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REHABILITATION OF VISION LOSS DUE TO TRAUMA TO EYE OR BRAIN: A PRELIMINARY REPORT*

Joseph N. Trachtman, O.D., Ph.D.
Institute for Advanced Vision Therapy[SM]

Millions of people in the United States suffer injuries due to traffic accidents. Many of these injuries involve trauma to the head and/or eye with a concomitant vision loss. For head trauma, the typical vision loss is hemianopsia with sparing of the macular and retention of good visual acuity. For ocular trauma, the typical vision loss involves both a loss of visual field and acuity. Two patient histories are presented. Patient 1 suffered brain trauma resulting in hemianopsia following an automobile accident, and Patient 2 suffered optic nerve contusion resulting in visual field loss and reduced corrected visual acuity. A neurotherapy technique combining electroencephalogram and accommodative biofeedback, was utilized for each patient. For Patient 1, there was a restoration of the visual field after 14 training sessions, and for Patient 2, there was both a restoration of the visual field and corrected visual acuity after 13 training sessions. A review of the literature shows that there are two basic theoretical mechanisms of brain neurophysiology: localization and holographic. The proposed mechanism for the improvements involve the hypothalamus-pituitary-adrenal axis with its regulation of the chemical messengers, the cytokines and the neuropolypeptides. These chemical messengers, it is hypothesized, either act locally by stimulating loss cell function or holographically by stimulating new cells to assume lost cell function. Further research is suggested to validate the procedure, and investigate the specific relationship of the cytokines and peptides to restoration of lost vision function.

Key Words: vision, rehabilitation, sports, biofeedback

Introduction

As a consequence of trauma to the head or the eye, a loss of vision may result. The age of those involved in head and/or ocular trauma tends to be younger than 40-years-old, and related primarily to automobile and sports accidents (Gelman, 1990). For example, in 1997 traffic injuries in the United States totaled 3,450,000; 2,182,660 drivers, 1,125,890 passengers, 76,550 pedestrians, and 64,900 pedalcyclists (National Highway Traffic Safety Administration, 1998). Data for 1997 is not yet available for motorcycles injuries, however, in 1996 the number was 51,000 (National Highway Traffic Safety Administration, 1997). In cases of head trauma, the vision loss may be manifested in a condition known as hemianopsia. A brief description of the anatomy of the vision system will explain the phenomenon. The nasal optic nerve fibers from the eyes cross over from one side to the other, known as semi-decussation, so that what is seen to the left of the mid-line is from the right brain, and what is seen to the right of the mid-line is from the left brain (Duke-Elder and Wybar, 1961). The occipital lobe of the cerebral cortex is the primary center for vision processing (Last, 1961). Therefore, if there is damage to the left occipital lobe, there is a loss of the visual field to the right of the mid-line. In cases of ocular trauma the vision loss may be manifested in a variety of vision impairments to the same eye.

Address for correspondence and reprint requests to:
Joseph N. Trachtman
Institute for Advanced Vision Therapy[SM]
26 Schermerhorn Street
Brooklyn Heights, New York 11201

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Review of Literature

Incidence

It is estimated that in the United States the incidence of head injury is 7,000,000 people per year (Falconer, 1998), and of eye injury is 2,400,000 people per year (Zabelbaum, 1997) for a total of 9,400,000. The effects of all these injuries can be measured in hospital, doctor, and rehabilitation costs, disability expenditures, loss of income, and most importantly the loss of the quality of life of the patient and his family (Rivara, et al., 1994; Hall, et al., 1994). For example, for head injury alone, an average of 110 days of rehabilitation are required (Whitlock and Hamilton, 1995).

It is well-known that accidents to the head and eye occur during athletic activity. According to National Society to Prevent Blindness (1980), there are more than 35,000 eye injuries from sports activities per year in the United States. In a report (Larrison et al., 1990) on 202 patients with sports-related ocular trauma, 28.7% were from basketball, 19.8% were from baseball/softball, 11.4% were from racquetball, 7.4% were from tennis, 7.4% were from soccer, 4.5% were from hockey, and 4.5% were from football. Other sports comprised the remaining 16.5% The amount of those with head trauma would only make the numbers substantially larger. The sports with the greatest risk for both blunt trauma to the eye and head injury are baseball, basketball, boxing, canoeing/kayaking, golf, handball, skating, soccer, tennis, and volleyball (AOA Guide).

Vision Loss

The vision loss from trauma to the head or the eye can be put into two of several categories: 1. Field of View - how much we see, and 2. Acuity - how clearly we see. For example, if someone has an accident or stroke to the right side of the head, there will be a loss of the field of view (in both eyes) to the patient's left, known as left homonymous hemianopsia, with the clarity of vision basically undisturbed (Harrington, 1964). On the side where there is the loss of the field of view, with damage commonly to parietal lobe, a phenomenon known as "side of neglect" or "unineglect" develops (Heilman, Schwartz, and Watson, 1978). More recent reports of "side of neglect" have been noted in patients with damage to other brain structures such as the thalamus and basal ganglia circuit (Robertson and Marshall, 1997). "Side of neglect" is a perceptual and emotional experience, whereby, the patient has a complete loss or decreased awareness of that body side or that direction in space (Kubio and Van Deusen, 1995). Assuredly, "side of neglect" is devastating to both the patient and his family, and is a tremendous hindrance in rehabilitation. For eye trauma to the optic nerve, there will be a loss of both the field of view and clarity in the affected eye only (Apple and Rabb, 1991). The amount of loss of the field of view, and loss of clarity varies from patient to patient, and is dependent on the magnitude and location of the trauma.

Treatment

For loss of field of view from head injury there is no known treatment. There is, however, an aid to help a limited number of patients in a limited way. By using special eyeglasses, known as prisms, the lost field of view is partially shifted into the field with vision (Padula, 1988). This allows a small amount of the lost field to be seen, although the new view is constricted - much like looking though the other end of binoculars.

For loss of vision from eye trauma to the optic nerve, typically there is a week-long, hospitalized treatment with steroids. In a recent report of 23 patients, 19 patients still remained legally blind after the steroid treatment (Choi, et al., 1996). It is important to note that in this study the average age was 26 years, unfortunately, leaving many years of visual disability. Another important consideration in steroid treatment is the prevalent development of diabetes (Gunnarsson et al., 1980; and Jindal, Sidner, and Milgrom, 1997).

Biofeedback

Biofeedback may be defined as providing a person with information about a body function or process that the person would not usually be aware of. For example, if someone's finger temperature is measured in 0.01 degree Fahrenheit increments and display such changes with auditory and/or visual feedback, the person will readily learn how to control the temperature of their finger. In 1969 the area of biofeedback was launched into the scientific community with the publication of Neal Miller's classic paper on visceral and glandular learning (Miller, 1969).

Miller conducted this most important research at Rockefeller University. Even with his well-recognized status, there was quite a bit of controversy about some of Miller's reported results. However, time has proven that his theories were accurate. Basically Miller stated that previously believed automatic functions can be learned - through the technique of biofeedback.

Neurotherapy Technique

Combining electroencephalogram (EEG) and accommodative biofeedback, Trachtman and Venezia (1993), described the successful restoration of the visual field loss in stroke patients. The instruments utilized in the training procedure have been previously described (Trachtman, 1991). The Accommotrac® Vision Trainer (AVT) (Biofeedtrac Inc.) was used to train relaxation of accommodation via providing auditory biofeedback. Electroencephalogram (EEG) auditory and visual biofeedback to increase the amplitude of alpha and theta brain waves was performed by a two-channel EEG (Biofeedtrac Inc.). Central visual fields were measured using a one-meter tangent screen with 7 foot-candles of illumination. Peripheral visual fields were measured using a 1/3 meter hemisphere (Good-Lite Co.) with 5 foot-candles of ambient illumination.

Patients

Patient 1

A 42-year-old female reported vision loss after regaining consciousness following an automobile accident. She was evaluated eight months post-trauma. Upon evaluation, she showed a right homonymous hemianopsia (see Figures 1 and 2).

The training program consisted of 14 weekly

Figure 1
Patient 1, Pre-Training Visual Field O.D., 8/27/95

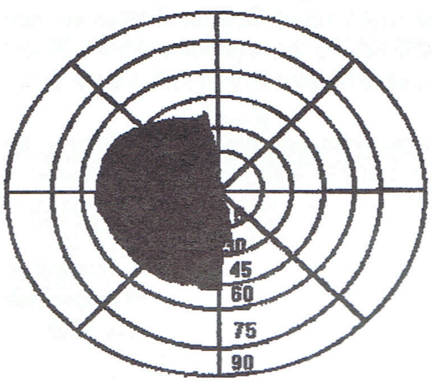
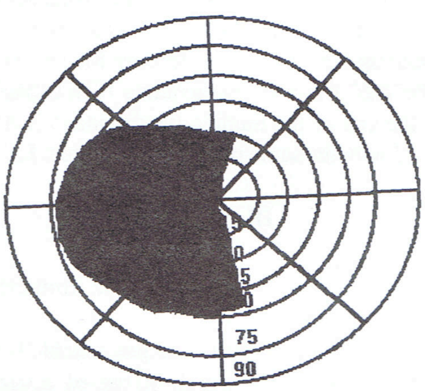


Figure 2
Patient 1, Pre-Training Visual Field O.S., 8/27/95



Pre-training visual fields show a right homonymous hemianopsia following trauma to the left occiptal lobe as a result of an automobile accident.

Figure 3
Patient 1, Post-Training Visual Field O.D., 8/27/95

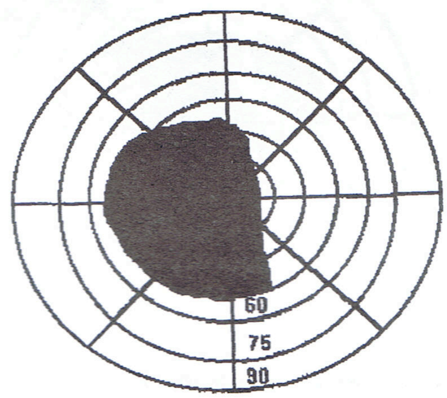
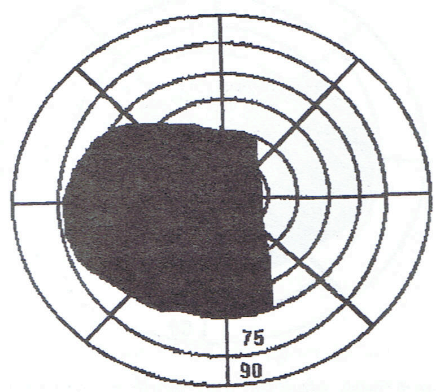


Figure 4
Patient 1, Post-Training Visual Field O.S., 8/27/95



sessions of EEG biofeedback to increase the amplitude of the left hemisphere with electrodes placed at O_1 and O_2 (O_1 and O_2 are one inch below and one inch to the right and left of the inion respectively - placing them on top the occipital lobes). Post-training changes were noted in both visual fields after the first training session (see Figures 3 and 4). Approximately 90% restoration was attained after the 14 training sessions (see Figures 5 and 6). Analysis of the EEG shows an increase in the amplitude from O_2, the left occipital lobe (see Figures 7 and 8). Independent pre-training data were not available. Her unaided visual acuity pre- and post-training was 20/20.

Figure 5
Patient 1, Post-Training Visual Field O.D., 1/14/96

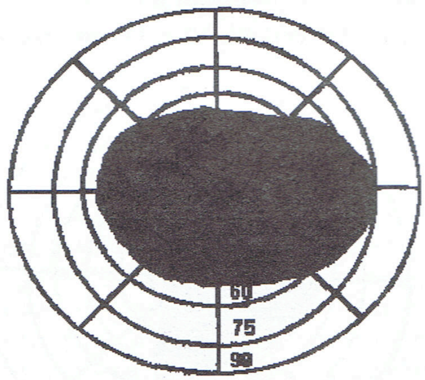
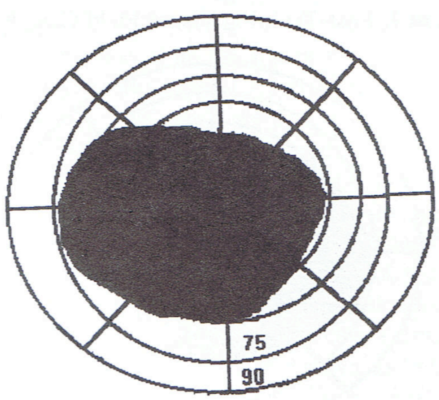


Figure 6
Patient 1, Post-Training Visual Field O.S., 1/14/96



Visual fields after the fourteenth training session showing an almost complete restoration of the visual fields in both eyes, the visual field of the right becoming larger than that of the left.

A one month follow-up revealed maintenance of the vision and EEG improvements. Four additional vision training sessions were provided combining the EEG and accommodative biofeedback. Three years post-training, the patient reports that her vision is still improved, and she proudly talks about her driver's license.

Patient 2

A 14-year-old male presented blurry vision within a restricted visual field following trauma to the O.S. after falling off his bicycle. The diagnosis was contusion of the optic nerve, O.S. The first week post-trauma, he was hospitalized with a course of steroid treatment. Independent post-steroid treatment visual fields show O.D. normal, and the O.S. an area of vision within the central 25° restricted to the superior nasal quadrant (see Figures 9 and 10). Pre-training visual fields showed no change compared to the post-steroid treatment visual fields, which were taken one week previously (see Figures 11 and 12).

The first training session showed an increase in the visual field in the superior and nasal fields, with a small change in the inferior-nasal quadrant (see Figure 13).

On the following day the patient was given the second treatment with still more enlargement of the visual field in the superior and nasal fields, and the inferior-nasal quadrant (see Figure 14).

The visual field continued to increase until the thirteenth training session, 4 weeks later, where the size of the visual field O.S. was now equal to that of the unaffected O.D. (see Figure 15).

A comparison of the pre- and post-training EEG's show an increase in the electrical activity at O_2, the left occipital lobe, post-training (see Figures 16 and 17).

The patient's pre-training distance visual acuity was 20/140 with his habitual Rx, -3.25 = -0.25 cx 81°. On the ninth training session and continuing for ten more sessions, he was given accommodative biofeedback training. At the end of the training his distance visual acuity was 20/25 with the same pre-training habitual RX.

Discussion

Three questions immediately arise from the above reported vision restoration:

1. Were the visual field changes reliable?
2. What possible mechanism of action can account for the changes?
3. How do the changes relate to theories of brain function?

Figure 7

Patient 1, Pre-Training EEG., 8/27/95

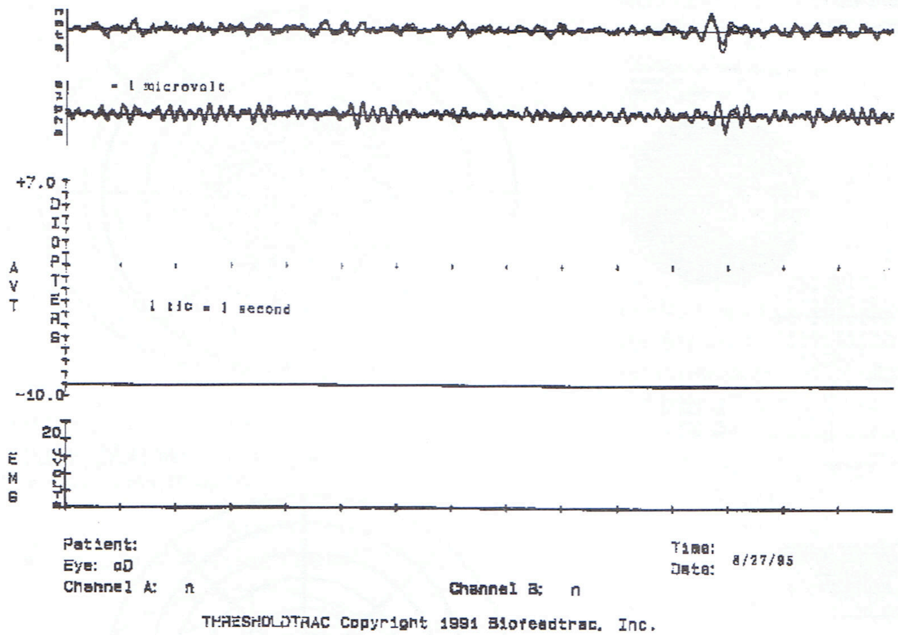
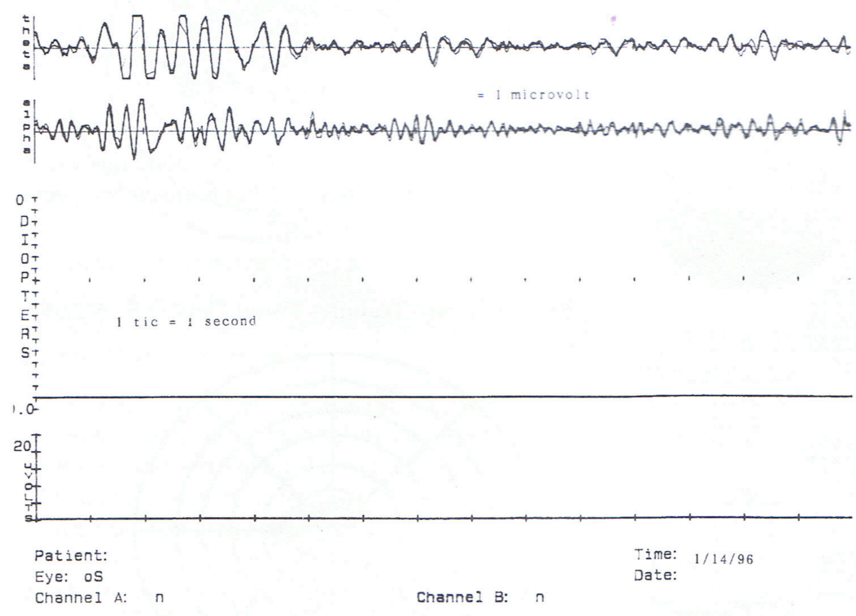


Figure 8

Patient 1, Post-Training EEG., 1/14/96



Both brain wave graphs have the same format. The x-axis is in seconds with one tic mark equal to one second. The y-axis is amplitude in microvolts, with the marker indicating 1 microvolt. The recordings are shown on the theta and alpha axes indicating O_1, the right occiptal lobe, and O_2, the left occipital lobe.

The post-training EEG pattern shows a larger amplitude of the EEG and an increase in amplitude from O_2, the left occiptial lobe, as compared to the pre-training EEG pattern.

Figure 9
Patient 2, Post-Steroid Treatment Visual Field O.D., 5/14/97

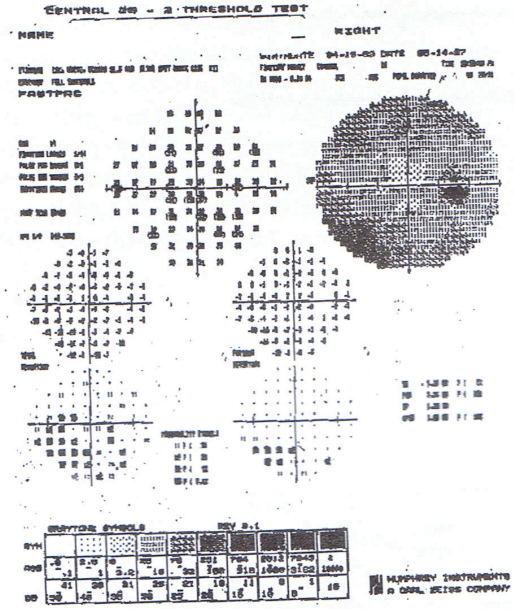
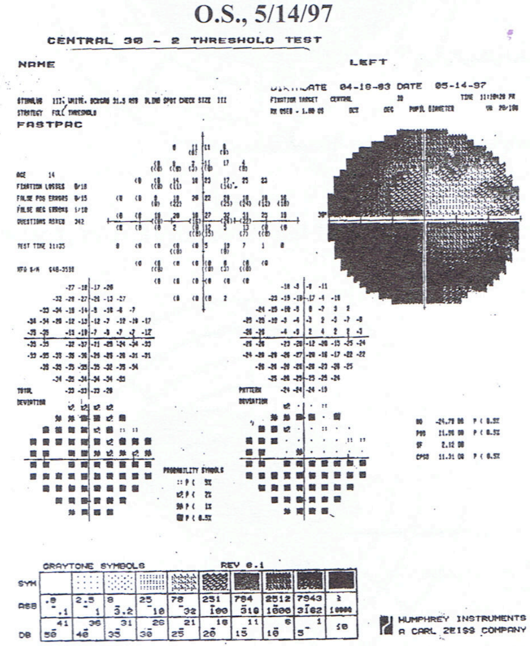


Figure 10
Patient 2, Post-Steroid Treatment Visual Field O.S., 5/14/97



The post-steroid treatment visual fields were independently assessed and show O.D. a normal visual fields, and O.S. an area of vision within the central 25° restricted to the superior nasal quadrant. The patient had a bicycle accident two weeks earlier falling on the left side of his head by the orbit.

Figure 11
Patient 2, Pre-Training Visual Field O.D., 5/22/97

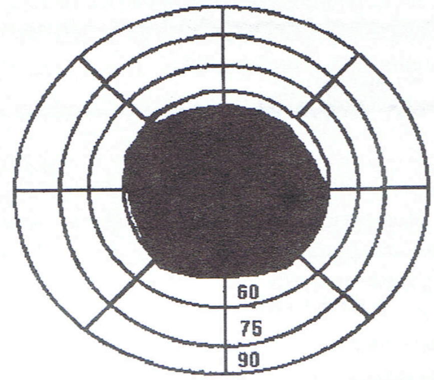
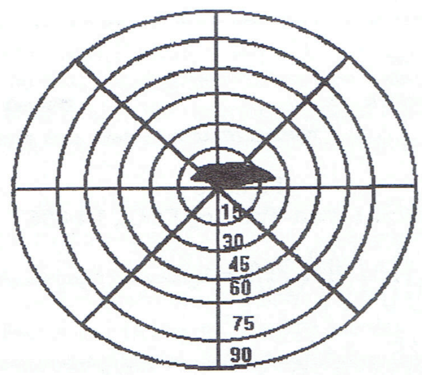
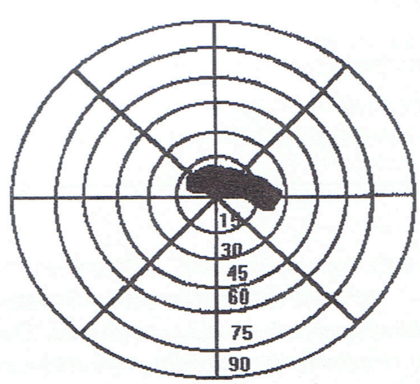


Figure 12
Patient 2, Pre-Training Visual Field O.S., 5/22/97



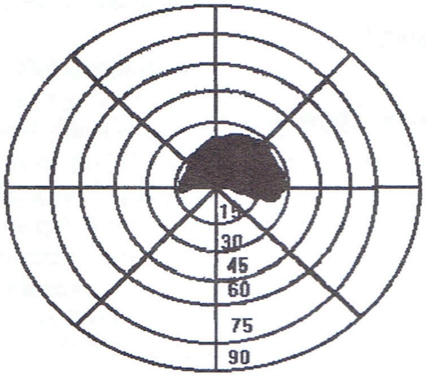
The pre-training visual fields show good agreement with the post-steroid visual fields taken the previous week.

Figure 13
Patient 2, Post-Training Visual Field O.S., 5/22/97



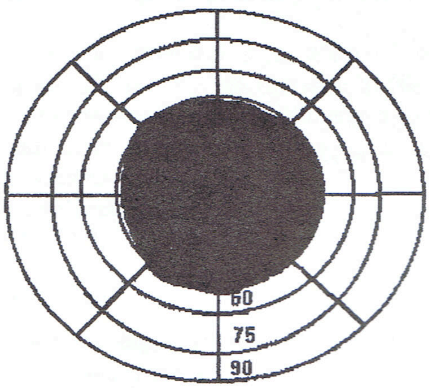
Following the first training session, there is a small increase in the visual field in the nasal quadrant.

Figure 14
Patient 2, Post-Training Visual Field O.S., 5/23/97



Following the second training session, there is a small but very noticeable, increase in the visual field in the nasal and superior quadrants.

Figure 15
Patient 2, Post-Training Visual Field O.S., 6/20/97



Following the thirteenth training session, the visual field of the left eye is approximately equal to that of the full visual field of the unaffected right eye (see Figure 11 for comparison).

1. Were the visual field changes reliable?

Both central and peripheral fields were conducted with the examiner facing the patients. In an instance of a saccadic eye movement off the central fixation target, that measurement would be repeated.

As shown in Figures 1 to 4, for Patient 1, and 12 to 14, for Patient 2, there was an enlargement of the visual field when comparing the pre- to post- training fields on the same day. This lends strong support that the improvements were not spontaneous.

2. What possible mechanism of action can account for these changes?

By virtue of there being dramatic improvements in vision for both patients, who received the same treatment for different causes for their vision loss, would indicate that the mechanism of action is most likely general (brain/nervous system) rather than local (ocular).

According to Dilman and Dean (1992), "However, the immune system doesn't function as an isolated system."[a] As the "center" of the immune system, the most likely mechanism for its regulation is the hypothalamus-pituitary- adrenal axis. See also McCann, et al. (1994), Meaney, et al. (1993), and Berkenbosch (1992), as well as Berntson, Cacioppo, and Quigley (1991) for a recent model of ANS function.

Some fibers from the retina go to the hypothalamus via three distinct bundles (Sadun, Johnson, and Schaechter, 1986). Also, the sympathetic nervous system (SNS) innervation for accommodation originates in the hypothalamus (Walsh, 1992). Therefore, there is a complete feedback loop between the vision system and the hypothalamus.

While discussing the vision changes that occur via EEG biofeedback, it will be helpful to keep in mind the global regulation of the bodily functions by the hypothalamus, and the concept of the dual nature of nervous system. This dual nature includes information transmission, neural pathways, and chemical messengers, such as cytokines (Haour, 1994; Sadun, Petrovich, and Madigan, 1995), and peptides (Snyder, 1980; Kuljis and Karten, 1988; Tornquist and Ehinger, 1988; Straznicky and Hiscock, 1989). The relationship between EEG biofeedback and hypothalamic activity has been previously reported (Trachtman, 1991).

3. How do the visual field changes relate to theoris of brain function?

Historically, there are two major theories of how the brain works: localization and holographic.

Localization

Carl Wernicke (Kiernan, 1987), a late nineteenth century German clinical neurologist, is given the credit for first describing a localization of function to areas of the brain. He described the temporoparietal area of the left cerebral hemisphere as being responsible for receptive language. Later, Paul Broca (Kiernan, 1987), described an area in the left temporal cerebral cortex as responsible for expressive language and became known as Broca's area

Figure 16

Patient 2, Pre-Training EEG., 5/22/97

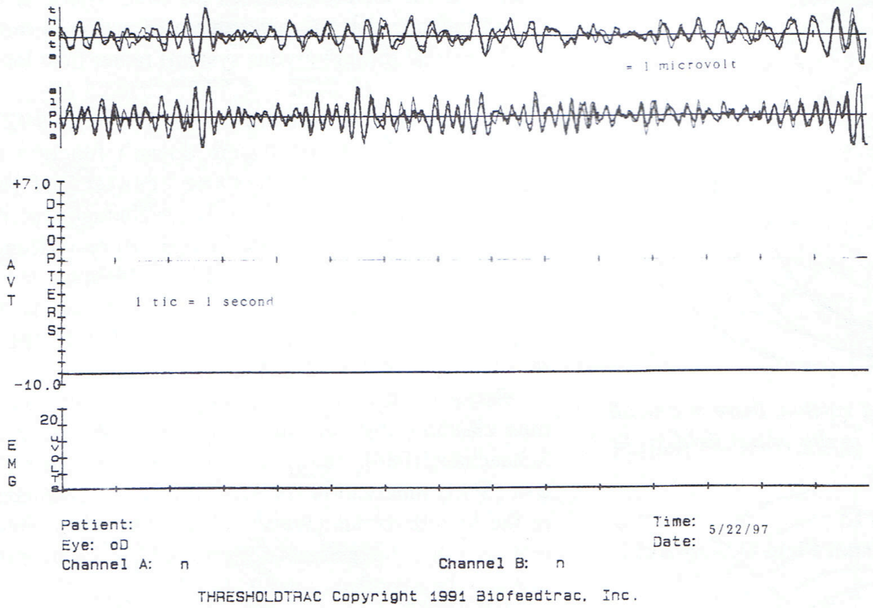
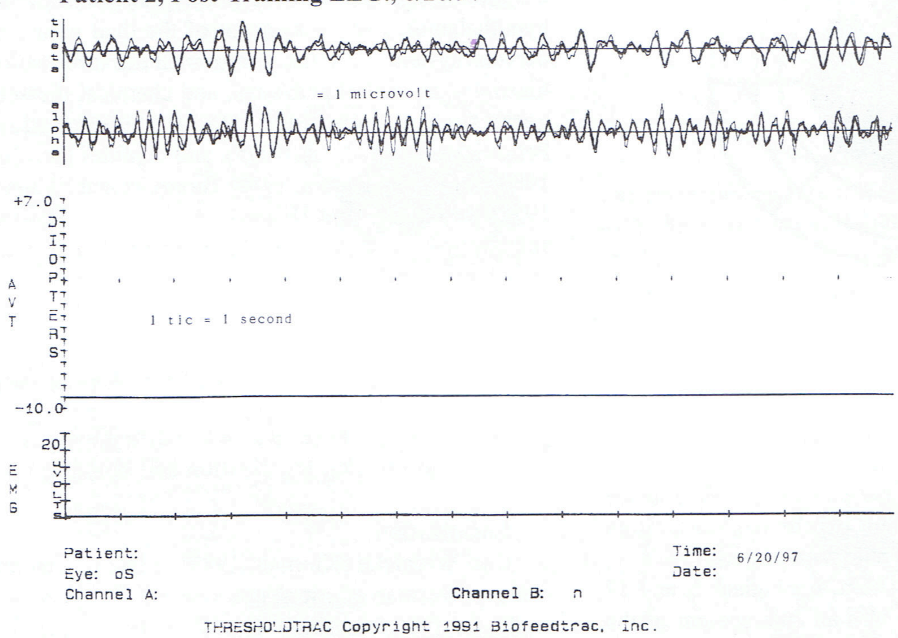


Figure 17

Patient 2, Post-Training EEG., 6/20/97



Both brain wave graphs have the same format. The x-axis is in seconds with one tic mark equal to one secon[c] The y-axis is amplitude in microvolts, with the marker indicating 1 microvolt. The recordings are shown on th[e] theta and alpha axes indicating O_1, the right occipital lobe, and O_2, the left occipital lobe.

The post-training EEG pattern shows a markedly larger amplitude of the EEG and an increase in amplitude fro[m] O_2, the left occipital lobe, as compared to the pre-training pattern.

44. Broca further elaborated other specific areas of the brain, i.e. the occipital lobes as being areas 17, 18, and 19 and being related to vision function.

Holographic

In the 1920's and 1930's, Karl Lashley (Kling and Riggs, 1971) systematically "scooped out" sections of the brains of laboratory animals, and then tested their behavior on a set number of tasks. Although Lashley was influenced by the previous theories of Wernicke and Broca, he abandoned their localization theories of brain function for a holographic theory first proposed by Pierre Flourens (1794-1867) (Sheridan, 1971). The holographic theory proposed that each brain cell has the ability (and/or information) of other cerebral cells. Among the proponents of the holographic theory are Pribram (1991) and Ashby (1960).

In summary, the duality of neurological signal transmission, physical and chemical, allows a broader understanding of "plasticity" of the nervous system.

In the current report, as a result of the EEG biofeedback training, an increase in the EEG was noted for both patients. It may, therefore, be concluded that either function was restored to some brain cells or other cells assumed the lost function or may be a combination of the two.

Conclusion

Two patients suffering vision loss after traffic accidents received a novel neurotherapy training program to improve vision function. The results of the training program clearly show a marked enlargement of the visual field for both patients. The proposed mechanism for the improvements is related to the hypothalamus-pituitary-adrenal axis and chemical messengers such as cytokines and/or peptides. Further research should measure these chemical levels during the training process.

As there are no other reports of such neurotherapy treatment, it is important, to have the technique validated by independent investigation. If validated, the research holds great promise not only in the area of sports vision rehabilitation; but all treatment programs for vision loss as a result of neurological impairment.

Note

[a] Dilman, V. and Dean, W. *The neuroendocrine theory of aging and degenerative disease.* (S.W. Fowkes, ed.).Florida: The Center for Bio-Gerontology, 1992, p. 84

References

Apple, D.J. and Rabb, M.F. *Ocular pathology:Clinical applications and self-assessment*, Fourth Edition, St. Louis: Mosby Year Book, 1991

Ashby, W.R. *Design for a brain.* London:Chapman and Hall, 1960

Berkenbosch, F. Macrophages and astroglial interactions in repair to brain injury. In *Ontogenetic and phylogenetic mechanisms of neuroimmunomodulation.* (N. Fabris, B.D. Jankovic', B.M. Markovic', and N.H. Spector, eds.), Annals of the New York Academy of Sciences, Volume 650, 1992

Berntson, C.G., Cacioppo, J.T., and Quigley, K.S. Autonomic determinism: The modes of autonomic control, the doctrine of autonomic space, and the laws of autonomic constraint. *Psychological Review,* 1991, 98(4):459-87

Carlson, N.J. (Ed.) (1984) *American Optometric Association sports vision section sports vision guide*, (Number I). St. Louis, MO: American Optometric Association.

Carlson, N.J. (Ed.) (1985) *American Optometric Association sports vision section sports vision guide,* (Number II). St. Louis, MO: American Optometric Association.

Choi, P.I., Sadun, A.A., Chen, Y.C., Su, W.Y., Lin, S.Z., and Lee, C.C. Clinical experiences in the management of traumatic optic neuropathy. *Neuro-ophthalmology*, 1996, 16(6), 325-36

Dilman, V. and Dean, W. *The neuroendocrine theory of aging and degenerative disease.* Pensacola, Florida:The Center for Bio-Gerontology, 1992

Duke-Elder, S. and Wybar, K.C. *System of Ophthalmology*: Volume II The anatomy of the vision system. St Louis: C.V. Mosby, 1961

Falconer, J.A. *Head injury as a community problem.*

Neurotrauma Law Center: Homepage, www,neurolaw.com/ July 7, 1997

Kling, J.W. and Riggs, L.A. (eds.) *Woodworth and Schlosberg's Experimental psychology*. Third Edition. New York: Holt, Rinehart and Winston, 1971

Gelman, D. How the brain recovers. *Newsweek*, 1990, 115(15), 48-50

Gunnarsson, R., Lundgren, G., Magnusson, G., Ost, L. and Groth, C.G. Steroid diabetes — a sign of overtreatment with steroids in the renal graft recipient? *Scand J Urol Nephrol Suppl*, 1980, 54: 135-8

Hall, K.M., Karzmark, P., Stevens, M., Englander, J., O'Hare, P., and Wright, J. Family stressors in traumatic brain injury: A two-year follow-up. *Archives of Physical Medicine Rehabilitation*, 1994, 75(8), 876-84

Haour, F., et al. Interleuken-1 receptors in brain and pituitary Characterization and modulation during infection and stress. In *Neuroimmunodulation: The state of the art*. (N. Fabris, B.M. Markovic', N.H. Spector, and B.D. Jankovic', eds), Annals of the New York Academy of Sciences, Volume 741, 1994

Harrington, D.O. *The visual fields*. St. Louis: The C.V. Mosby Company, 1964

Heilman, K.M., Schwartz, H.D., and Watson, R.T. Hypoarousal in patients with neglect syndrome and emotional indifference. *Neurol.*, 1978, 28:229-32

Jindal, R.M., Sidner, R.A., and Milgrom, M.L. Post-transplant diabetes mellitus. The role of immunosuppression. *Drug Safety*, 1997, 16(4), 242-57

Kiernan, J.A. *Introduction to human neuroscience*. Philadelphia:J.B. Lippincott Co., 1987

Kubio, K.B. and Van Deusen, J. Relation of perceptual and body image dysfunction to activities of daily living of persons after stroke. *American Journal of Occupational Therapy*, 1995, 49(6), 551-9

Kuljis, R.O. and Karten, H.J. Neuroactive peptides as markers of retinal ganglion cell populations that differ in anatomical organization and function. *Visual Neuroscience*, 1988, 1:73-81

Larrison, W.I., Hersh, P.S., Kunzweiler, T., & Shingleton, B.J. (1990). Sports- related ocular trauma. *Ophthalmology,* 9(10), 1265-1269

Last, R.J. (ed.) Eugene Wolff's *Anatomy of the eye and orbit*. Fifth Edition. Philadelphia: W.B. Saunders Company, 1961

McCann, S.M., et al. Role of cytokines in the endocrine system. in *Neuroimmunodulation: The state of the art.* (N. Fabris, B.M. Markovic', N.H. Spector, and B.D. Jankovic', eds), Annals of the New York Academy of Sciences, Volume 741, 1994

Meaney, M.J. et al. Individual differences in the hypothalamic-pituitary-adrenal stress response and the hypothalamic CRF system. In *Corticotropin-releasing factor and cytokines: Role in the stress response.* (Y. Tache' and C. Rivier, eds.), Annals of the New York Academy of Sciences, Volume 697, 1993

Miller, N.E. The learning of visceral and glandlar responses. *Science,* 1969, 163:434-45

National Highway Traffic Safety Administration (March, 1998). *1997 Traffic crashes, injuries, and fatalities - Preliminary Report.* Washington, D.C.: United States Department of Transportation National Highway Traffic Safety Administration (December, 1997).

National Highway Traffic Safety Administration (December, 1977). *Traffic safety facts 1996.* Washington, D.C.: United States Department of Transportation

National Society to Prevent Blindness (1980). *Fact Sheet.* New York: National Society to Prevent Blindness

Padula, W.V. *A behavioral approach for persons with physical disabilities.* Santa Ana, California:Optometric Extension Program, 1988

Pribram, K.H. *Brain and perception*. New Jersey:Erlbaum, 1991

Rivara, J.B., Jaffe, K.M., Polissar, N.L., Fay, G.C., Martin, K.M., Shurtleff, H.A., and Liao, S. Family functioning and children's academic performance and behavior problems in the year following traumatic brain injury. *Archives of Physical Medicine Rehabilitation*, 1994, 75(4), 369-79

Robertson, I.H. and Marshall, J.C. (eds.) *Unilateral neglect*: Clinical and experimental studies. London: Taylor and Francis, 1997

Sadun, A. Neuroanatomy of the human visual system: Part I, Retinal projections to the LGN and pretectum as demonstrated with a new method. *Neuro-Ophthalmology,* 1986, 6(6), 353-361

Sadun, A.A., Johnson, B.M., and Schaechter, J. Neuroanatomy of the human visual system:Part III - Three retinal projections to the hypothalamus. *Neuro-Ophthalmology,* 1986, 6(6), 371-379

Sadun, A.A., Petrovich, M.S., and Madigan, M.C. Peritoxifylline:Clinical application in human immunodeficiency virus-associated optic neuropathy. *Annals of Neurology*, 1995, 37, 483

Sheridan, C.L. *Fundamentals of experimental psychology.* New York: Holt, Rinehart and Winston, 1971

Smith, A.D. & Ludington, R. (1989). Injuries in elite pair skater and ice dancers. *American Journal of Sports Medicine*. 17(4), 482-488

Snyder, S.H. Brain peptides as neurotransmitters. *Science,* 1980, 209(29), 976-983

Sonita, R., Broad, J.B., and Beaglehole, R. Ethnic differences in stroke incidence and case fatality in Auckland, New Zealand. *Stroke,* 1997, 28(4), 758-61

Straznicky, C. and Hiscock, J. Neuropeptide Y-like immuno activity in neurons of the human retina. *Vision Research*, 1989, 29(9), 1041-1048

Sudlow, C.L. and Warlow, C.P. Comparable studies of stroke and its pathological types: Results from an international collaboration; International Stroke Incidence Collaboration. *Stroke,* 1997, 28(3), 491-9

Tornquist, K. and Ehinger, B. Peptide immunoreactive neurons in the human retina. *Investigative Ophthalmology*, 1988, 29(5), 680-686

Trachtman, J.N. *The etiology of vision disorders.* Santa Ana, California: Optometric Extension Program, 1991

Trachtman, J.N. and Venezia, C.V. Expanding vision with biofeedback. *Biofeedback and Self Regulation,* 1993, 18(3), 190

Tysvaer, A.T. & Storli, O.V. (1989). Soccer injuries to the brain: A neurological and electroencephalograhic study of active football players. *American Journal of Sports Medicine*, 17(4), 573-578

Walsh, T.J. *Neuro-ophthalmology: Clinical signs and symptoms*. Philadelphia: Lea and Febiger, 1992

Whitlock, J.A. and Hamilton, B.B. Functional outcome after rehabilitation for severe traumatic brain injury. *Archives of Physical Medicine Rehabilitation*, 1995, 76(12), 1103-12

Zabelbaum, B. Sports-related eye injuries. *Sports Vision*, 1997 (Spring), 6-8