ESSAY

VISION THERAPY AS PERCEPTUAL LEARNING

INSIGHTS FROM THE VISION SCIENCES SOCIETY

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Abstract

The Vision Sciences Society (VSS) holds an annual meeting comprised of individuals from the broad range of disciplines that contribute to vision science. These disciplines include visual psychophysics, neuroscience, computational vision and cognitive psychology. In this forum many of the changes experienced by patients undergoing optometric vision therapy are expressed as elements of perceptual learning. Nevertheless, the terms "optometric vision therapy" and "behavioral optometry" are foreign to most of these accomplished vision scientists.

This essay reviews the experiences of two behavioral optometrists and a neurobiologist who traveled to the 2007 VSS meeting to participate in a demonstration of vision therapy procedures. Personal interactions set the stage for future potential collaborative efforts. These interactions reinforced the notion that the terminology used in vision therapy should be more indicative of supportive research in the cognitive neurosciences, such as perceptual learning.

Key Words

adults, neurocognition, neuroplasticity, perceptual learning, vision science, Vision Sciences Society, vision therapy

Vision is a learned process. Consequently, abnormal visual development reflects, to some degree, a failure to learn properly. Our colleagues in vision science have grasped this concept; they have coined the phrase *perceptual learning* to describe changes in performance attained through visuo-behavioral manipulations. This terminology was used in the program description of a recent symposium on Visual Plasticity in Abnormal and Damaged Adult Brains, held during the Annual Meeting of the Vision Sciences Society (VSS) meeting in Sarasota. See Table 1.

Before discussing the Vision Sciences Society, some background material on perceptual learning will make the appeal of this topic more apparent.

Perceptual Learning

The specific modification of perception and behavior following sensory experience is the essence of perceptual learning. It encompasses performance changes, brought about through practice, that improve an organism's ability to respond to its environment. A surge of interest by scientists in perceptual learning has been prompted by findings of considerable plasticity in the adult brain, particularly as applied to reversing amblyopia in adulthood,[1,2] and to recovery from traumatic brain injury.[3,4]

In order for sensory stimulation to be sufficient for learning, it must drive the neural system past the point of a learning threshold.[5] Neuro-cognitive factors, such as attention and reinforcement, augment learning responses.[6] Sensory input can be optimized through the application of lenses and prisms.[7] Learning responses are also gated by synchronization.[8] Synchronicity applies to visual processing in various ways attained, for example, through flicker rate with photic stimulation to counteract intermittent central suppression.[9] These augmented responses are brought about through indirect stimulation of visual pathways, though recent research provides evidence of direct stimulation through the application of transcranial magnetic stimulation (TMS).[10]

In Applications to Vision Therapy

Outside of the laboratory, motor learning serves as a bridge between cognition and perception.[11] In his review of the scientific basis for and efficacy of optometric vision therapy (VT) in nonstrabismic accommodative and vergence disorders, Ciuffreda addressed perceptual-motor skill acquisition in the context of motor learning.[12] See Figure 1. He used this par-

TABLE 1.
Topics in Symposium on Visual Plasticity
Vision Sciences Society 2007

Plasticity in human blindsight
Improving global motion perception in the blind field of adult humans with V1 damage
Improving vision in adult amblyopia by perceptual learning
Reactivation of juvenile-like ocular dominance plasticity in the adult visual cortex
Primate area V1 reorganization following retinal lesions: where do things stand?

adigm to demonstrate the need for training a wide range of oculomotor learning skills under increasing task complexity and in changing contexts. This serves to ensure development of a full complement of cognitive, perceptual, and motor skills that might otherwise not be transferred efficiently and automatically to one's everyday environment.[13]

Karni and Sagi raised the issue of the time course of learning a visual skill in the context of perceptual learning.[14] They noted that individuals engaged in visual learning often do not show immediate changes, but experience a delay in the time it takes for skills to become fully functional. The idea of a skill being consolidated over time through memory traces, serves as one of the important bases for understanding how perceptual learning takes place.

I have noticed that many patients continue to improve in various aspects of visual performance well beyond the completion of a formal vision therapy (VT) program. This can be related to the question that many patients (or parents) have as to "how long will the benefits of therapy last, and is this something that I (or my child) will have to continue to practice?" The concept of consolidation in learning, as addressed by Karni and Sagi,[14] supports the enfolding of learned visual skills into motor memory. Given enough experiences during the course of VT in a wide variety of skills, and learning how to apply those skills to a variety of cognitive problem-solving tasks, insures that skills will not only be retained, but will be consolidated into other learning paradigms.

These tenets for perceptual learning therefore become vital tools in the strategy and planning of effective VT, and can be summarized as follows:

a) projecting a time course of therapy
b) providing a wide range of activities in which the patient is to be engaged
c) setting the conditions for generalization of training-induced improvement
d) insuring the transfer and persistence of therapy effects.

The Vision Sciences Society

The Vision Sciences Society, an offshoot of the Association for Research and Vision in Ophthalmology (ARVO) is a non-profit organization of scientists interested in the functional aspects of vision, dedicated to improved understanding of vision and the brain. Their website logo (see www.visionsciences.org) is a prism dispersing into neuroscience, psychophysics, cognition, action, computation and development.

Perceptual Learning		**Motor Learning**		**Cognitive Processes**
Changes in neural circuits that detect a particular stimulus	←	Changes in neural circuits that detect a particular behavior	←	Neuromodulatory functions that gate learning thresholds

Figure 1. Adapted from Ciuffreda,[12] Perceptual Learning schematic.

VSS was founded in 2001 by Dr. Ken Nakayama (Harvard University) with the help of Dr. Tom Sanocki (University of South Florida). The main purpose of the society is to hold an annual meeting that serves as a forum for individuals from the broad range of disciplines that contribute to vision science. These disciplines include visual psychophysics, neuroscience, computational vision and cognitive psychology. The scientific content of the meetings reflects the breadth of topics in modern vision science; from visual coding to perception, recognition and the visual control of action, as well as recent developments in computer vision and neuroimaging.

During the annual VSS meeting, both new and established investigators from diverse disciplines and scientific perspectives present and discuss their work in a relaxed informal setting. Aside from the usual scientific posters and presentations commonplace at annual meetings of professional societies, a unique feature of the VSS meeting is "Demo Night."

Demo Night

Together with two collaborators, Paul Harris, O.D. and Susan Barry, Ph.D., ("Stereo Sue") I traveled to Sarasota, Florida in May, 2007 to participate in the annual "Demo Night" held at the G.Wiz Science Center, in conjunction with the Annual VSS Meeting. See Figure 2. Unlike other patients who have benefited from VT, Dr. Barry was in a unique position; not only had she been surprised that this effective optometric intervention was such a well kept secret, but unlike other patients who had benefited from VT, she had the wherewithal to take a proactive stance.

Sue attended the Society for Neuroscience meeting in 2006, and encountered Jeremy Wilmer, a postdoctoral fellow in the psychology department at the University of Pennsylvania. Jeremy was intrigued by Sue's story about her experiences with VT, and encouraged her to attend the VSS meeting in order to interact with an array of researchers who would share interest in her binocular vision makeover. It was at that point that Sue looked into the meeting, learned of "Demo Night," and decided that this would be an appropriate forum for behavioral optometrists to introduce vision researchers to VT procedures.

Demo Night proved to be a perfect setting. Sue, Paul and I set up shop in a foyer, strategically on the way to coffee and cookies. We had Brock Strings suspended in the air, in addition to other hands-on demonstrations of VT procedures. Even our assigned local high school student assistant from the G.Wiz Center got into the act, demonstrating the effects of yoked prisms after a tutorial by Paul. Three hours flew by and we were exhausted – but exhilarated by the gusto with which world-class vision researchers were partaking of VT procedures. Most of these researchers had never met an optometrist who provided VT, and had not experienced a VT procedure first-hand.

There, for example, stopped Ian Howard, a prolific researcher and author in binocular vision, who was fascinated to watch his own projection in real binocular space of Panum's fusional area. He also became aware of what patients with various binocular maladaptations would see. He was intrigued to learn that there were effective and relatively simple VT procedures that patients could undertake to improve their binocular function in free space. For many others, who waited patiently in line for their own turn to view these demonstrations, light bulbs glowed brightly on how they might incorporate these demonstrations into their respective courses on vision and visual perception.

Perceptual Learning in the Hallways

In a forum such as VSS, one learns just as much by chatting informally in the hallways, or over lunch, as one does sitting in a scientific session. Name badges at VSS do not have anyone's title or professional degree, only institutional pedigree. And even one's institutional affiliation is secondary because of the propensity for scientists to move based on career opportunities and collaborative interests. Ideas flow freely; thus, if scientist A felt you had something of substance to offer, and

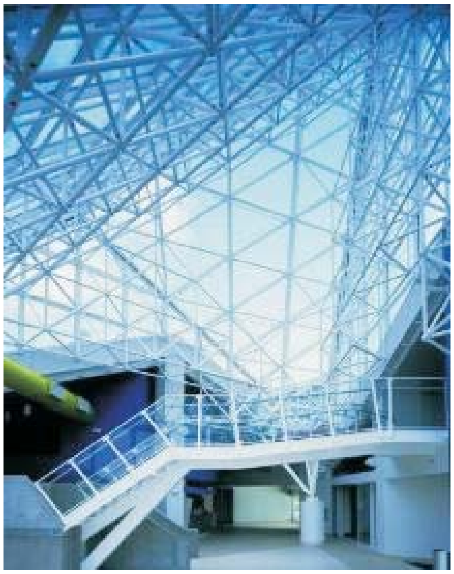

Figure 2. The G. Wiz Science Center in Sarasota

he was a respected colleague of Scientists B and C, they too would be interested to hear your thoughts.

This was word-of-mouth at its finest. For instance, Sue Barry introduced Jeremy Wilmer, Ph.D., to Paul Harris. Jeremy along with his mentor, Benjamin Backus, Ph.D., were in the process of moving from the University of Pennsylvania to the State University of New York, State College of Optometry to conduct applied research. In small world fashion, Paul's father, Dr. Gordon Harris**,** had been the Wilmer family optometrist when Jeremy was growing up in New York. Science in these forums is facilitated by social enterprise.

Among the scientists whose perspective Sue wanted to gain was Dennis Levi, O.D., Ph.D., Dean of the School of Optometry in the University of California, Berkeley, Dr. Levi co-authored a textbook on Amblyopia[15] with Ken Ciuffreda, O.D., Ph.D., and Arkady Selenow, O.D., in 1991 and has subsequently continued to publish prolifically on the subject of perceptual learning as related to amblyopia therapy.[16-19] While I had known Dennis through the annual meetings of the American Academy of Optometry, we had never sat down to discuss the enigma of misperceptions about VT at length. I could only smile as Sue peppered Dennis with questions about why it seemed to be so difficult for people to understand and accept the science behind vision therapy.

While Dennis didn't have any immediate answers, he was sensitive to the enigma. Amblyopia research was directly responsible for the recent surge of interest in plasticity about the visual system in the adult**.**[1,2] Excitement abounded for reports of plasticity in the adult nervous system, strongly linked to successful interventions in rehabilitation environments. Interestingly, the presenters at VSS weren't obsessed with arbitrary "gold standard" research; reports on a handful of subjects were the norm. The key seemed to be that interventions were grounded in theories of substance, and that they were replicable by other researchers and laboratories.

During a coffee break, Dennis introduced us to Ione Fine, Ph.D. Fine had recently been elevated to the status of neurocelebrity through her work with Mike May. Blinded at age 3 by a chemical explosion, May underwent a corneal transplant in adulthood and struggled to learn how to use his restored vision. Although his corneal transplant left him with the optics to see sharply, the neural networks in his brain had been reconfigured to function with limited external visual input. He literally needs to learn how to see again, and his initial attempts were frustrating. Neuropsychological testing by Fine documented Mike's relative strengths and weaknesses, but she was challenged in devising effective strategies for re-integration of vision. It remained for Mike, with his intellect, to discover ways of balancing this new visual input with his understanding of the objects and himself in the world. Here was a brave new world of object recognition and spatial configuration, yet a confusing one at best. The Fine-May collaboration took center stage at the meeting because it is chronicled in a book that became available during the meeting. The author, Robert Kurson aptly titled it *Crashing Through: A True Story of Risk, Adventure, And The Man Who Dared To See*.[20]

Plasticity and perceptual learning were put to the ultimate test. As I read Kurson's depiction on the plane ride home, I couldn't help but think that one important element was missing in the Fine-May story. This relates to the practice of at least some ophthalmic surgeons who place patients into radically altered environments without better positioning them for success. Wouldn't it have been logical to fit Mike with a high plus fog contact lens, and gradually reduce the fog as his newly gained eyesight could be synchronized with redeveloping visual pathways? Why leave the restoration of visual function hanging in the balance, without any visual guidance? When Mike pressed his surgeon to explain why his corneal transplanted eye was now healthy, but his vision was unreliable if not confounding, the surgeon concluded that this was outside his field.

Dr. Fine stumbled onto Mike's case serendipitously. She had prior experience with patients who struggled with perceptual learning after surgery to improve longstanding bilateral visual deprivation.[21] Surely brain science proved valuable in sorting out Mike's puzzle. Where was the appreciation of what *behavioral optometry* could have provided from our knowledge of visual performance? Missing from all the excitement about plasticity and perceptual learning in vision science itself, and in the chapters of too many patients' lives, was input from behavioral optometry. This philosophical and clinical approach has its roots not only in the basic human development of vision, but goes beyond into the development of the visual perceptuo/cognitive complex.[22]

Application of these concepts may have facilitated Mike's rehabilitation. He had lost optical clarity at three years of age. Consequently, his pathways for learning were re-mapped through the developmental route he followed. The sudden acquisition of optical clarity through surgery had occurred many years later. This was well after the visual pathways in his brain had been conscripted for other neuro-cognitive functions. This resulted in a dilemma that begged for guidance through behavioral optometry. Yet none of the professionals who interacted with Mike knew of behavioral optometry. They only knew of perceptual learning.

Making Vision Therapy Resonate

When I hold a conference with the parents of a child for whom I am prescribing VT, I advise them that the spirit of our therapy room is like that of the Liberty Science Center. This is a museum in New Jersey that is admired for having instructors who partner with students, guiding them in the exploration of scientific concepts. VT patients ideally learn about how their visual system is operating through various conditions we set to help them explore visual space. We have a T-shirt from NASA hanging on the door to the entrance of our vision therapy room that reads: "Failure Is Not An Option." This theme reminds our staff and patients that as we explore visual function, whether through lenses, prisms, or non-ophthalmic perceptual-motor-cognitive procedures, opportunities for learning present themselves. And we must seize the moment.

Sue Barry wrote: "I believe that members of the College of Optometrists in Vision Development play a crucial role in transforming the vision and therefore, the lives of many of their patients who struggle with a wide range of visual disorders. I am one of those lucky patients and will do all that I can to broadcast the importance and enormous benefits of optometric vision therapy."[23]

Holding to her promise, Sue picked up where she left off when she presented her experiences at the Annual COVD meeting in 2006. Beyond speaking at Colleges of Optometry and being in the process of authoring a book about her VT experiences, Sue has challenged us to have a presence in arenas where vision scientists "do science." Her intuition proved correct in encouraging Paul Harris and me to join her and engage individuals at the VSS whose research interests are aligned with the way we approach clinical vision care.

We should be receptive to terminology that provides a bridge between vision science research and the changes that occur through VT. We have used "vision therapy" as an umbrella term for a variety of therapeutic procedures, but our terminology may be obscuring the value of our services.[24] While I am not necessarily suggesting that *perceptual learning* is a term that is synonymous with all that occurs through VT, this term resonates with the vision science community. Broader use of this term to describe at least some elements of VT can be mutually beneficial.

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