Published in final edited form as:

Optom Vis Sci. 2018 August ; 95(8): 632–642. doi:10.1097/OPX.0000000000001257.

2017 Glenn A. Fry Award Lecture: Establishing an Evidence-based Literature for Vision Therapy - A 25 Year Journey

Mitchell M. Scheiman, OD, PhD, FAAO

Pennsylvania College of Optometry at Salus University, Elkins Park, Pennsylvania

Abstract

In this article, I summarize the 2017 Glenn A. Fry Award Lecture and my journey from student, to clinician, to optometric educator, and finally researcher/vision scientist. Although content for many years teaching and practicing vision therapy, the era of evidence-based healthcare created a level of discomfort as it became evident that my area of interest, vision therapy, had minimal quality evidence to support its use. Joining forces with a group of exceptional colleagues, we established the Convergence Insufficiency Treatment Trial Investigator group and we were able to achieve funding from the National Eye Institute for multiple randomized clinical trials. The results of our studies demonstrate that vision therapy is an effective treatment option for convergence insufficiency in children and office-based therapy is more effective than home-based therapy. These studies also demonstrated that home-based pencil pushups commonly used by both optometrists and ophthalmologists is no more effective than placebo therapy. More recently, working in a new arena of objective recording of vergence, accommodative, and versional eye movements, my research has demonstrated that objective outcome measures of vergence are feasible for future randomized clinical trials. In pilot studies with both naturally-occurring convergence insufficiency and concussion-related convergence insufficiency statistically significant and clinically meaningful changes have been found in both disparity vergence peak velocity and response amplitude after office-based vision therapy. With new evidence about the high prevalence of concussion-related convergence insufficiency, there is much work to be accomplished to study the effectiveness of vision therapy for convergence insufficiency as well as the underlying mechanisms for how and why vision therapy is effective.

Keywords

convergence insufficiency; vision therapy; near point of convergence; office-based vision therapy; home-based pencil push ups

“Man not only survives and functions in his environment, he shapes it and he is shaped by it.”

René Dubos

When I look back at my 43 years in optometric practice, it is evident that a number of my key career decisions were strongly shaped by the environment in which I was trained and

practiced. For example, my optometry education took place between 1971 and 1975 which coincided with the very end of the era of optometry as a drugless profession. Although the first diagnostic pharmaceutical agent (DPA) law passed in Rhode Island in 1971, it wasn't until 1997 when Massachusetts passed a therapeutic drug law, that all 50 states permitted optometrists to use both diagnostic and therapeutic drugs. Thus, when I was in optometry school, the scope of optometric practice was quite limited. As a second-year student at the Massachusetts College of Optometry, I remember wondering whether I would be able to maintain my enthusiasm and interest in the profession for the next 30 to 40 years. In fact, after completing my second year of optometry school, I seriously contemplated applying to medical school.

When I started my third year of optometry school in 1974, I was at a crossroad – continue my optometry career or apply to medical school. Fortunately, the course on the diagnosis and treatment of binocular vision disorders was presented that first semester. I was challenged by the complexity of the vergence and accommodative systems, intrigued by the potential to restore normal accommodative and binocular function using vision therapy, and thrilled to learn that this area of eye care was unique to the profession of optometry. My experience in this course changed the direction of my career. I made the decision that if I were to sustain my enthusiasm for a 30- to 40-year career in optometry that the area of binocular vision disorders and vision therapy would have to be my primary clinical interest. *Serendipitously*, in 1975 the State University of New York College of Optometry started the first residency program for optometry and the residency was in the area of vision therapy. After graduating from optometry school in 1976, I was accepted into the second year of the SUNY Residency Program in Vision Therapy and that experience set the stage for the rest of my career.

Upon completion of my residency program, I settled into a career in optometric education, first at the New England College of Optometry, and then in 1982 at the Pennsylvania College of Optometry at Salus University. Although my exact role as an optometric educator has changed over the years, my primary responsibilities were clinical and didactic teaching in the areas of binocular vision, pediatric optometry, and vision therapy. In my early years as an optometric educator I was content — happy with my career decision and pleased with the successful outcomes I was achieving clinically by prescribing vision therapy programs to treat my patients' binocular vision dysfunctions and visual information processing deficits. And then the era of evidence-based healthcare began in the early 1990s and everything changed; this second environmental factor dramatically changed my career path.

The term '*evidence-based*' was coined by Dr. David Eddy in 1987.¹ Two years later, the term '*evidence-based medicine*' was published by the Evidence-Based Medicine Working Group.² As a result of this new evidence-based healthcare culture, greater scrutiny was placed on clinical studies and grading systems to determine the "level of evidence" or quality of the research for clinical treatments. At the same time, the effectiveness and value of vision therapy was under a relentless and often harsh attack by professionals and organizations in the fields of ophthalmology, pediatrics, and at times the professions of psychology and education.³⁻⁹ Given the evidence-based healthcare environment, questions were raised about the lack of quality evidence for the effectiveness of vision therapy. This

negativity about vision therapy was troublesome for the profession of optometry, for me personally, and for many colleagues who taught this subject in the schools and colleges of optometry around the country and provided this service in their clinics. As a relatively young clinical optometric educator with minimal research experience, my initial reaction was that while these attacks were disconcerting I was certainly not in a position to initiate research that would address the lack of high-quality research in the area of vision therapy. I had no formal training in research and my assumption was that the more senior members of the profession would take the lead and produce the required quality evidence necessary to counter the negativity about vision therapy. However, as the years past, and I became a middle-aged optometric educator, it became evident that I would have to take some responsibility for the lack of quality evidence. Of course, there were many other optometric educators in the same dilemma, and in 1994 several formed a working group with the goal of conducting a series of randomized clinical trials to study the effectiveness of vision therapy.

It was with this environmental backdrop that my primary interest changed from teaching vision therapy and providing vision therapy in the clinic, to conducting high-quality research to study the effectiveness of vision therapy. Although I had no formal training as a researcher, in the late 1990's I was fortunate to be asked by Jane Gwiazda and Leslie Hyman to be the principal investigator of a clinical site at Salus University for the multi-center Correction of Myopia Evaluation Trial (COMET)¹⁰ evaluating the effectiveness of progressive addition lenses in slowing the progression of childhood myopia. Shortly thereafter, I became involved in the Pediatric Eye Disease Investigator Group (PEDIG) and served as a co-protocol chair for several randomized clinical trials.^{11–13} These two experiences provided me with invaluable training in the conduct of randomized clinical trials, which eventually allowed me to assume a leadership role in the Convergence Insufficiency Treatment Trial (CITT) studies.

Origins of Optometric Vision Therapy (1896–1960)

To understand the state of the vision therapy literature in the early 1990's, it is important to provide a concise history of vision therapy and the literature supporting its effectiveness. Although the origins of vision therapy can be found in the orthoptic literature dating back to work by Javal in 1896¹⁴, the emergence of 'optometric' vision therapy had its genesis with the work of Skeffington, Getman, and Brock.¹⁵ From the 1930s through 1960's these optometry leaders transformed the art and practice of vision therapy from a treatment aimed primarily at improving vergence and binocular function into a more sophisticated treatment that included treatments for accommodative, eye movement, and visual processing problems. During this time, the practice of vision therapy became accepted as an integral part of optometric care with almost all state laws including vision therapy as a component of the practice of optometry. However, the research base substantiating the effectiveness of optometric vision therapy for various vision disorders was virtually non-existent.

It was not until the 1970s that optometry began investigating the effectiveness of vision therapy. Early research consisted primarily of case reports, case series, and retrospective studies.^{16–18} Then, in the 1980s the level of research improved primarily because of research conducted by Kent Daum and Jeffrey Cooper. From 1982–1987, Daum published the results

from a series of prospective studies investigating the effectiveness of vision therapy for non-strabismic binocular vision disorders^{19–29} and accommodative problems.^{30–32} Then Cooper and colleagues demonstrated the effectiveness of vision therapy for convergence insufficiency using a well-designed, placebo-controlled, cross-over clinical trial.³³ They used the same study design several years later to demonstrate that vision therapy was an effective treatment for adults with accommodative infacility.³⁴ While the studies conducted by Daum and Cooper were a vast improvement from the retrospective chart reviews of previous decades there were still limitations in the vision therapy research literature.

A number of authors incorporated objective outcome measures into their study designs as an attempt to minimize bias associated with the use of unmasked examiners.^{35–38} Liu³⁵ and Bobier³⁶ both used objective measures of accommodation to evaluate accommodative response before and after vision therapy. Grisham^{37, 38} used eye tracking devices to assess the dynamics of the disparity vergence response as outcomes measures after vision therapy.

Thus, the quality of the evidence on the effectiveness of vision therapy gradually improved; however, there were still no randomized clinical trials until 1999 when Birnbaum and colleagues published the results of the first randomized clinical trial evaluating the effectiveness of vision therapy for convergence insufficiency in adults.³⁹ Although the study was a randomized clinical trial, there were a number of study design limitations, including no placebo control, unmasked examiners, and the use of a symptom questionnaire that had not been validated.

Thus, in the pre-evidence-based healthcare era, the literature suggested that vision therapy was effective for the treatment of accommodative and binocular vision disorders.^{16–19,21,22,24,26,31–52} However, the highest quality evidence in the form of randomized clinical trials was lacking, and without such data it was difficult to argue with vision therapy skeptics.

History of the Convergence Insufficiency Treatment Trial (CITT) Investigator Group

Early Funding Efforts

Frustrated by the persistent attacks on vision therapy by various professional groups and individuals, a number of like-minded optometric educators, scientists, and statisticians formed an investigator group in 1994 named the Vision and Reading Research Interest Group. The stated goal of this group was to design and implement a randomized clinical trial to study whether vision therapy would lead to improvement in reading ability. In 1995, this group re-organized and changed its name to the Convergence Insufficiency and Reading Study (CIRS) Group because they became more focused on a specific vision disorder – convergence insufficiency. Original members of this group were the Study Chair Michael Rouse, and members Eric Borsting, Ralph Garzia, David Grisham, Harold Solan, Michael Wesson, Leslie Hyman, and Mohamed Hussein. A year later, Susan Cotter, Leonard Press, and I joined the group. Our primary objective at that time was to achieve funding from the National Eye Institute for a randomized clinical trial that would investigate the effectiveness

of vision therapy for improving reading in children with symptomatic convergence insufficiency.

The efforts of the CIRS Group were instrumental in preparing for a subsequent National Eye Institute grant application submission. From 1995 to 1998, the CIRS Group completed critical preliminary studies pertaining to convergence insufficiency that formed the foundation for the CITT Investigator Group activities in later years. These studies included the following: development of the Convergence Insufficiency Symptom Survey (CISS)⁵³; determination of school-based prevalence estimates of convergence insufficiency^{54,55}; establishing the reliability of clinical measures of binocular vision⁵⁶, describing the reading ability of a cohort of children with convergence insufficiency⁵⁷, ascertaining the treatments of choice that eye care professionals prescribe for convergence insufficiency⁵⁸, and defining how eye care professionals reach the diagnosis of convergence insufficiency.⁵⁹ In 1994, Mike Rouse and Leslie Hyman had a joint meeting with project officers from the National Eye Institute and the National Institute of Child Health and Human Development, where they were advised that their question of interest – Does vision therapy lead to improved reading in children with symptomatic CI? – had little chance of being funded. The National Institute of Child Health and Human Development had most of its money tied up in core grants and the National Eye Institute was not interested at the time. It was noted at this meeting that because there were no quality data to answer the more basic question of whether vision therapy was even an effective treatment for convergence insufficiency, it was premature to suggest a clinical trial to investigate whether vision therapy would improve reading performance.

This disappointing news led to the establishment of the Convergence Insufficiency Treatment Trial Investigator Group (CITT) with a new set of objectives. Some of the original members of CIRS along with new members met during the four-day 1998 Summer Invitational Research Institute held at the Southern California College of Optometry and sponsored by the American Academy of Optometry and the American Optometric Association. This group of new investigators (Eric Borsting, Jeffrey Cooper, Susan Cotter, Paul De Land, Richard London, G. Lynn Mitchell, Michael Rouse, and Mitchell Scheiman) decided that the most compelling research issue in the area of vision therapy was the treatment of convergence insufficiency. Convergence insufficiency was chosen because it is the most common binocular vision disorder, affecting between 4.2% to 17.6% of the population.^{55, 60–62} It is often associated with symptoms that interfere with everyday function such as frequent loss of place, loss of concentration, having to re-read, reading slowly, trouble remembering what was read, sleepiness, blurred vision, diplopia, headaches, and/or eyestrain during reading or other near work.^{52, 63–65} In addition, convergence insufficiency was a well-accepted medical diagnosis that was recognized by both optometrists and ophthalmologists. Our group began to develop a general outline for a clinical trial to investigate different treatment modalities for convergence insufficiency. Then, our CIRS Study Chair Michael Rouse became ill and was no longer able to lead the group. I vaguely remember someone volunteering me as the new Study Chair and that was the beginning of my leadership role in CITT.

Between September 1998 and July 1999 we developed a preliminary draft of a National Eye Institute, R21 planning grant proposal. Because of the importance of this project to both optometrists and ophthalmologists and to create a planning committee more representative of the eye care community, we added two more members in July 1999, Jonathan Holmes and Michael Repka, both pediatric ophthalmologists with significant clinical trial experience.

To help determine the treatment arms that should be studied in a randomized clinical trial we surveyed both optometrists and ophthalmologists to determine their first-line treatment for convergence insufficiency.⁵⁸ The most common treatment prescribed by the optometrists was pencil push-ups (36%), followed by home-based vision therapy (22%) and office-based vision therapy (16%). Among the ophthalmologists, the most common treatments prescribed were pencil push-ups (50%), followed by home-based vision therapy (21%) and base-in prism (10%). In October 2000, the National Eye Institute funded our CITT planning grant. The objective of this pilot study was to compare the effectiveness of office-based vision therapy, home-based pencil push-ups, and office-based placebo vision therapy as treatments for symptomatic convergence insufficiency in children and young adults. We had two separate cohorts – 47 children ages 9 to 17 years⁶⁶ and 46 young adults ages 18 to 30 years⁶⁷ (refer to Table 1 for a summary of the study results). Although the sample size of each cohort was modest, this was the first randomized clinical trial of vision therapy for any condition that included a placebo control group and masked examiners. We found that the most effective treatment for children and adults was office-based vision therapy, the treatment that was least likely to be prescribed by eye care providers. Figures 1A-C show the study results for the clinical outcome measures of the near point of convergence and positive fusional vergence at near and the Convergence Insufficiency Symptom Survey (CISS) in the pediatric cohort in the CITT pilot study along with several other randomized clinical trials. In Figure 1A the horizontal black line is located at 6 cm. Any finding below this level is considered normal. As the graph shows, only participants in office-based vision therapy achieved this normal level. Symptoms, which were similar in all groups at baseline, were statistically significantly reduced from baseline to outcome in the office-based vision therapy group but not in the pencil push-ups or placebo vision therapy. In Figure 1C the horizontal black line is located at 16. Any finding below this level is considered asymptomatic. As the graph shows, only participants in office-based vision therapy achieved this asymptomatic level. In addition, only patients in the office-based vision therapy group demonstrated both statistically and clinically significant changes in the clinical measures of near point of convergence and positive fusional vergence at near. Similar results were found for the adult population. Office-based vision therapy was the only treatment that produced clinically and statistically significant improvements in the near point of convergence and positive fusional vergence. All three groups demonstrated statistically significant changes in symptoms (42% office-based vision therapy, 31% office-based placebo vision therapy, and 20% home-based pencil push-ups).

The experience that our CITT Group gained from our CITT R21 Planning Grant had a major impact on our future funding success with the National Eye Institute. By successfully implementing and completing a randomized clinical trial, we established our ability to recruit and retain subjects, function as a team, carefully implement and follow study protocol, and disseminate our findings through presentations and publications. Using a

rigorous design, we demonstrated the effectiveness of office-based vision therapy for convergence insufficiency, and we generated the necessary data to determine the sample size that would be required for a large-scale randomized clinical trial. Of great significance was the development and successful implementation of a placebo therapy protocol. This study demonstrated that 83% of subjects randomized to placebo therapy thought they were receiving “real” vision therapy.⁶⁸

Based on the results of this pilot study, recruitment and retention performance at the clinical sites, and the sample size calculation, changes were made in the clinical study site composition with some additions, and deletions to the original CITT group (Pennsylvania College of Optometry, State University of New York College of Optometry, The Ohio State University College of Optometry, Southern California College of Optometry, Pacific University College of Optometry, University of Houston College of Optometry). Five new sites were selected (Bascom Palmer Eye Institute, NOVA Southeastern University College of Optometry, the University of Alabama School of Optometry, Mayo Clinic, and the Ratner Eye Center at the University of California at San Diego), and two were eliminated (Pacific University College of Optometry, University of Houston College of Optometry). This new group formed the CITT study team for our next endeavor – the development of a large-scale, randomized clinical trial.

CITT Large-Scale Randomized Clinical Trial, Randomized Clinical Trial of Base-in Prism, and Home-Based Vision Therapy Studies

Between 2002 and 2004 we completed a randomized clinical trial to investigate the effectiveness of base-in reading glasses for children with convergence insufficiency (Table 1).⁶⁹ Finding that base-in reading glasses were no more effective than placebo glasses eliminated this treatment modality as a potential treatment arm for our next grant application. Between 2002 and 2004, we submitted grant applications for a large-scale, multi-center, randomized clinical trial to study the effectiveness of treatments for symptomatic convergence insufficiency to the National Eye Institute 3 times. After two unsuccessful attempts, the National Eye Institute funded our large-scale CITT clinical trial for 5 years. From 2004 to 2007, 221 children with symptomatic convergence insufficiency were enrolled into the study. Each child received treated for 12 weeks and was followed for one year thereafter. We are extremely proud of the quality of the study; we fulfilled our recruitment goal in only 15 months, had a 99% retention rate at outcome, and <2% of 2643 visits were missed. Table 1 provides a summary of the study results and Figures 1A–1C illustrate the final values after 12 weeks of treatment for the CISS score, the near point of convergence, and for positive fusional vergence. In summary, after 12 weeks of treatment, the office-based vergence/accommodative therapy group’s CISS score was statistically significantly lower than the scores for the home-based pencil push-up therapy group, the home-based computer vergence/accommodative therapy and pencil push-ups group, and office-based placebo therapy group. The office-based vergence/accommodative therapy group also demonstrated a significantly improved near point of convergence and positive fusional vergence ranges compared with the other groups. We concluded that office-based

vision therapy should be the first-line treatment for symptomatic convergence insufficiency in children 9 to 17 years old.^{70,71}

A one-year follow-up of subjects who were successful at 12 weeks showed that most children aged 9 to 17 years, who were asymptomatic after a 12-week treatment program of OBVAT for convergence insufficiency, maintained their improvements in symptoms and signs for at least 1 year after discontinuing treatment.⁷² In addition, a systematic review of treatments of symptomatic convergence insufficiency concluded that “research suggests that outpatient vision therapy/orthoptics is more effective than home-based convergence exercises or home-based computer vision therapy/orthoptics for children.”⁷³ Another CITT manuscript documented important findings about treatment kinetics showing that the rate of improvement is more rapid for clinical signs (NPC and PFV) than for symptoms. The pattern of change in symptoms after treatment⁷⁴ and the relationship between symptoms and clinical measures⁷⁵ were explored in other manuscripts. We also documented improvement in a number of academic behaviors after successful treatment of convergence insufficiency using a 6-item survey named the Academic Behavior Survey.^{76,77} In these manuscripts, we demonstrated that successful or improved outcome after CI treatment was associated with a reduction in the frequency of adverse academic behaviors and parental concern associated with reading and school work as reported by parent. Finally, we were able to demonstrate the effectiveness of office-based vision therapy to treat accommodative disorders in the 74% of subjects in CITT that also presented with accommodative dysfunction.⁷⁸

Encouraged by these results, we decided to revisit our original plan in 1994 – to submit a grant application to study the effectiveness of office-based vision therapy for symptomatic convergence insufficiency on reading and attention in children. This plan included the need to conduct pilot studies first. Between 2008 and 2012, we performed pilot studies [(CITT-Reading Study (RS))] to generate the data necessary to make sample size calculations for a randomized clinical trial and to determine the appropriate outcome measures for reading and attention.^{79, 80} In the main pilot study, parents of 44 children ages 9 to 17 years with symptomatic convergence insufficiency completed the Conners 3 ADHD Index (a 10-item scale designed to identify children who are at increased risk of ADHD) before and after office-based vision therapy. Following therapy, children showed a significant mean improvement ($P < .0001$, effect size of 0.58) on the Conners 3 ADHD Index with the largest changes occurring in the 23 children who had the highest baseline score.^{79, 81} In regard to the reading outcome, statistically significant improvements were found for reading comprehension ($P = 0.009$) as measured by the Wechsler Individual Achievement Test II at the 24-week outcome visit.⁸⁰ Thus, the pilot study results were encouraging, with statistically significant changes found in both attention and reading, although we did not have a control group in this study.

With these valuable pilot data in hand we submitted a grant application to the National Eye Institute entitled the CITT Attention and Reading Trial (CITT-ATT) in 2012. We were not funded the first time, but our resubmission was funded in 2014. The objectives of this placebo-controlled, randomized clinical trial were to determine the effect of office-based vergence/accommodative therapy on reading performance and on attention in 9 to 14-year-old children in grades 3 through 8 with symptomatic convergence insufficiency. Measures of

reading and attention were assessed at baseline and after 16 weeks of treatment.⁸² Recruitment for the study has ended and all subjects have completed their primary outcome visits; however, some subjects have not yet completed their 1-year follow-up examinations. Manuscripts are now in preparation and we estimate publication of the data in the fall of 2018.

During this same period of time (2012–2014), I served as co-protocol chair for a Pediatric Eye Disease Investigator Group study entitled the Convergence Insufficiency Treatment Study (CITS). This randomized trial was developed because proponents of home-based computer therapy for convergence insufficiency suggested that in the CITT study, the home-based therapy was not monitored as closely as necessary. In the CITS, participants were randomized into three home-based treatments groups - pencil push up therapy, computer-based therapy, or placebo therapy. The protocol was carefully designed to monitor adherence to the home-therapy protocols. The results are summarized in Table 1 and Figures 1A–1C. Unfortunately, the trial was stopped early because of insufficient recruitment (reaching only 34% of that originally planned). In addition to poor recruitment there were significant and differential retention problems. The majority of participants with symptomatic convergence insufficiency did not have a successful outcome at 12 weeks, and the two active therapies were no more effective than placebo therapy.⁸³ Although the estimates of success were not precise because of the insufficient recruitment and the differential loss to follow-up among groups, the best-case success scenario was still disappointingly low, again supporting the results of the CITT that home-based therapy is not as effective as office-based therapy.

Convergence Insufficiency: Current and Future Research

Although the CITT Investigator Group has demonstrated that vision therapy is an effective treatment option for convergence insufficiency in children and that office-based therapy is more effective than home-based therapy, many additional research questions related to convergence insufficiency remain. These questions include:

- Is vision therapy effective for other age groups such as young children (6 to 8 years old), or presbyopes?
- What are the underlying mechanisms that account for the improvement in clinical signs and symptoms?
- What physiological changes occur after successful vision therapy?
- Can we evaluate the effect of vision therapy on convergence insufficiency using objective measures?
- Using information about mechanisms and physiological changes, can we develop vision therapy protocols that led to better success rates?

My current research is designed to address some of these issues. In recent years, I have been fortunate to collaborate with Tara Alvarez, PhD, a biomedical engineer from the New Jersey Institute of Technology. Dr. Alvarez, an internationally recognized expert in vergence and eye movements, and has used convergence insufficiency as a model to study neural control of oculomotor movements, adaptation, learning, and plasticity of eye movements. In the past

5 years, Dr. Alvarez and I have demonstrated that an objective vergence eye movement assessment can serve as an outcome measure for clinical studies in children.^{84–86} Dr. Alvarez was the first researcher to use objective eye movement recordings and fMRI as outcome measures to assess the mechanism for change that occurs after vision therapy for convergence insufficiency in young adults.^{86,87} In more recent studies, we have shown the value of objectively assessing disparity vergence, as evidenced by the statistically significant changes in disparity vergence peak velocity and response amplitude found after successful office-based vision therapy in children with convergence insufficiency.^{84,85,88,89} Figure 2 illustrates an ensemble plot of multiple, convergence movements evoked from symmetrical 4-degree vergence stimuli in a subject with normal binocular vision. There is very little variance in the multiple responses and the response amplitude closely matches the 4-degree symmetrical binocular visual stimulus when compared with the convergence insufficiency data. In contrast, Figure 3A shows an ensemble plot of 4-degree vergence responses for a subject who exhibited substantial impairment of convergence, with the convergence responses reaching only ~2.5-degrees on average with considerable variance in the convergence responses (varying from less than 2-degrees to 4-degrees) including one response in which it appears the participant loses convergence altogether (i.e., loss of fusion) and then attempts to converge again. After therapy (Figure 3B), the convergence response amplitude is more accurate and the maximum response is achieved in less than 1 second. These objective measures provide additional information about vergence that is not accessible with clinical tests.

I am currently collaborating with Dr. Alvarez on her National Eye Institute-funded R01, entitled “Functional Mechanisms of Neural Control in Convergence Insufficiency.” In this randomized clinical trial, objective assessments of vergence and accommodation and fMRI’s are the outcome measures used to study the underlying mechanisms of changes in visual function after vision therapy for young adults with symptomatic convergence insufficiency. In this study 100 subjects (50 with convergence insufficiency and 50 with normal binocular vision) have been randomized to either office-based vision therapy or office-based placebo therapy. In addition to the traditional clinical measures, subjects undergo objective vergence and accommodation testing and an fMRI at baseline and again at outcome. We expect to publish these study results in the fall of 2018.

Concussion-Related Research

It is now recognized that vision problems are common after mTBI/concussion and serendipitously, convergence insufficiency appears to be the most common concussion-related vision disorder.^{90,91} With the assumption that concussion-related convergence insufficiency is physiologically different from naturally-occurring convergence insufficiency, it is important to determine the effectiveness of treatments of concussion-related convergence insufficiency. In 2017, we formed the Convergence Insufficiency and Concussion Investigator Group (CICON) with a goal of achieving NIH funding for a multicenter clinical trial. As Study Chair of the CICON investigator group, I am excited that optometrists are now working closely with pediatricians, sports concussion physicians, physical therapists, and neuropsychologists in a collaborative relationship to study post-concussion convergence insufficiency.

Our group has been able to complete a series of pilot studies to determine if it is feasible to use objective eye movement recordings as outcome measures,⁸⁴ to demonstrate the prevalence of concussion-related convergence insufficiency,⁹⁰ and to show preliminary retrospective data about the effectiveness of vision therapy for concussion-related convergence insufficiency.⁹²

We have already submitted our first NEI application for a randomized clinical trial and are currently performing a series of pilot studies to 1) determine the natural history of concussion-related convergence insufficiency, 2) investigate whether concussion-related convergence insufficiency is physiologically different from naturally occurring convergence insufficiency, and 3) validate of a symptom survey for concussion-related convergence insufficiency.

Looking Back

The year 1994 marked the origin of our CITT investigator group and we now had almost 25 years of collaboration, with more than 200 investigators from multiple professions (optometry, ophthalmology, pediatric medicine, physical rehabilitative medicine, neurology, biostatistics, education, psychology, physical therapy) having been a part of our studies. We have been funded by the National Eye Institute for three randomized clinical trials in an era in which such funding is difficult to secure for all researchers, let alone optometrists. An important accomplishment of our group is our contribution of high-quality evidence-based data into the vision therapy literature to help guide clinical decision making in regard to the treatment of convergence insufficiency. I am extremely proud that our CITT Investigator Group was highly effective and completed multiple clinical trials, always reaching recruitment goals in the allotted period of time, with very high participant retention rates (98% and greater), and very low missed-visit rates (3% or less).

Of the greatest significance to me, however, is that numerous optometric educators from various schools and colleges of optometry, have gained valuable experience participating in our randomized clinical trials. In addition, a template has now been established that can be used by other clinician scientists to study the effectiveness of vision therapy for other binocular vision, accommodative, and eye movement disorders. This template combined with the valuable experience of participating in these trials bodes well for the future of research related to vision therapy research. My hope is that some of these individuals will become future leaders as we begin to study other eye disorders that are treated with vision therapy. While the challenges of this type of research can be formidable (25 years to finally answer our original question), the rewards are satisfying and long-lasting.

ACKNOWLEDGMENTS

I want to acknowledge a number of colleagues with whom I have worked during my career as an optometric educator and vision researcher. Without the help of these individuals I could not have been successful. My very first taste of vision research was with Jane Gwiazda at MITT in her infant vision research laboratory in 1977. She was a wonderful role model for me in the late 1970s and again when I participated in the COMET study. I had the opportunity to observe Jane function as a Study Chair for 15 years. During that time I also was fortunate to work with Leslie Hyman, an ocular epidemiologist with vast clinical trial experience. Working with Jane and Leslie was equivalent to having completed a residency in the conduct of clinical trials. While I have had the pleasure of working with many outstanding principal investigators at the CITT clinical sites, 3 exceptional members of the

CITT Investigator Group have been critical to the success of our research. I want to thank Susan Cotter and Marjean Kulp who served as Vice-Chairs for the CITT studies, and Gladys Lynn Mitchell, the principal investigator for the CITT Data Coordinating Center, for their enthusiasm, clinical trial expertise, hard work, and dedication to achieve our objectives. Eric Borsting played a major role in many of the key pilot studies and development of the CISS. And thank you to my early role models who were responsible for teaching me the wonders of binocular vision and vision therapy; Nathan Flax, Irwin Suchoff, Martin Birnbaum, Arnold Sherman, Jack Richman, and Jerome Rosner. As a resident at SUNY in 1976, I had the privilege of being a student of Jeffrey Cooper who was a young faculty member at the time. He was the epitome of a clinical vision scientist and became my primary role model. And I want to thank my friend and colleague Michael Gallaway. We have shared a love of vision therapy and binocular vision and I have had the pleasure of working side-by-side with Michael for over 30 years, planning and implementing many clinical research studies. Finally, to my colleague and good friend, the late Michael Rouse, who lead the CITT investigator group and planned and implemented so many of the early studies that were essential for the success that we achieved over the years – we miss you and your fervor for clinical research.

Supported by the National Eye Institute of the National Institutes of Health, Department of Health and Human Services, Bethesda, Maryland: U10EY022599; U10EY014713.

REFERENCES

1. Eddy D History of Medicine. The Origins of Evidence-Based Medicine – a Personal Perspective. Virtual Mentor 2011;13:55–60.23134763
2. Evidence-Based Medicine Working Group. Evidence-Based Medicine. A New Approach to Teaching the Practice of Medicine. JAMA 1992;268:2420–5.1404801
3. American Academy of Optometry AOA. Vision, Learning and Dyslexia: A Joint Organizational Policy Statement. J Am Optom Assoc 1997;68:284–6.9170793
4. American Academy of Pediatrics Committee on Children with Learning Disabilities, American Association for Pediatric Ophthalmology and Strabismus, and American Academy of Ophthalmology. Learning Disabilities, Dyslexia, and Vision. Pediatrics 1992;90:124–6.1614764
5. Beauchamp GR . Optometric Vision Training. Pediatrics 1986;77:121–4.3940351
6. Beauchamp GR , Kosmorsky G . Learning Disabilities: Update Comment on the Visual System. Pediatr Clin North Am 1987;34:1439–46.3317239
7. Helveston EM , Weber JC , Miller K , et al. Visual Function and Academic Performance. Am J Ophthalmol 1985;99:346–55.3976812
8. Keogh BK , Pelland M . Vision Training Revisited. J Learn Disabil 1985;18:228–36.3886820
9. Shaywitz SE . Dyslexia. N Engl J Med 1998;338:307–12.9445412
10. Gwiazda J , Hyman L , Hussein M , et al. A Randomized Clinical Trial of Progressive Addition Lenses Versus Single Vision Lenses on the Progression of Myopia in Children. Invest Ophthalmol Vis Sci 2003;44:1492–500.12657584
11. Pediatric Eye Disease Investigator G. Home-Based Therapy for Symptomatic Convergence Insufficiency in Children: A Randomized Clinical Trial. Optom Vis Sci 2016;93:1457–65.27575992
12. Scheiman MM , Hertle RW , Beck RW , et al. Randomized Trial of Treatment of Amblyopia in Children Aged 7 to 17 Years. Arch Ophthalmol 2005;123:437–47.15824215
13. Pediatric Eye Disease Investigator Group. A Prospective, Pilot Study of Treatment of Amblyopia in Children 10 to <18 Years Old. Am J Ophthalmol 2004;137:581–3.15013894
14. Javal E [Theoretical Handbook of Strabismus.] Paris: G. Masson; 1896.
15. Press LJ . Applied Concepts in Vision Therapy. St. Louis: Mosby-Year Book; 1997.
16. Hoffman L , Cohen A , Feuer G . Effectiveness of Non-Strabismic Optometric Vision Training in a Private Practice. Am J Optom Arch Am Acad Optom 1973;50:813–16.4520500
17. Wick B Binocular Vision Therapy for General Practice. J Am Optom Assoc 1977;48:461–66.874271
18. Weisz CL . Clinical Therapy for Accommodative Responses: Transfer Effects Upon Performance. J Am Optom Assoc 1979;50:209–16.379112
19. Daum KM . The Course and Effect of Visual Training on the Vergence System. Am J Optom Physiol Opt 1982;59:223–7.7072825

20. Daum KM . A Comparison of the Results of Tonic and Phasic Vergence Training. *Am J Optom Physiol Opt* 1983;60:769–75.6681470
21. Daum KM . Divergence Excess: Characteristics and Results of Treatment with Orthoptics. *Ophthalmic Physiol Opt* 1984;4:15–24.
22. Daum KM . Equal Exodeviations: Characteristics and Results of Treatment with Orthoptics. *Aust J Optom* 1984;67:53–9.
23. Daum KM . Modelling the Results of the Orthoptic Treatment of Divergence Excess. *Ophthalmic Physiol Opt* 1984;4:25–9.6709366
24. Daum KM . Convergence Insufficiency. *Am J Optom Physiol Opt* 1984;61:16–22.6702996
25. Daum KM . Classification Criterion for Success in the Treatment of Convergence Insufficiency. *Am J Optom Physiol Opt* 1984;61:10–5.6702995
26. Daum K Double-Blind Placebo-Controlled Examination of Timing Effects in the Training of Positive Vergences. *Am J Optom Physiol Opt* 1986;63:807–12.3777111
27. Daum KM . Negative Vergence Training in Humans. *Am J Optom Physiol Opt* 1986;63:487–96.3740204
28. Daum KM . Characteristics of Exodeviations: II. Changes with Treatment with Orthoptics. *Am J Optom Physiol Opt* 1986;63:244–51.3706478
29. Daum KM , Rutstein RP , Eskridge JB . Efficacy of Computerized Vergence Therapy. *Am J Optom Physiol Opt* 1987;64:83–9.3826293
30. Daum KM . Accommodative Dysfunction. *Doc Ophthalmol* 1983;55:177–98.6884172
31. Daum KM . Accommodative Insufficiency. *Am J Optom Physiol Opt* 1983;60:352–9.6881261
32. Daum KM . Predicting Results in the Orthoptic Treatment of Accommodative Dysfunction. *Am J Optom Physiol Opt* 1984;61:184–9.6720864
33. Cooper J , Selenow A , Ciuffreda KJ . Reduction of Asthenopia in Patients with Convergence Insufficiency after Fusional Vergence Training. *Am J Optom Physiol Opt* 1983;60:982–89.6660282
34. Cooper J , Feldman J , Selenow A , et al. Reduction of Asthenopia after Accommodative Facility Training. *Am J Optom Physiol Opt* 1987;64:430–36.3631199
35. Liu JS , Lee M , Jang J , et al. Objective Assessment of Accommodative Orthoptics: 1 Dynamic Insufficiency. *Am J Optom Physiol Opt* 1979;56:285–94.495685
36. Bobier WR , Sivak JG . Orthoptic Treatment of Subjects Showing Slow Accommodative Responses. *Am J Optom Physiol Opt* 1983;60:678–87.6624867
37. Grisham D The Dynamics of Fusional Vergence Eye Movements in Binocular Dysfunction. *Am J Optom Physiol Opt* 1980;57:645–55.7425088
38. Grisham JD , et al. Vergence Orthoptics: Validity and Persistence of the Training Effect. *Optom Vis Sci* 1991;68:441–51.1891195
39. Birnbaum MH , Soden R , Cohen AH . Efficacy of Vision Therapy for Convergence Insufficiency in an Adult Male Population. *J Am Optom Assoc* 1999;70:225–32.10457698
40. Cornsweet TN , Crane HD . Training the Visual Accommodation System. *Vision Res* 1973;13:713–5.4693413
41. Provine RR , Enoch JM . On Voluntary Ocular Accommodation. *Percept Psychophys* 1975;17:209–12.
42. Wick B Vision Therapy for Presbyopic Nonstrabismic Patients. *Am J Optom Physiol Opt* 1977;54:244–47.910873
43. Wold RM PJ , Keddington J . Effectiveness of Optometric Vision Therapy. *J Am Optom Assoc* 1978;49:1047–53.701721
44. Cohen AH , Soden R . Effectiveness of Visual Therapy for Convergence Insufficiencies for an Adult Population. *J Am Optom Assoc* 1984;55:491–94.6747179
45. Shorter AD , Hatch SW . Vision Therapy for Convergence Excess. *N Eng J Optom* 1993;45:51–3.
46. Ficcara AP , Berman J , Rosenfield M , et al. Vision Therapy: Predictive Factors for Success in Visual Therapy for Patients with Convergence Excess. *J Optom Vis Dev* 1996;27:213–9.

47. Gallaway M , Scheiman M . The Efficacy of Vision Therapy for Convergence Excess. *J Am Optom Assoc* 1997;68:81–6.9120214
48. Adler P Efficacy of Treatment for Convergence Insufficiency Using Vision Therapy. *Ophthalmic Physiol Opt* 2002;22:565–71.
49. Abdi S , Rydberg A . Asthenopia in Schoolchildren, Orthoptic and Ophthalmological Findings and Treatment. *Doc Ophthalmol* 2005;111:65–72.16514487
50. Aziz S , Cleary M , Stewart HK , Weir CR . Are Orthoptic Exercises an Effective Treatment for Convergence and Fusion Deficiencies? *Strabismus* 2006;14:183–9.17162439
51. Vaegan JL . Convergence and Divergence Show Longer and Sustained Improvement after Short Isometric Exercise. *Am J Optom Physiol Opt* 1979;56:23–33.484701
52. Borsting EJ , Rouse MW , Mitchell GL , et al. Validity and Reliability of the Revised Convergence Insufficiency Symptom Survey in Children Aged 9–18 Years. *Optom Vis Sci* 2003;80:832–8.14688547
53. Borsting E , Rouse MW , De Land PN . Prospective Comparison of Convergence Insufficiency and Normal Binocular Children on CIRS Symptom Surveys. Convergence Insufficiency and Reading Study (CIRS) Group. *Optom Vis Sci* 1999;76(4):221–8.10333184
54. Rouse MW , Hyman L , Hussein M , et al. Frequency of Convergence Insufficiency in Optometry Clinic Settings. *Optom Vis Sci* 1998;75:88–96.9503434
55. Rouse MW , Borsting E , Hyman L , et al. Frequency of Convergence Insufficiency among Fifth and Sixth Graders. *Optom Vis Sci* 1999;76:643–49.10498006
56. Rouse MW , Hyman L , Hussein M . Reliability of Binocular Vision Measurements Used in the Classification of Convergence Insufficiency. *Optom Vis Sci* 2002;79:254–64.11999151
57. Rouse MW , Borsting E , Hyman L , et al. Convergence Insufficiency and Reading Ability among 5th and 6th Graders. *Invest Ophthalmol Vis Sci* 1997;38:S975.
58. Scheiman M , Cooper J , Mitchell GL , et al. A Survey of Treatment Modalities for Convergence Insufficiency. *Optom Vis Sci* 2002;79:151–57.11913841
59. Rouse MW , Hyman L , CIRS Study Group. How Do You Make the Diagnosis of Convergence Insufficiency? Survey Results. *J Optom Vis Devel* 1997;28:91–7.
60. Hussaindeen JR , Rakshit A , Singh NK , et al. Prevalence of Non-Strabismic Anomalies of Binocular Vision in Tamil Nadu: Report 2 of Band Study. *Clin Exp Optom* 2016.
61. Davis AL , Harvey EM , Twelker JD , et al. Convergence Insufficiency, Accommodative Insufficiency, Visual Symptoms, and Astigmatism in Tohono O’odham Students. *J Ophthalmol* 2016;2016:6963976.27525112
62. Wajuihian SO , Hansraj R . Vergence Anomalies in a Sample of High School Students in South Africa. *J Optom* 2016;9:246–57.26750804
63. Daum KM . Convergence Insufficiency. *Am J Optom Physiol Opt* 1984;61:16–22.6702996
64. Cooper J , Duckman R . Convergence Insufficiency: Incidence, Diagnosis, and Treatment. *J Am Optom Assoc* 1978;49:673–80.355298
65. Borsting E , Rouse MW , Deland PN , et al. Association of Symptoms and Convergence and Accommodative Insufficiency in School-Age Children. *Optometry* 2003;74:25–34.12539890
66. Scheiman M , Mitchell GL , Cotter S , et al. A Randomized Trial of the Effectiveness of Treatments for Convergence Insufficiency in Children. *Arch Ophthalmol* 2005;123:14–24.15642806
67. Scheiman M , Mitchell GL , Cotter S , et al. A Randomized Clinical Trial of Vision Therapy/Orthoptics Versus Pencil Pushups for the Treatment of Convergence Insufficiency in Young Adults. *Optom Vis Sci* 2005;82:583–95.16044063
68. Kulp M , Borsting E , Mitchell GL , et al. Feasibility of Using a Placebo Vision Therapy/Orthoptics Control in a Multicenter Clinical Trial. *Optom Vis Sci* 2008;85:255–61.18382340
69. Scheiman M , Cotter S , Rouse M , et al. Randomised Clinical Trial of the Effectiveness of Base-in Prism Reading Glasses vs. Placebo Reading Glasses for Symptomatic Convergence Insufficiency in Children. *Br J Ophthalmol* 2005;89:1318–23.16170124

70. Convergence Insufficiency Treatment Trial Investigator Group. A Randomized Clinical Trial of Treatments for Symptomatic Convergence Insufficiency in Children. *Arch Ophthalmol* 2008;126:1336–49.18852411
71. Scheiman M , Rouse M , Kulp MT , et al. Treatment of Convergence Insufficiency in Childhood: A Current Perspective. *Optom Vis Sci* 2009;86:420–8.19319008
72. Convergence Insufficiency Treatment Trial Study Group. Long-Term Effectiveness of Treatments for Symptomatic Convergence Insufficiency in Children. *Optom Vis Sci* 2009;86:1096–103.19668097
73. Scheiman M , Gwiazda J , Li T . Non-Surgical Interventions for Convergence Insufficiency. *Cochrane Database Syst Rev* 2011:CD006768.21412896
74. Barnhardt C , Cotter SA , Mitchell GL , et al. Symptoms in Children with Convergence Insufficiency: Before and after Treatment. *Optom Vis Sci* 2012;89:1512–20.22922781
75. Bade A , Boas M , Gallaway M , et al. Relationship between Clinical Signs and Symptoms of Convergence Insufficiency. *Optom Vis Sci* 2013;90:988–95.23958713
76. Borsting E , Mitchell GL , Kulp MT , et al. Improvement in Academic Behaviors after Successful Treatment of Convergence Insufficiency. *Optom Vis Sci* 2012;89:12–8.22080400
77. Rouse M , Borsting E , Mitchell GL , et al. Academic Behaviors in Children with Convergence Insufficiency with and without Parent-Reported ADHD. *Optom Vis Sci* 2009;86:1169–77.19741558
78. Scheiman M , Cotter S , Kulp MT , et al. Treatment of Accommodative Dysfunction in Children: Results from a Randomized Clinical Trial. *Optom Vis Sci* 2011;88:1343–52.21873922
79. Borsting E , Mitchell GL , Arnold LE , et al. Behavioral and Emotional Problems Associated with Convergence Insufficiency in Children: An Open Trial. *J Atten Disord* 2016;20:836–44.24271946
80. Scheiman M , Chase C , Borsting E , et al. Effect of Treatment of Symptomatic Convergence Insufficiency on Reading in Children: A Pilot Study. *Clin Exp Optom* 2018;3 25:e-pub ahead of print: doi 10.1111/cxo.12682.
81. Scheiman M , Chase C , Mitchell GL , et al. The Effect of Successful Treatment of Symptomatic Convergence Insufficiency on Reading Achievement in School-Aged Children. In: ARVO 2011. [move to text as: “Scheiman et al. IOVS 2011;52:E-Abstract 6370.”]
82. CITT-ART Investigator Group. Convergence Insufficiency Treatment Trial - Attention and Reading Trial (CITT-ART): Design and Methods. *Vis Dev Rehabil* 2015;1:214–28.26942226
83. Scheiman MM , Hoover DL , Lazar EL , et al. Home-Based Therapy for Symptomatic Convergence Insufficiency in Children: A Randomized Clinical Trial. *Optom Vis Sci* 2015;92. [move to text as: “Scheiman et al. OVS 2015;92:E-Abstract 150015.”]
84. Scheiman MM , Talasan H , Mitchell GL , Alvarez TL . Objective Assessment of Vergence after Treatment of Concussion-Related CI: A Pilot Study. *Optom Vis Sci* 2017;94:74–88.27464574
85. Talasan H , Scheiman M , Li X , Alvarez TL . Disparity Vergence Responses before Versus after Repetitive Vergence Therapy in Binocularly Normal Controls. *J Vis* 2016;16:7.
86. Alvarez TL , Vicci VR , Alkan Y , et al. Vision Therapy in Adults with Convergence Insufficiency: Clinical and Functional Magnetic Resonance Imaging Measures. *Optom Vis Sci* 2010;87:985–1002.
87. Alvarez TL , Jaswal R , Gohel S , Biswal BB . Functional Activity within the Frontal Eye Fields, Posterior Parietal Cortex, and Cerebellar Vermis Significantly Correlates to Symmetrical Vergence Peak Velocity: An Roi-Based, FMRI Study of Vergence Training. *Front Integr Neurosci* 2014;8:50.24987340
88. Scheiman M , Ciuffreda KJ , Thiagarajan P , et al. Objective Assessment of Vergence and Accommodation after Vision Therapy for Convergence Insufficiency in a Child: A Case Report. *Optom Vis Perf* 2014;2:7–12.
89. Scheiman M , Talasan H , Alvaez TL . Effectiveness of VT for CI in Children: Use of Objective Outcome Measures. American Academy of Optometry Annual Meeting 2016. [move to text as: “Scheiman et al. OVS 2016;93:E-Abstract 165013.”]
90. Master CL , Scheiman M , Gallaway M , et al. Vision Diagnoses Are Common after Concussion in Adolescents. *Clin Pediatr (Phila)* 2016;55:260–7.26156977

91. Brahm KD , Wilgenburg HM , Kirby J , et al. Visual Impairment and Dysfunction in Combat-Injured Servicemembers with Traumatic Brain Injury. *Optom Vis Sci* 2009;86:817–25.19521270
92. Gallaway M , Scheiman M , Mitchell GL . Vision Therapy for Post-Concussion Vision Disorders. *Optom Vis Sci* 2017;94:68–73.27505624
93. Rouse M , Borsting E , Mitchell GL , et al. Validity of the Convergence Insufficiency Symptom Survey: A Confirmatory Study. *Optom Vis Sci* 2009;86:357–63.19289977

Figure 1.

(A) Comparison of final NPC values for office-based vision therapy vs placebo, home-based pencil push-ups vs placebo, home-based computer vergence therapy vs placebo from recent randomized clinical trials. Any value below the black horizontal line is a normal value. (B) Comparison of final PFV values for office-based vision therapy vs placebo, home-based pencil push-ups vs placebo, home-based computer vergence therapy vs placebo from recent randomized clinical trials. (C) Comparison of final CISS values for office-based vision therapy vs placebo, home-based pencil push-ups vs placebo, home-based computer vergence

therapy vs placebo from recent randomized clinical trials. Any value below the black horizontal line is a normal value.

Author Manuscript

Author Manuscript

Author Manuscript

Author Manuscript

Figure 2.

Each colored trace is an individual convergence eye movement response to a 4° symmetrical binocular disparity vergence step stimulus from a non-symptomatic binocularly normal control participant.

Figure 3.

(A-B) Each gray line is an individual eye movement response from a 4° symmetrical binocular disparity vergence step stimulus. The blue traces show the average position before office-based vision therapy for a subject, and (B) shows the same data after office-based vision therapy for the subject.

Table 1

Summary of CITT Randomized Trials for Children/Adults with Symptomatic Convergence Insufficiency.

N	Treatment Groups	Key Results
Treatments for Symptomatic Convergence Insufficiency in Children Ages 9–17 Years: Pilot Study⁶⁶		
47	1. Home-based pencil push-ups 2. Office-based vergence/accommodative therapy 3. Office-based placebo therapy	<ul style="list-style-type: none"> • Office-based vergence/accommodative therapy was more effective than home-based pencil push-ups and office-based placebo therapy in reducing symptoms & improving clinical signs associated with symptomatic convergence insufficiency • Neither home-based pencil push-ups nor office-based placebo therapy was effective in improving symptoms or signs
Treatments for Symptomatic Convergence Insufficiency in Children Ages 9–17 Years (CITT)⁷⁰		
221	1. Home-based pencil push-ups 2. Home-based computer vergence /accommodative therapy and pencil pushups 3. Office-based vergence/accommodative therapy 4. Office-based placebo therapy	Office-based vergence/accommodative therapy results in significantly greater improvement in symptoms and clinical measures (NPC & PFV), and greater percentage of participants reaching predetermined criteria of success compared with home-based pencil push-ups, home-based computer vision therapy & pencil pushups, or office-based placebo therapy
Treatments for Convergence Insufficiency in Young Adults 18–30 Years: Pilot Study⁶⁷		
46	1. Home-based pencil push-ups 2. Office-based vergence/accommodative therapy 3. Office-based placebo therapy	<ul style="list-style-type: none"> • Only subjects in the office-based vergence/accommodative therapy group demonstrated statistically and clinically significant changes in the near point of convergence
Effectiveness of Home-Based Therapy for Symptomatic convergence insufficiency in Children Ages 9–17 Years (CITS)¹¹		
204	1. Home-based pencil push-ups 2. Home-based computer vergence/accommodative therapy 3. Home-based-Based placebo therapy	<ul style="list-style-type: none"> • The majority of participants with symptomatic CI did not have a successful outcome at 12 weeks. There was no difference between either of the home-based therapies and home-based placebo therapy
Effectiveness of Base-in Prism Reading Glasses vs. Placebo Reading Glasses for Symptomatic Convergence Insufficiency in Children Ages 9–17 Years ⁶⁹		
72	1. Base-in prism reading glasses 2. Placebo reading glasses	<ul style="list-style-type: none"> • Base-in prism reading glasses no more effective in alleviating symptoms or improving clinical signs than placebo reading glasses

Symptomatic convergence insufficiency defined as: 1) exodeviation at near at least 4 prism diopters (p) greater than far, 2) receded near point of convergence (NPC) break ≥ 6 cm, 3) insufficient positive fusional vergence at near (PFV) (i.e., failing Sheard's criterion or minimum PFV of ≥ 15 p base-out blur or break), and 4) convergence insufficiency Symptom Score (CISS)^{52, 93} score ≥ 16 .