

Neuroplasticity: Teaching an Old Brain New Tricks

Research shows that adults do, in fact, exhibit neuroplasticity. You can use this innate ability to treat a variety of visual system disorders.

By Dominick M. Maino, O.D., M.Ed.

A “sea change” is a transformation of such magnitude that it alters the very nature of the subject. Recently, we have experienced such a change in the study of neuroplasticity.

The current science of neuroplasticity shows us “a phenomenon where different stimuli lead to an increase or decrease in the number of brain cells and remodeling of synapses,” says Rudraprosad Chakraborty, M.D., D.P.M., senior resident at the Ranchi Institute of Neuropsychiatry and Allied Sciences.¹ “Neuroplasticity research has established, beyond doubt, that instead of being a static cell mass, our brain is actually a dynamic system of neural networks that has the capability of significant growth under favorable circumstances.”¹

Indeed, the brain is not simply a static, soft mass bathed in fluid and surrounded by a hard case. It is not finished in its development once we reach a certain age. The brain can grow. The brain can change—and with that change, end organs, such as the eye and its functional status, can be cortically altered, show improvement after insult and injury, and be remediated and enhanced.

Until very recently, many optometrists and ophthalmologists appeared unwilling to accept this conceptual sea change, when most other clinicians, scientists and lay individuals seemed to have already received the message.²⁻⁵

Critical and Sensitive Periods

In the past, optometrists and ophthalmologists who resist the concepts of neuroplasticity have frequently justified their beliefs by citing the work of Torsten N. Wiesel, M.D., and David H. Hubel, M.D.⁶ This justification rests on the misinterpretation of critical periods, periods of sensitivity and neuroplasticity. Further, this misinterpretation may have resulted in delayed treatments for many functional brain disorders, such as amblyopia.

Critical period. The critical period occurs when an individual is more sensitive to outside environmental influences and stimulation than at most other periods during his or her lifetime.⁷ The concept of a critical period does not imply that neuroplasticity ends at a certain age. The critical period should have a beginning of strong plasticity in response to a sensory experience, a well-defined time period when initiation of plasticity is possible, and a time of reduced sensitivity when plasticity to the same stimulus no longer happens (at the same intensity level). The critical period includes three phases:⁷

- The **precritical phase**, which is the initial formation of neuronal circuits that is not dependent on a visual experience.
- The **critical phase**, a distinct onset of robust plasticity in response to the visual experience, at which time the initially formed circuit can be modified by this experience.
- **Closure of the critical phase** at which time the same visual experience no longer elicits the same degree of plasticity.

After closure of the critical period, the same degree of plasticity may not be available; however, varying degrees of neuroplasticity, under particular circumstances, may occur at some point in the individual’s lifetime.⁷ This is an essential and fundamental concept that is the basis of the sea change in our perspective on neuroplasticity. All aspects of the critical period must occur in a precise, chronological manner to attain a maximum result. Nevertheless, animal studies show that both initiation and closure of the critical period may occur at various ages and can be changed or regulated by physiological and molecular manipulation, interference and enhancement.⁷

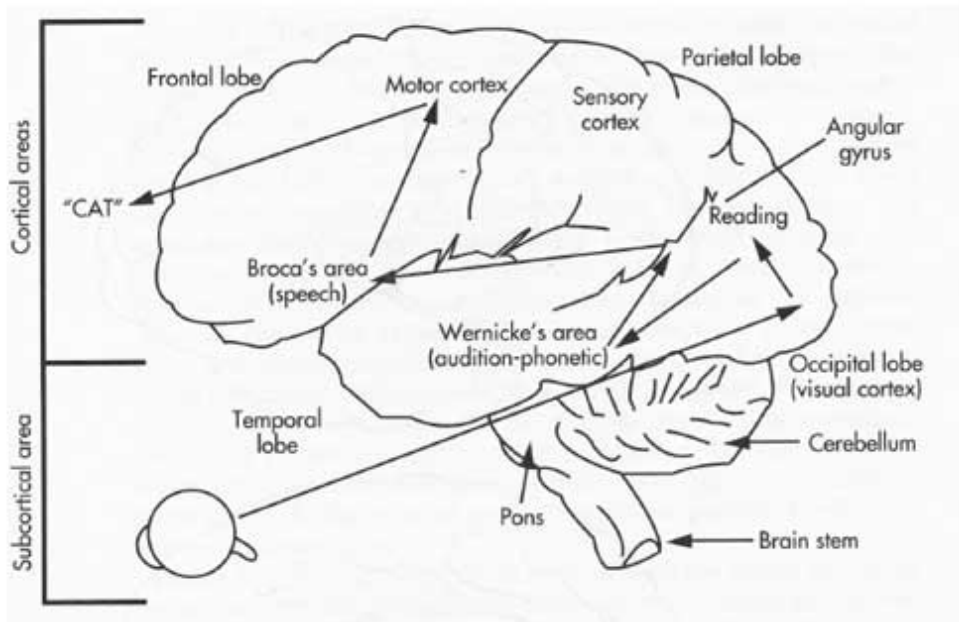
Sensitive period. The sensitive period is somewhat different than the critical period—not only does it begin and end gradually, but also it provides a timeline for maximum sensitivity to stimuli. Sensitive periods may affect how subcortical regions of the visual system develop. For instance, recent studies have found that sensitive periods of visual development are similar to those of cortex development.⁷ This period of synaptic refinement spans the time of initial eye opening; but, it is spontaneous retinal activity, not vision, that drives the resultant changes to the visual system. The concept of a sensitive period also implies that neuroplasticity does not end at a specific age.⁷⁻⁹

Neuroplasticity and the Brain

Can adult brain neurons actually exhibit neuroplasticity? The short answer: yes. Adult neural stem and/or progenitor cells are now known to continuously generate new neurons throughout life in various areas of the mammalian central nervous system.¹⁰ Neurogenesis is necessary for some forms of adult learning, memory and mood regulation to occur. The phrase “life-long

learning” should now take on new significance for optometrists. Adults can learn throughout their entire lives. This means that we can make a considerable difference in the lives of all our patients, including adults. One study suggested that adults taught how to juggle demonstrated a significant transient bilateral expansion of gray matter in the mid-temporal area and the left posterior intraparietal sulcus between baseline brain scan and follow-up.¹¹ The findings were specific to training stimulus; individuals who were not instructed how to juggle demonstrated no change in gray matter over the same period.¹¹ These findings oppose the conventional understanding that the anatomical structure of the adult brain does not change over time (except for alterations in form and structure caused by normal aging or disease).¹¹

In a similar study, the authors noted that long-term bimanual training also increases gray matter volume in experienced adult typists.¹² These results suggest that learning not only affects function, but also structure in adult brains.



With continued sensory processing in the adult brain, lateralization increases, as does the integration between subcortical areas.⁷³

Neuroplasticity and Rehabilitation

To improve a patient's brain function and take advantage of any neuroplasticity, Jeffrey A. Kleim, Ph.D., and Theresa A. Jones, Ph.D., suggest that we follow these 10 key principles:¹³

- *Use it or lose it.* If you do not drive specific brain functions, functional loss will occur.
- *Use it and improve it.* Therapy that drives cortical function enhances that particular function.
- *Specificity.* The therapy you choose determines the resultant plasticity and function.
- *Repetition matters.* Plasticity that results in functional change requires repetition.
- *Intensity matters.* Induction of plasticity requires the appropriate amount of intensity.
- *Time matters.* Different forms of plasticity take place at different times during therapy.
- *Salience matters.* It has to be important to the individual.
- *Age matters.* Plasticity is easier in a younger brain, but is also possible in an adult brain.
- *Transference.* Neuroplasticity, and the change in function that results from one therapy, can augment the attainment of similar behaviors.
- *Interference.* Plasticity in response to one experience can interfere with the acquisition of other behaviors.

These 10 principles can play a major role in how we treat our patients after the diagnosis has been made. Now that we know adults can exhibit neuroplasticity, which can result in not only anatomical and physiological changes in the cortex but also in functional changes of behavior, it is appropriate to review the current eye- and vision-care research that supports the concept of neuroplasticity as it applies to clinical optometry.

Neuroplasticity and Optometry

Though the definition of neuro-plasticity may change somewhat between professions and disciplines, Stanislav Trojan, M.D., D.Sc., and Jan Pokorny, Ph.D., have defined neuroplasticity and its various iterations in such a manner that it fits appropriately into the patient care schema of many O.D.s.¹⁴ They note that mechanisms associated with neuroplasticity can be the result of natural or artificial stimuli, which may occur within an individual's internal or external environment. The end results of these stimuli on neuroplasticity can be positive or negative, and they can occur during development (evolutionary neuroplasticity), after short-term exposure (reactive plasticity), and after enduring or uninterrupted stimuli (adaptational plasticity).¹⁴ They also note that neuroplasticity can occur during functional or structural recovery from damaged neuronal circuits (reparation plasticity).

- Evolutionary neuroplasticity is ideally suited for the developmental O.D. who specializes in vision function as it changes over time, either with or without intervention.
- Reactive plasticity can be thought of as the immediate effect that initial optometric treatment may have on a system. This can be reflected in an immediate, but often transient, change in the individual's accommodative system—i.e., when an uncorrected myope initially puts on his or her new spectacles.
- Adaptational plasticity could describe the long-term effects of in-office optometric vision therapy on disorders of the binocular vision system.
- Reparation plasticity, in contrast to adaptational plasticity, may occur during treatment by a low vision specialist or an O.D. working with those who have experienced a traumatic brain injury (TBI).

Neuroplasticity and Visual System Disorders

Which disorders of the visual system involve neuroplasticity? Almost any anomaly associated with visual development, visual perception or vision function is in this category.

- *Refractive error development.* Several recent studies have noted that neuroplasticity plays a significant role in refractive error development.¹⁵⁻²⁰ This research suggests that numerous external factors, such as retinal defocus, could affect the development of refractive error, and it details how optometric intervention may influence the onset and progression of a variety of refractive errors (i.e., myopia).

Previous research on optometric intervention in the development of refractive error yielded mixed results.²¹ However, recent studies have been much more promising. Several clinical trials have suggested that, by altering an individual's vision through the use of progressive addition lenses or ophthalmic drugs, the practitioner can decrease myopia development.²²⁻²⁵

One study showed that progressive lenses significantly reduced the progression of myopia in Chinese children, while another clinical trial produced a similar conclusion for Japanese children.^{22,23} The results from the Correction of Myopia Evaluation Trial (COMET) also showed reduced myopic progression for those who used progressive addition lenses.²⁴ Additionally, one of the latest drug studies that used an M1-antagonist to slow myopia demonstrated nearly a 50% reduction in myopia progression over a two-year period.²⁵

As optometrists, we can and should alter refractive error development by using the tools readily available to us. In the not-too-distant future, additional lens applications, drugs and clinical approaches may be developed.

- *Amblyopia.* The Pediatric Eye Disease Investigator Group (PEDIG) is a research network funded by the National Eye Institute that consists of 80 distinct sites, 132 pediatric ophthalmologists, 52 pediatric optometrists and 11 colleges of optometry. This single entity has done more to dispel the myths and expand the science surrounding amblyopia and its treatment than any other single group in modern history.

One of PEDIG's most significant studies dispelled the myth that amblyopia cannot be treated in older children and young adults (individuals under 18 years).²⁶ The existence of neuroplasticity in older children and young adults allows an optometrist to treat amblyopia at any age. This study also noted that prescribing spectacles is an important first step in the treatment of amblyopia; 25% of the patients demonstrated improvement with glasses alone.

Another PEDIG study concluded that the treatment of bilateral refractive amblyopia with spectacle correction improves binocular visual acuity in children between three and 10 years of age; most improved to 20/25 or better within one year.²⁷ Further, a similar PEDIG paper concluded that strabismic amblyopia can be improved, or even resolved, with spectacle correction alone.²⁸ Once again, these results demonstrate that we can positively alter visual function in our patients by the appropriate use of spectacles.

Is optometric vision therapy an effective form of treatment for amblyopia? Though the necessary clinical trial has yet to be developed, a PEDIG pilot study suggested that performing near activities while patched may be beneficial in the treatment of amblyopia.²⁹ Other PEDIG studies have endorsed the use of atropine and reduced patching time.^{30,31}

We can diagnose and treat amblyopia in all our patients, no matter their age. Age may be a factor in how we choose to treat this disorder, but it should seldom dictate the range of available treatment options. Neuro- and cortical plasticity that occurs in the adult brain suggests that our treatment options are open and will continue to grow.

- *Strabismus and non-strabismic, non-amblyopic binocular vision disorders.* Much like PEDIG's work on amblyopia treatments, Mitchell Scheiman, O.D., and his Convergence Insufficiency Treatment Trial (CITT) colleagues have researched new treatments for binocular anomalies. The Randomized Clinical Trial of Treatments for Symptomatic Convergence Insufficiency in Children has clearly demonstrated the superiority of in-office optometric vision therapy (in conjunction with home therapy) vs. out-of-office therapy alone.³² The study concluded that optometric vision therapy/orthoptics was more effective than pencil push-ups or placebo vision therapy/orthoptics in reducing symptoms and improving clinical signs of convergence insufficiency.³² More clinical trials are needed to test how neuroplasticity may be applied to new treatment modalities for binocular vision disorders in patients of all ages.
- *Learning-related vision problems and vision development or perception disorders.* Accepted therapy strategies for learning-related vision problems and vision development or perception disorders are widely supported by non-clinical trial research. This research includes an examination of the role vision plays in reading, the effect of vergence and accommodative therapy on reading eye movements and reading speed, the diagnosis and treatment of perceptual disorders, and the effect of therapy on various learning anomalies.³³⁻⁴³ Current research strongly favors a therapeutic approach that incorporates the principles of neuroplasticity.
- *Vision dysfunction associated with developmental disabilities.* Within both optometry and ophthalmology, there is a lack of documented research regarding proper treatment of special needs patients.⁴⁴ There are many barriers that restrain individuals with disabilities from being full participants in the health-care arena, such as poor training of health-care providers on how to address such patients and the inability of the patients to effectively communicate their symptoms.^{45,46}

Neuroplasticity and Visual System Disorders

Neuroplasticity can play a role in the current and future treatment of the following disorders:

- Refractive error development.
- Amblyopia.
- Strabismus.
- Non-strabismic, non-amblyopic, binocular vision disorders.
- Learning-related vision anomalies.
- Vision development or perception disorders.
- Vision dysfunction associated with developmental disabilities.
- Vision dysfunction associated with acquired brain injury.

The limited research that does exist on this topic notes that many problems might be overcome with the proper education of eye-care professionals.^{47,48} Practitioner education in this area is essential, considering that many patients who suffer from vision information processing dysfunction are special needs patients.⁴⁹⁻⁵⁸

Accommodative dysfunctions and esotropia in patients who have Down syndrome can be managed with multifocal lenses.^{59,60} Also, optometric vision therapy is an effective treatment for both accommodative and functional vision anomalies found in patients with cerebral palsy.⁶¹⁻⁶⁵

Neuroplasticity is present in patients with developmental disabilities and is usually noted in early intervention programs, such as Head Start.^{66,67} Research on neuroplasticity and Down syndrome is currently being examined in animal models, and similar research on cerebral palsy is now being conducted in clinical trials.^{68,69}

For patients with developmental disabilities, neuroplasticity will play a larger role in our treatment protocol; however, more research is needed to determine how we will apply the science of neuroplasticity to these special needs patients.

- *Vision dysfunction associated with acquired brain injury.* Neuroplasticity should play a major role in your management of patients with acquired brain injury. TBI, cerebral vascular accident, and other forms of cortical insult could have a

significant effect on the overall visual function of your patients. Patients with TBI often demonstrate accommodation anomalies, version eye movement dysfunction, vergence dysfunction (both strabismic and non-strabismic), photosensitivity, visual field loss and significant ocular health problems.⁷⁰

Research suggests that we can improve the oculomotor abilities of patients with TBI.⁷¹ But can we sufficiently rehabilitate their oculomotor skills to perform demanding visual tasks, such as reading? One study showed that optometric vision therapy facilitated rehabilitation of reading-related oculomotor skills and produced significant subjective and objective gains in reading ability.⁷²

Also, neuroplasticity may play a role in the treatment of perceptual anomalies that are often caused by brain injury, such as agnosia, alexia, color dyschromatopsia and prosopagnosia.⁷³ Treatment of these perceptual disorders is often initiated by a psychologist, psychiatrist or physical therapist—not an optometrist. Nevertheless, following treatment, patients with prosopagnosia and alexia have demonstrated functional improvement.^{74,75}

Improving Brain Function and Neuroplasticity

Although the topic of improving brain function and neuroplasticity could be a book unto itself, it must be at least briefly discussed. The belief that there are specific “brain foods” dates back quite a long way—or at least as far back as the lifetimes of our grandmothers who fed us cod liver oil to “cure all ills and make us smart.” Today, we see an increasing abundance of research about the positive systemic and ocular effects of omega-3 fatty acids.⁷⁶⁻⁷⁹ Current research on the overall health benefits of increased omega-3 fatty acids is still somewhat mixed, but several experts believe that increased intake may improve brain functionality.⁷⁹

Interestingly, recent research has shown that certain medications may enhance neuroplasticity. The antidepressant Prozac (fluoxetine, Eli Lilly) has been used to restore plasticity in the adult visual cortex.⁸⁰ Tianeptine, another antidepressant, affects glutamate, which regulates neuroplasticity.⁸¹ Erythropoietin, a glycoprotein hormone, and L-arginine, a precursor of creatine synthesis, may also enhance plasticity.^{82,83} Still, there seems to be no “magic pill” that consistently promotes neuroplasticity.

Conclusion

We have experienced a sea change in the understanding of neuroplasticity. Now, it is evident that we can take advantage of neuroplasticity to help correct many disorders of the visual system—we, as clinicians, simply have to begin utilizing these treatment options for the benefit of our patients.

In the meantime, if there is a magical switch for increasing neuroplasticity, research shows that it involves exercise, practice and exposure to new stimuli.⁸⁴

As for me, I just wanted a simple pill, an easy fix. Unfortunately, it now looks like I have to actually work for my neuroplasticity. See you in the gym or in the library.

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