# THE ETIOLOGY OF VISION DISORDERS

A NEUROSCIENCE MODEL

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OPTOMETRIC EXTENSION PROGRAM

### **CHAPTER 5**

# VISION AND THE HYPOTHALAMUS<sup>1</sup>

### **Abstract**

Vision has been defined typically by its sensory and motor processes. The purpose of this report is to present evidence for autonomic nervous system (ANS) involvement with the vision system, with particular emphasis on the role of the hypothalamus.

The most studied ANS component of the vision system is the accommodative mechanism via parasympathetic and sympathetic innervation to the ciliary muscle for the focusing process known as accommodation. The accommodative process is related to the etiology of myopia and hyperopia, and other vision disorders.

In addition to accommodation, other aspects investigated in relation to the ANS are intraocular pressure (IOP), EMG tension, attention, brain wave patterns, and color vision. The results demonstrate a significant relationship between vision and the ANS on many levels.

Sympathetic nervous system fibers originate in the hypothalamus on their way to the superior cervical ganglion, where they synapse, to the ciliary muscle. Fibers also have been discovered to go from the retina to the hypothalamus. Such a dynamic, closed-loop system demonstrates the interdependence of vision and hypothalamic activity.

An independent series of studies have reported on the effect of visualization on the immune system. The suggested center for this activity has been identified as the hypothalamus. A discussion of the specific neurophysiological mechanisms will be presented later in this chapter.

### Introduction

There is certainly no doubt that vision involves much more than just these sensory and motor processes. The effects of imagery on behavior have been shown to be dramatic. For example, in relation to emotional behavior the use of eidetic imagery has been effective as short term therapy (Ahsen, 1973), and in

psychosomatic illness the use of visualization has been found to bolster the immune system for cancer and AIDS patients (Halley, 1988; Norris, 1988). We see things that make us happy, sad, hungry, thirsty, full of energy, and tired.

There have been previous reports on the relationship between the ANS and vision disorders. These reports clearly demonstrate that most vision disorders are trainable with substantial improvements. In addition, these reports have contributed to the body of knowledge leading to an understanding that disorders such as myopia and hyperopia are behaviors related to more central mechanisms such as learning and memory.

Information related by patients during this training led to the investigation of non-visual changes as a result of the treatments. In addition to accommodation, other aspects investigated in relation to the ANS are intraocular pressure (IOP), EMG tension, eidetic imagery, attention, brain wave patterns, and color vision. A detailed discussion about IOP will be included in this chapter. The other physiological functions will be discussed in detail in Chapters 13 and 14 and only a brief discussion of them will be presented here.

The method used is a biofeedback-based therapy primarily using an instrument specifically designed to train voluntary accommodative control. The instrument measures the focusing power of the eye 40 times per second and provides immediate auditory feedback. In the initial stages of training there are no visual cues, while such cues are introduced in later stages, where generalization is being trained (Trachtman and Giambalvo, 1986).

A number of subsequent studies were conducted to investigate the relationship of intraocular pressure (IOP), EMG tension, attention, brain wave patterns, and color vision with the ANS.

The results demonstrated a significant relationship between vision and the ANS on many levels. There was a significant lowering of IOP with a concurrent relaxation of accommodation and reduction of nearsightedness. The lowering of IOP can occur either via a localized release of noradrenalin or by a more central process. The finding of other concurrent ANS changes with accommodative relaxation lead to the conclusion that there was a central process with possible localized activity as well. One of the principle findings related to an increase in sympathomimetic activity is an increase in the size of the visual field with a concomitant reduction in reaction time within the increased visual field. These changes are suspected to be related to stimulation of the reticular activating system (RAS) and the nucleus locus coeruleus (NLC) (Schmidt, 1985).

Another interesting finding was a change in color perception based on the accommodation training. There was a shift in the patients' sensitivity to color with more accuracy in color matching. The shift showed more errors in the blue-green region and fewer errors in the yellow-green region. The reason for the shift can be attributed to the lack of blue color photoreceptors in the center of the fovea of the eye. One of the effects of the accommodation training is improved foveal fixation of objects in space. These data also reinforce recent findings of increased sympathetic nervous system activity in the retina (Jacobs, 1972, Hadjiconstantinou et al., 1983, Kuljis and Karten, 1988, Tornquist and Ehinger, 1988, and Straznicky and Hiscock, 1989).

With the simultaneous use of EMG equipment to monitor muscle tension in the frontalis, masseter, and trapezius muscles, a decrease muscle tonus was found to be related to relaxation of accommodation. Similarly, a relaxation of accommodation was found to be consistently related to an increase in the measure of alpha brain wave activity with eyes open. Both of these effects lend even more support to a central mechanism involved in the relaxation of accommodation and the many non-visual related events.

Sympathetic nervous system fibers originate in the hypothalamus on their way to the superior cervical ganglion and finally to the ciliary muscle. Fibers also have been discovered to go from the retina to the hypothalamus. Such a dynamic, closed-loop system demonstrates the interdependence of vision and hypothalamic activity. The search for a central mechanism mediating the numerous non-visual changes to accommodative relaxation, therefore, should demonstrate considerable hypothalamic involvement.

Clinical reports, dating from even before Freud's time, have identified a difference in vision status with character changes in multiple personalities (see Chapter 9-Psychology of Vision Disorders).

An independent series of studies have reported on the effect of visualization on the immune system. The suggested center for this activity has also been identified as the hypothalamus. Although the exact neurophysiological mechanisms for these visual and nonvisual changes related to accommodation have not been elaborated, some suggestions can be made. Recently discovered neuropeptides (Snyder, 1980) have been identified in different layers of the retina. Neuropeptides are known to be found at sympathetic nervous system synapses. These neurotransmitters are also well known to be common to specific parts of the body, i.e., vasoactive intestinal polypeptide, which is common to the brain and the gut. The suspected mechanism is not one of a systemic release of adrenalin, but rather a learned relationship between anatomical structures based on specific releases of neuropeptides mediated by hypothalamic sympathetic nervous system activity.

For more discussion on the peptides see Chapter 4--Animal Models of Refractive Conditions.

# Experiment I - Intra-Ocular Pressure (IOP)<sup>2</sup>

### 1. Abstract

The relationship between accommodation and intraocular pressure (IOP) has been the topic of controversy for nearly 100 years. Some researchers claimed that there was a lowering of IOP with increased accommodation and others claimed that IOP was raised after prolonged accommodation. Biofeedback was selected as the procedure to decrease tonic accommodation implicating increased sympathetic nervous system activity to the ciliary body. A highspeed, infra-red optometer measured accommodative status and provided immediate auditory feedback 40 times per second. The first 100 patient visits during a five week time period were selected. Each patient had IOP measured before and after the biofeedback training session to reduce tonic accommodation. The Keeler Air-Pulse Tonometer was utilized to measure IOP because it automatically makes measurements when it is aligned. Four measurements were made for each eye, before and after, and the arithmetic mean was used as the measure of IOP. The right eye was always measured first. The biofeedback consisted of five minutes of training the right eye, five minutes of training the left eye, 10 to 15 minutes of rest, five minutes of training the left. The results showed that for patients with before IOP's of 14 mm/Hg or greater, there was a significant reduction in IOP (p < 0.05). The reduction effect can be explained by the general sympathomimetic stimulation from the biofeedback training producing a norepinephrine effect on the aqueous production and/or outflow mechanism. This is consistent with experiments testing the effects of exogenous and endogenous released norepinephrine on IOP.

### 2. Introduction

The effects of biofeedback of accommodation and intra-ocular pressure (IOP) are not well known and will require explanation of two topics: biofeedback of accommodation and biofeedback of IOP.

Biofeedback of accommodation has been used primarily to reduce myopia (Trachtman, 1987a), although its use for hyperopia and presbyopia has also shown significant reductions (Trachtman and Pelcyger, 1986). The mechanism for the myopia reduction involves stimulation of the sympathetic nervous system and dilation of the ciliary muscle (Trachtman, 1987b). With sympathetic nervous system stimulation, there is a dynamic, generalized response of the sympathetic nervous system to other parts of the brain and the body (Trachtman, 1986). The ciliary muscle is a component of the ciliary body, the ciliary body being responsible for the production of aqueous humor. Both mechanisms, accommodation and aqueous humor production, have alpha-1 and 2, and beta-1 and 2 sympathetic nervous system innervation (Moolchandani et al., 1986). A reasonable hypothesis is that a change in the function of one of these mechanisms would have an effect on the other.

The research into the field of biofeedback of IOP has been conducted mostly by Raczynski and his coworkers (Raczynski et al., 1985; Silvia et al., 1984). They used facial muscle EMG biofeedback to reduce IOP. In these papers and from personal communication with Raczynski, it is their conclusion that there is a relationship between stress and IOP, the more stress the higher the pressure. Unfortunately, as of July 1986, they discontinued their studies to pursue other research.

To the best of my knowledge there is no present investigation into the area of biofeedback to reduce IOP.

From other optometrists who use the Accommotrac® Vision Trainer (AVT), I have been informed of individual cases where there were IOP reductions after the training. Although, I have also received reports where there were no changes in IOP after the training. I must admit that under such circumstances I had to conclude that both sets of reports must be accurate, but I did not understand why. I, therefore, decided to test the hypothesis that biofeedback training has an effect on IOP.

### 3. Methods

### **Subjects**

The subjects were selected from my private practice of optometry. The criterion for selection in the study was to be among the patients receiving the first 100 treatment sessions for biofeedback of accommodation to reduce myopia, training beginning on September 15, 1987 and ending five weeks later. Most patients were measured more than once, since they usually were given biofeedback once per week. The subjects ranged in age from 10 to 55 years. Only one subject had been diagnosed as having glaucoma.

### **Apparatus**

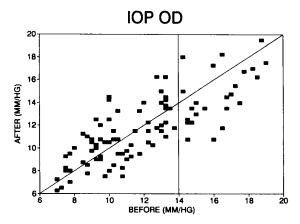
The Keeler Air-Pulse tonometer was used to measure IOP. This instrument was selected because it makes measurements automatically when it is properly aligned with the eye. The Accommotrac® Vision Trainer was used to provide biofeedback of accommodation.

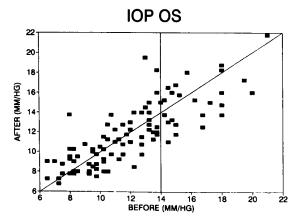
### **Procedure**

Before each training session the subjects had their IOP measured. Four measurements were taken and the arithmetic mean was used in the calculations. The right eye was always measured first. The same protocol was followed after the one-hour training sessions. Subjects were generally scheduled for appointments on the same day of the week, and at the same time of the day to reduce the effects of diurnal IOP variations.

### 4. Results

From the two data graphs on the following page, Figures 5.1 and 5.2, it is apparent that for IOPs below 14 mm/Hg, the training had no effect.





Figures 5.1 and 5.2. Experiment I The results of IOP measurements by the Keeler Air-Pulse tonometer of 100 myopic patients Before and After biofeedback to relax accommodation. The diagonal line represents the location where the Before and After IOPs would be equal. Any data points above the line indicate IOPs that were higher After the training, while any data points below the line indicate IOPs were lower After the training. Particular notice is called for IOPs 14 mm/Hg and higher. More data points fall below than above the diagonal line. Such a pattern is not observed for IOPs lower than 14 mm/Hg. For the IOPs 14 mm/Hg and higher, this difference was statistically significant as shown in Table 5.1.

However, for IOPs greater that 14 mm/Hg, there was a reduction in the IOP after the training. This is true for both the right and left eyes. An easy way to view these data is to note that any points along the diagonal line mean the IOP was equal Before and After the training. As can be seen from Figures 5.1 and 5.2, below 14 mm/Hg the scatter points for any level of IOP fall equally above and below the diagonal line. Above 14 mm/Hg the majority of the points fall below the diagonal line because the After IOP is lower than the Before IOP. T-test analysis does not show 0.05 significance for the entire data. If the data are separated and another analysis is made for the Before IOPs measurements of greater that 14 mm/Hg (n=33), there was a statistically significant reduction for both the right and the left eyes. (see Table 5.1).

For one patient, R.P., an attempt was made to reduce his elevated IOP as shown in Figures 5.3 and 5.4.

| TABLE 5.1 ANALYSIS OF THE DATA - EXPERIMENT I |               |        |       |      |        |       |      |
|---|---------------|--------|-------|------|--------|-------|------|
|   |               |        |       |      |        |       |      |
|   |               | T-TEST | MEAN  | SD   | T-TEST | MEAN  | SD   |
| O.D.  | BEFORE        | .877   | 11.85 | 3.09 | 1.97*  | 15.21 | 2.08 |
|   | <b>AFTER</b>  |        | 11.67 | 2.87 |        | 14.46 | 2.16 |
| <b>O.S</b> .                                  | <b>BEFORE</b> | .799   | 12.00 | 3.35 | 2.98*  | 15.53 | 2.42 |
|   | AFTER         |        | 11.85 | 3.30 |        | 14.55 | 2.72 |

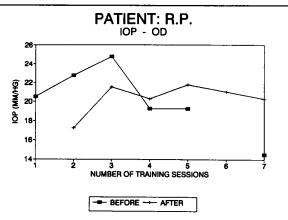


Figure 5.3 Experiment I IOP-RP-OD

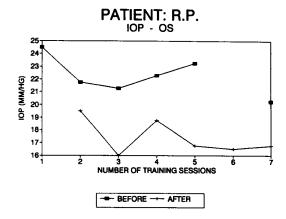


Figure 5.4 Experiment I IOP-RP-OS The results of seven training sessions to reduce IOP via biofeedback to relax accommodation show that there was no difference between the Before measurement from the first session to the After messurement from the seventh session for the right eye. For the left eye, the initial Before IOP of 24.5 mm/Hg was reduced to 16.5 mm/Hg After by the end of the training. These data suggest that although accommodation is related to IOP regulation, other factors are involved.

He was given seven biofeedback of accommodation sessions to relax accommodation. The sessions were conducted at the same time of day to eliminate any diurnal variation effects.

The initial IOP OD was 20 mm/Hg before the training began. After seven training sessions the IOP was the same, although after the second training session the IOP was 17.75 mm/Hg, and before the third session it was 25 mm/Hg. The initial IOP OS was 24.5 mm/Hg, and after the seventh training session was lowered to 16.5 mm/Hg. The IOP OS had been reduced after the second session and remained lowered during the rest of the training.

### 5. Discussion

As reported by Ludlam (1985), there is a high correlation between IOP, myopia, and axial length in children from the time of birth to 9 years of age. The present data confirm such a relationship in adults as well, with accommodation as the mediating process. The suspected mechanism is either a local and/or central release of sympathomimetic chemicals. As will be discussed in Chapter 14--Associated Changes, there is a generalized increase in SNS activity as a result of the relaxation of accommodation. As suggested by the data for RP, accommodation has an important relationship with IOP, but apparently other factors are involved as well.

Some unanswered questions as a result of this study are:

- Is glaucoma another stress-related disease?
- Will the IOP reductions be long lasting?
- Will others be able to replicate my results with other populations?
- My impression from the measurements was that the more accommodative spasm, the higher the IOP. Is this a possible mechanism for axial elongation in myopia?
- Will we able to develop an efficacious technique for biofeedback in the management of ocular hypertension and glaucoma?
- Would the results be different with emmetropes and/or hyperopes?

I plan to pursue these questions soon. Also, I would like to obtain more data on the treatment of elevated IOP with some of the ophthalmologists who use the Accommotrac® Vision Trainer. I hope to be able to report on those results in the near future.

## Experiment 2-Emotions<sup>3</sup>

### 1. Abstract

Do we see better when we are happy?" and "Does seeing clearly make us happy?" Perhaps these are questions with obvious answers. Intuitively, the answer would be "yes" to both questions. But, for some, intuitional and observational information are not convincing.

Being happy is one of our basic emotions and not only makes us appear better, but feel better as well. The recently developed topic of psychoimmunology has taught us this latter information. Whenever we discuss the emotions, the hypothalamus should always be considered. The hypothalamus is an important component of the limbic system, which is the regulator of emotional behavior. As we have discussed previously, there is a strong relationship between the hypothalamus and vision.

Fibers for the sympathetic nervous system (SNS) control of accommodation, originate in the hypothalamus. These fibers synapse at the superior cervical ganglion and then proceed to the ciliary muscle of the eye. The ciliary muscle also has parasympathetic nervous system (PNS) innervation. The SNS innvervates the dilation of the muscle responsible for a decrease in focus of the eye (accommodation) for distance vision, while the PNS innervates the constriction of the muscle for an increase in focus of the eye for near vision. Also, fibers from the retina are found in three distinct retinohypothalamic tracts. Each of these three tracts supply different types of vision information to three separate areas of the hypothalamus. It is also suspected that there are some hypothalamic-retinal fibers in these pathways. There is, therefore, a sophisticated, closedloop feedback system between the vision system and the hypothalamus. The study of the further relationship between vision and the hypothalamus can proceed by investigating the effect of emotion on vision.

Because the behavior of smiling is readily observable and measurable, it has been selected as an index of being happy. Seeing clearer also can be measured with the process of visual accommodation as its index.

### 2. Methods

### **Subjects**

Ten patient's seeking vision improvement, via biofeedback, were selected at random as subjects in the experiment. The age range was from 25 to 63 years, with a mean of 38.5 years and a standard deviation of 11.9 years. There were two males and eight females. No other selection criteria were utilized. The subjects were blind as to the nature of the experiment.

### **Procedure**

Smiling, an index of being happy, was measured by an increase in EMG tension recorded from the massetter muscle (Davicon M44), and clearer vision was measured by a decrease in accommodation as measured by an opto-electronic optometer (Accommotrac® Vision Trainer). Real-time plots of both measures, EMG tension and accommodation, were made simultaneously by computer, using software of original design. A baseline of both EMG tension of the massetter muscle and of accommodation were

made for 18 seconds. After approximately 18 seconds, the investigator asked the subject to smile. The instructions were repeated usually a second time to have two records of the desired measurements.

### 3. Results

The results showed that there was a measurable reduction in accommodation approximately 0.3 to 2 seconds after each subject had smiled. These results were consistent for each of the nine of the 10 subjects. The amount of decreased accommodation varied from subject to subject; but that may be a function of the number of previous vision therapy sessions. The data may be seen in Figures 5.5 to 5.14.

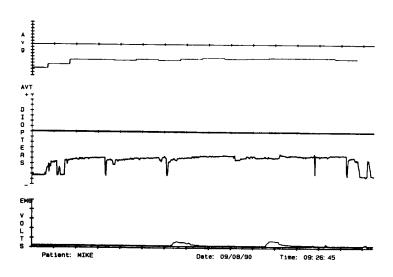


Figure 5.5

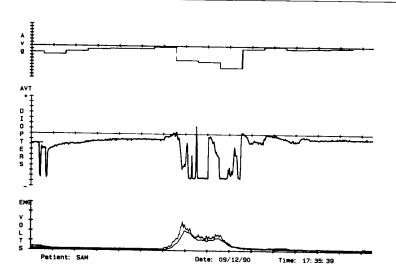


Figure 5.6

# Figures 5.5 to 5.14 Accommodation and EMG— Experiment II

The graphs show simultaneous recordings of accommodation and masseter muscle tension. On the top scale, Avg indicates the average amount of accommodation every one second. The tick marks across the scales represent one second.

In Figure 5.5, at the 6 and 11 second marks the patient was asked to smile. As a result of the smile there was an increase in masseter muscle tension, indicated by a rise on the bottom scale. An increase along the accommodation scale can be observed at these instances, indicating accommodative relaxation. Such a change can be noticed in Figures 5.5 to 5.13. In Figure 5.10, Adeline showed a small change with the smile at the two-second mark, but it was not sustained. In Figure 5.14, Kathy showed no measurable change in accommodation as she smiled. As noted in the text, she has a history of being a "fake" smiler, smiling without emotion. Editor's note: The bottom, EMG, scale is recording tension in the jaw (massetter) muscles. When someone smiles, there is an increase in tension of this muscle, which causes the lines on the bottom scale to go upward. On the intermediate (AVT) scale, accommodation is recorded, with the "+" direction indicating relaxation of accommodation, and the "-" direction indicating increased accommodation. As there is an increase in jaw muscle tension (on the bottom scale), there is an upward movement of the recording of accommodation (on the intermediate scale) indicating relaxation of accommodation as a result of a smile.

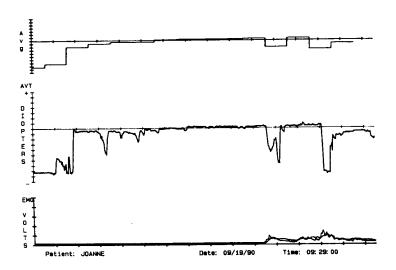


Figure 5.7

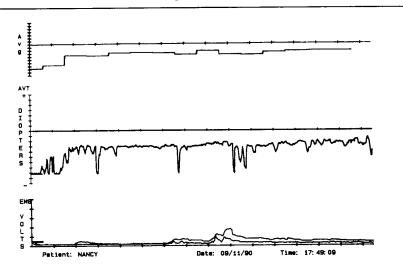


Figure 5.8

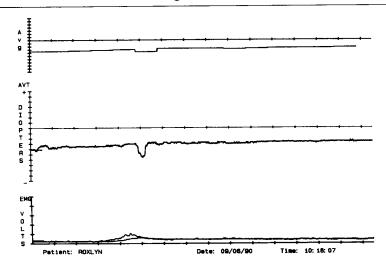


Figure 5.9

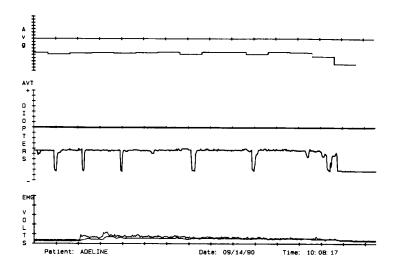


Figure 5.10

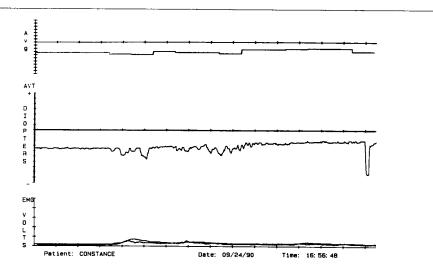


Figure 5.11

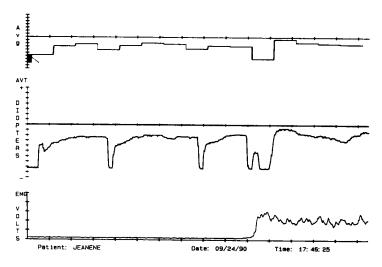


Figure 5.12

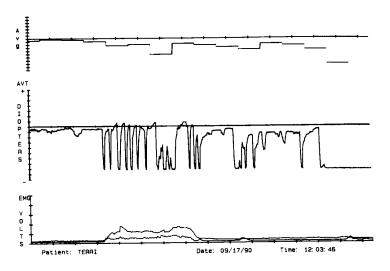
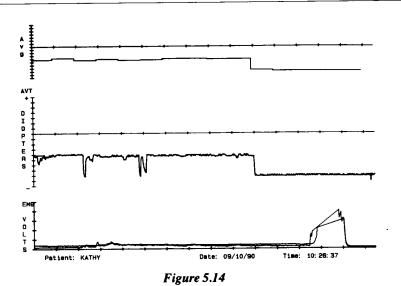


Figure 5.13



The onset of the smile may be observed on the figures as a transient increase in the EMG level for the masseter muscles. Directly above this increase, a relaxation in accommodation is observed as a movement of the line upward toward the top of the paper.

### **Discussion**

We have previously noted that other hypothalamic functions are related to vision, such as intraocular pressure, temperature, and memory. By being able to correlate vision with emotional behavior, an addition to the above list can be made.

The implications for the measured relationship are multifold, ranging from perceptual concepts of the self and others, to psychoimmunology. One important aspect of the self is egocentric locus, where we feel we are in terms of the space around us. If we are able to see clearer, we can identify people and objects better. We also will have a better sense of depth perception because fine depth discrimination, stereopsis, is dependent on the sharpness of our vision. In addition, the concept of psychological myopia must be considered. Psychological myopia is a form of information processing where behavior is determined by shortsighted and ego-driven goals. These personality characteristics have also been given to people who have vision myopia, nearsightedness, which is related to the status of the ciliary muscle. In other words, the way we process information is related to how we see and vice versa.

How we feel is not only important and related to how we see, but has developed into the new and exciting subject of psychoimmunology. Recent successful treatments of cancer and AIDS patients, have shown the importance of being happy in self-healing. It would be interesting to measure the vision of these patients before and after their treatment.

Whether clearer vision makes us happy or being happy gives us clear

vision, it is one of those can't lose situations. Who would not want not only to see clearer, but be happier at the same time? Such are the reports of many of our patients. It is not unusual for patients to ask us if there is any relationship between mood and the vision therapy. One subject, Kathy, where there was no change in accommodation after a smile, informed us that she has been accused of not smiling very much since early childhood. In fact, it was very difficult for her to smile during the experiment--she would have to think about what to do in order to smile. The other patient with little change was Adeline, whose accommodative spasm was tight and embedded, she was 63 years of age at the time of the measurement and had been wearing eyeglasses for over 50 years. Her initial myopia was OD -9.50 -0.75 cx 180°, and OS -9.25  $-1.00 \text{ cx } 002^{\circ}$ .

We also have had patients tell us that they feel healthier as their vision has been improving. We hope to investigate the empirical relationship between these other variables in the near future.

One related topic is psychoimmunology, a relatively new field of study of the relationship between behavior and the immune system. Behavioral techniques such as biofeedback are currently being used successfully in the treatment of AIDS and cancer patients (Halley, 1988; Norris, 1988). One optometric researcher has already reported on the effects of vision therapy and health (Albalas, 1985). The field of psychoimmunology, although new, is exciting and has great promise for vision specialists and all other health professionals.

### **Footnotes**

- Based on a presentation by Trachtman JN and Venezia CM. Vision and the hypothalamus. Association for Applied Psychophysiology and Biofeedback Meeting, Washington, D.C., March 24, 1990.
- Based on an unpublished manuscript by Trachtman JN, Giambalvo V and Pagano V. Biofeedback of accommodation and IOP - A Draft. October 27, 1987.
- Based on a presentation by Trachtman JN and Venezia CM. Be happy and see better or see better and be happy. Association for Applied Psychophysiology and Biofeedback Meeting, Dallas, March 18, 1991.