1.00	+1.00	36	+.0278
29	-1.50	31	-1.00	+ .50	21	+.0238
	-1.50	31	-1.00	+ .50	21	+.0238
29	-1.25	29.5	- .50	+ .75	6	+.1250
	-1.75	29.5	- .75	+1.00	6	+.1667

N=52 EYES=110

LIST OF REFERENCES

Alexander, F. M. The Resurrection of the Body. New York: Dell Publishing, 1969.

Apell, R. and Lowry, R. W. Jr. Preschool Vision, St Louis: American Optometric Association, 1959.

Bach-y-Rita, P. and Ito, F. In vivo studies on fast and slow muscle fibers in cat extraocular muscles. Journal of General Physiology, 1966, 49, 1177.

__________, Collins, C. C. and Tengroth, B. M. Influence of extraocular muscle co-contracture on globe length. American Journal of Ophthalmology, 1968, 66, 906-908.

Back, F. Transient myopia after use of aceazolanide. American Medical Association Archives of Ophthalmology, 1956, 55, 546-547.

Baldwin, W. R. Some Relationships between Ocular, Anthropometric, and Refractive Variables in Myopia. Unpublished doctoral dissertation, Indiana University, Bloomington, Indiana, 1964.

Bard, P. Medical Physiology. St. Louis: C. V. Mosby, 1961.

Bates, W. H. The Cure of Imperfect Sight by Treatment Without Glasses. New York: Central Fixation Publishing, 1920.

__________, Throw away your glasses. Hearst's International, September, 1928.

Berens, C., Giraard, S., and Fonda, G. Tachistoscopic training. American Journal of Ophthalmology, 1957, 44, 25-48.

Borish, I. Clinical Refraction (ed. 2). Chicago: Professional Press, 1954.

Borrello, G. The importance of choloiditis in myopia. Rassegna ital. d'ottalmol, 1951, 20, 320-322.

Bothman, L. The relation of the basal metabolism rate to progressive myopia. American Journal of Ophthalmology, 1931, 14, 918-924.

Brown, E. V. L. Net average yearly changes in refraction of atropinized eyes from birth to beyond middle life. American medical Association Archives of Ophthalmology, 1938, 19, 719-734.

Burch, E. B. Psychosomatic problems in ophthalmology. Canadian Medical Association Journal, 1954, 75, 9-17.

Campbell, W. Personal communication. 1977.

Darwin, C. The Expression of the Emotions in Man and Animals. Chicago: University of Chicago Press, 1965 (1872).

Dellaporta, A. A. A case of transitory myopia after prontosil. Proceedings of the Ophthalmological Society of Vienna, 1942, 87, 11-13.

DeVreis, D. The statistical relationship between the occurrence of myopia and stroma in school children. Tidschrift voor Sociale Genneskunde, Delft, 1950, 28, 79-80.

Feldenkrais, M. Awareness Through Movement. New York: Harper and Row, 1972.

Feldman, J. B. Myopia, vitamin A and calcium. American Journal of Ophthalmology, 1950, 33, 777-785.

Ferguson, M. Brain/Mind Bulletin, 1977, 2, (16), 1-3.

Filatov, V. P. and Volokitenho, A. E. Osmotherapy in high myopia without macular changes. Vestnik Oftalmol., 1940, 17, part 5, 515-519.

Fox, J. Functional Factors in Myopia. Unpublished doctoral dissertation, UCLA Psychology Department, Los Angeles, 1959.

Frankeschetti, A. J. Zur Refraktionskurve des Neugebornen, Klin. Monattsbl. genet. humaine, 1953, 2, 283.

Francois, J. Heredity in Ophthalmology. St. Louis: C. V. Mosby, 1961.

Fry, G. A. Comment on the possible role of the contents of the orbit and action of the extraocular muscles in the development of the size and shape of the eye. N.I.N.D.B. Monograph No. 5: Refractive Anomalies of the Eye. Bethesda, MD.: U.S. Department H.E.W., P.H.S., N.I.H., N.I.N.D.B., 1967.

Galin, M. A., et. al. Deamox induced myopia. American Journal of Ophthalmology, 1962, 54, 237-277.

Getman, G. Techniques and Diagnostic Criteria for the Optometric Care of Children's Vision. Duncan, OKL., Optometric Extention Program, 1958.

Giddings, J. W. and Lanyon, R. I. Modification of refractive error through conditioning: an exploratory study. Behavior Therapy, 1971, 2, 528-542.

Gesell, A., Ilg, F. L., and Bullis, G. E. Vision, its Development in Infant and Child. New York: Hoebner, 1949.

Gregg, J. R. The Story of Optometry. New York: Ronald Press, 1965.

Grosvenor, T. Refractive anomalies of the eye—Part 11: A survey of adult refractive changes. Optometric Weekly, 1977, 68, 44-45.

Halpern, A. and Kulvin, M. M. Transient myopia during treatment with carbonic anhydrase inhibitors. American Journal of Ophthalmology, 1955, 48, 388-411.

Harman, W. W. Old wine in new wineskins—the reasons for the limited world view. In Bugental, J. T. F. (ed.), Challenges of Humanistic Psychology. New York: McGraw-Hill, 1967.

Henderson, T. The constitutional factor in myopia. Transcripts of the Ophthalmological Society of the United Kingdom, 1934, 54, 451-459.

Hildreth, H. R., Mainberg, W. H., Milder, B., Post, L. T., and Sanders, T. E. The effects of visual training on existing myopia. American Journal of Ophthalmology, 1947, 30, 1563-1576.

Hirsch, M. J. Relation of visual acuity to myopia. Archives of Ophthalmology, 1945, 34, 226-231.

________, The changes in refraction between the ages of 5 and 14, theoretical and practical considerations. American Journal of Optometry and Archives of the American Acadamy of Optometry, 1952, 29, 32-36.

________, Hirsch, M. J. The refraction of children. In Hirsch, M. J. and Wick, R. E. (eds.), Vision of Children. New York: Chilton, 1963.

________, and Levin, H. Myopia and dental caries. American Journal of Optometry and Archives of the American Acadamy of Optometry, 1973, 50, 484.

History in the Making: William Horatio Bates, Margaret Darst Corbett. New York: James T. White, 1944.

Hofstetter, H. W. and Rife, S. C. Miscellaneous optometric data on twins. American Journal of Optometry and Archives of the American Academy of Optometry, 1953, 30, 139-150.

Huxley, A. The Art of Seeing, New York: Harper and Brothers, 1942.

Jackson, E. Norms of refraction. Journal of the American Medical Association, 1932, 98, 132-140.

Jones, F. R. Body Awareness in Action, New York: Schaken, 1976.

Kelley, C. R. Psychological Factors in Myopia. Unpublished doctoral dissertation, New School for Social Research, New York, 1958.

_________, Improving defective vision: a new approach. An amplification of remarks to the U. S. Office of Education Conference on Low Vision, San Francisco, November 29, 1970.

_________, New Techniques of Vision Improvement. Los Angeles: Interscience Research Institute, 1971.

Kephart, N. C. and Unger, R. M. An investigation of visual performance among selected groups of school children. American Journal of Optometry and Archives of the American Academy of Optometry, 1953, 30, 635-643.

Knapp, A. A. Vitamin D complex in progressive myopia. American Journal of Ophthalmology, 1939, 22, 1329-1337.

Kramb, R. A. A case of transient myopia due to ingestion of sulfa. American Journal of Optometry and Archives of the American Academy of Optometry, 1952, 29, 209-211.

Lanyon, R. I., and Giddings, J. W. Psychological approaches to myopia: a review. American Journal of Optometry and Physiological Optics, 1974, 51, 271-281.

Law, F. W. Calcium and parathyroid therapy in progressive myopia. Transcripts of the Ophthalmological Society of the United Kingdom, 1934, 54, 281-290.

Lijo, P. J. Snythetic testicular hormones in treatment of progressive myopia. Review of Oto-neuro-opt., 1939, 14, 161.

Linder, K. New thoughts on myopia. Klin Monattsbl. f. Augenheilk, 1939, 103, 582.

Livingston, P. C. Myopia among war prisoners. Transactions of the Ophthalmological Society of the United Kingdom, 1946, 66, 248-264.

Loeb, C. Review of W. H. Bates, American Journal of Ophthalmology, 1919, 2, 320.

Lowen, A. The Language of the Body, New York: Grune and Stratton, 1958.

_________, The Eyes are the Mirrors of the Soul, New York: (Mimeographed material), 1968.

Luckeish, M. and Moss, F. K. Ocular changes in school children during the fifth and sixth grades. American Journal of Optometry and Archives of the American Academy of Optometry, 1939, 16, 443-450.

Macdonald, L. W. Accommodative rock—its purpose and value. Visual Training, Duncan, OKL: Optometric Extension Program, 1963, 2, 9-15.

Mackworth, N. H. Stimulus density limits the useful field of view. In Monty, R. A. and Senders, J W. (eds.), Eye Movements and Psychological Processes. New York: Lawrence Erlbum Associates, 1976.

Maslow, A. H. Neurosis as a failure of personal growth. Humanitas, Journal of the Institute of Man, 1967, 8, 154-169.

McLaren, D. S. Malnutrition and the Eye, New York: Academic Press, 1960.

Matyushkin, N. Slow and fast fibers in extraocular muscles. Archives of Soviet Monographs, 1964, 23, 1103.

Meyer-Schwickerath, G. Statistical research in twins on peristatic factors influencing the degree of myopia. Von Graefe's Archives of Ophthalmology, 1949, 149, 695-700.

Mull, H. K. Myopia and introversion. American Journal of Psychology, 1948, 61, 575.

Newell, F. W. and Hirsch, M. J. Clinical importance of refractive anomalies. N.I.N.D.B. Monograph No. 5: Refractive Anomalies of the Eye, Bethesda, MD., U. S. Dept. H.E.W., P.H.S., N.I.H., N.I.N.D.B., 1967.

Ogle, K. N. Promising avenues for future investigation. N.I. N.D.B. Monograph No. 5: Refractive Anomalies of the Eye. Bethesda, MD., U. S. Dept. H.E.W., P.H.S., N.I.H., N.I.N. D.B., 1967.

Palmer, R. D. Visual acuity and excitement. Psychosomatic Medicine, 1966, 28, 364-442.

Pelletier, K. R. Mind as Healer Mind as Slayer. New York: Dell Publishing, 1977.

Penfield, W. and Brodrey, E. Somatic motor sensory representation in the cerebral cortex of man as studied by electrical stimulation. Brain, 1937, 60, 389-443.

Pribram, K. H. Languages of the Brain: Experimental Paradoxes and Principles in Neuropsychology. Englewood Cliffs, N.J., Prentice-Hall, 1971.

__________, How is it that sensing so much we can do so little? In Central Processing of Sensory Input, Neurosciences, (Volume 3), Boston: M.I.T. Press, 1974.

__________, Toward a holonomic theory of perception. In Ertle, Kemmler, and Stadler (eds.), Gestaltteorie in der modernen Psycholgie, 1975.

__________, and McGuinness, D. Arousal, activation and effort in the control of attention. Psychological Review, 1975, 82, 116-149.

Price, A. Nutrition and physical degeneration. American Medical Association Archives of Ophthalmology, 1939, 22, 1983-2089.

Reed, J. G. Malnutrition among war prisoners. Transcripts of the Royal Society of Tropical Medical Hygine, 1947, 40, 411.

Reich, W. Character Analysis (ed. 3). New York: Orgone Institute Press, 1949.

Rosanes, M. B. Psychological Correlates of Myopia Compared to Hyperopia and Emmetropia. Unpublished doctoral dissertation, Yeshiva University, New York, 1966.

Rubin, M. L. Surgical procedures available for influencing refractive error. N.I.N.D.B. Monograph No. 5: Refractive Anomalies of the Eye. Bethesda, MD: U. S. Dept of H.E.W., P.H.S., N.I.N.D.B., N.I.H., 1967.

Sato, T. Acquired Myopia. Lecture delivered at the First International Conference on Myopia, New York. Chicago: Professional Press, 1964.

Shapero, M. and Hirsch, M. J. The relationship of refractive error and Guilford-Martin temperament scores. American Journal of Ootometry and Archives of the American Academy of Optometry, 1952, 29, 32-36.

Slataper, F. J. Age norms of refraction and vision. American Medical Association Archives of Ophthalmology, 1950, 466-481.

Segall, M. H., Campbell, D. T., and Herskovits, M. J. The Influence of Culture on Visual Perception. New York: Bobbs-Merrill, 1966.