Article ▸ Objective Assessment of Vergence and Accommodation After Vision Therapy for Convergence Insufficiency in a Child: A Case Report

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ABSTRACT

Background: To evaluate objective changes in vergence and accommodation after treatment of symptomatic convergence insufficiency (CI) with office-based optometric vision therapy in a pediatric patient.

Case Report: A 10-year, 10-month-old child with symptomatic CI was treated with 16 visits of office-based vision therapy with home reinforcement. Pre- and post-therapy testing included both traditional clinical measures and objective laboratory measures of vergence and accommodation. The main clinical outcome measures were the CI Symptom Survey (CISS), near point of convergence (NPC), positive fusional vergence range at near (PFV), accommodative amplitude, and accommodative facility. The objective vergence range outcome measures were peak velocity, time constant, total response time, and steady-state response variability as assessed with the Power Refractor II. The objective accommodative outcome measures were peak velocity, time constant, total response time, steady-state response variability, and steady-state level, as assessed with the Grand Seiko WAM-5500. Most accommodative and vergence objective laboratory parameters improved/normalized following the vision therapy. Gains were greater for vergence than for accommodation. These objective measures confirmed the concurrent improvements in the clinical tests and markedly reduced symptom levels.

Conclusions: This is the first study to document, objectively, improvements in laboratory-based dynamic measures of both accommodation and vergence following conventional office-based optometric vision therapy for CI in a child. Objective oculomotor measures can and should be performed in similar future studies in children, as well as in adults.

Keywords: accommodation, CISS, computer vergence/accommodative therapy, convergence insufficiency, objective assessment, orthoptics, symptom survey, vergence, vergence/accommodative therapy, vision therapy

Introduction

Convergence insufficiency (CI), a common condition in school children, often results in visual symptoms including headaches, eyestrain, blurred vision, loss of place while reading, and diplopia during near visual activities. Consequently, their presence may interfere with reading performance.[1-5] Two recently completed randomized clinical trials have demonstrated that office-based vergence/accommodative vision therapy combined with home reinforcement is an effective treatment for symptomatic CI in children 9 to 17 years of age.[6, 7] These studies used traditional optometric clinical measures of vergence and accommodation, along with a validated symptom questionnaire score, as outcome measures. However, both the symptom questionnaire and clinical measures are subjective measurements that depend on the child's ability to report accurately what he/she is experiencing and seeing, and hence may be prone to bias. Although a randomized clinical trial design can help control for this confounder, it would be useful to incorporate correlated *objective* measures of changes in oculomotor function, in addition to the traditional clinical measures used in clinical trials.

There is a paucity of studies related to the present investigation in which children have received some form of oculomotor training for vergence dysfunction, including convergence insufficiency.[8,9] In the Bucci et al[9] investigation, a formal vergence orthoptic program of 12 sessions was conducted in four children (ages 8-16 years), each with a clinical diagnosis of CI. In addition to marked improvement in clinical signs and reduction of symptoms after therapy, the objective measures of vergence revealed somewhat faster responses: peak velocity increased and duration decreased. In the Jainta et al study,[8] 8 children (ages 9-16 years) with clinical vergence deficits performed a simple oculomotor task: they executed 80 convergence and 80 divergence responses to midline targets at distances of 25, 68, and 153 cm, all performed in in a single session. Immediately following

the task, there were small but significant improvements in vergence dynamics: duration decreased and velocity increased for both convergence and divergence. Latency was normal and remained constant in all cases. However, accommodative dynamics were not assessed in either study.

We are not aware of any previous reports on the effectiveness of vision therapy for children with symptomatic CI on objective measures of both vergence and accommodation in the pediatric population. Herein, we present a case report of a 10-year-old child with symptomatic CI who completed a 16-week program of office-based vision therapy with home reinforcement. We report our ability to achieve accurate objective measurements in a child, as well as find correlated changes in symptoms, clinical measures, and objective measures of both vergence and accommodation, thus demonstrating positive remediation effects over an array of domains.

Methods

The tenets of the Declaration of Helsinki were followed throughout the study. The institutional review board of the State University of New York, College of Optometry approved the protocol and informed consent form. The parent of the study patient gave written informed consent, and the patient gave assent to participation. Health Insurance Portability and Accountability Act (HIPAA) authorization was obtained from the parent.

Eligibility Criteria

To be eligible for the study, it was required that the child be between nine and 17 years of age, have an exodeviation at near at least 4Δ greater than at far, a receded near point of convergence (NPC) break point (6 cm or greater), a reduced positive fusional vergence range at near (PFV; convergence amplitude) (i.e., failing Sheard's criterion [PFV less than twice the near phoria][10] or minimum PFV of ≤15Δ base-out blur or break), and a CI Symptom Survey (CISS, described in Outcome Measures section later) score of ≥16.

Examination Procedures

Eligibility testing included administration of the CISS to identify whether or not the child was symptomatic.[11-13] Other eligibility tests included: best-corrected visual acuity at distance and near, a sensorimotor examination (cover test at distance and near, NPC, positive and negative fusional vergence at near, near stereoacuity, monocular accommodative amplitude, monocular accommodative facility), cycloplegic refraction, and an ocular health evaluation.

Pre-Treatment Clinical Findings

KL, a 10-year, 10-month-old child, was identified as a potential subject for this study by the clinical faculty at the State University of New York, College of Optometry. She presented with a history of significant visual symptoms associated with reading and other near-related visual activities. A comprehensive vision examination revealed 20/20 visual acuity in each eye, low hyperopia (OD: +0.50D, OS: +0.50D), and normal eye health. There was no significant medical history of illness or trauma, and KL was not taking any medications. A diagnosis of convergence insufficiency was reached after this first examination based on a higher degree of exophoria at near than at distance, reduced positive fusional vergence range, and a receded near point of convergence.[7] After consent/assent were obtained, the pre-treatment study measures were assessed and are presented in Table 1. These data substantiate the presence of symptomatic CI in this child. There was no previous history of treatment for CI.

Table 1: Pre-treatment subjective clinical measures compared to post-treatment measures

Test	Pre-Treatment	Post-Treatment
Convergence Insufficiency Symptom Survey Score (CISS)	33	7
Cover test (distance)	ortho	ortho
Cover test (near)	8 pd exophoria	6 pd exophoria
Near point of convergence (break) (average of 3 measures)	13.3 cm	3.5 cm
Near point of convergence (recovery) (average of 3 measures)	15.3 cm	5.3 cm
Negative fusional vergence (near)	X/10/6 (pd)	12/16/12 (pd)
Positive fusional vergence (near) (average of 3 measures)	6/11/6 (pd)	X/40/35 (pd)
Monocular amplitude of accommodation (OD only)	10D	14D
Monocular accommodative facility (OD only)	12.5 cpm	12 cpm

Subjective Clinical Outcome Measures

The symptom score as measured by the CISS was used to assess the change in symptoms after treatment.[13] The questionnaire consisted of 15 items that were read aloud by the examiner to the child, while the child viewed a card with the possible answers and was instructed to choose one of five possible answers (never, infrequently, sometimes, fairly often, always). Each response was scored as 0 to 4 points, with 4 representing the highest frequency of symptom occurrence (i.e., always). The 15 items were summed to obtain the total CISS score. The lowest possible total score (fewest symptoms) was 0, and the highest was 60 (most symptoms). A CISS score of less than 16 is considered asymptomatic, and a decrease of at least 10 or more points is considered improved.[11,13]

Table 2: Office-based vergence/accommodative therapy protocol

Phase One

Gross Convergence, Positive Fusional Vergence, and Monocular Accommodative Therapy Techniques		
Gross Convergence	*Positive Fusional Vergence*	*Monocular Accommodative Amplitude*
Brock String Barrel Card	Vectograms (Clown) Computer Orthoptics (RDS) Life Saver Cards	Loose Lens Accommodative Rock Letter Chart Accommodative Rock
Home Vision Therapy		
Brock String Loose Lens Accommodative Rock HTS	Barrel Card Life Saver Cards	

Phase Two

Ramp Fusional Vergence and Monocular Accommodative Therapy Techniques	
Ramp Fusional Vergence	*Monocular Accommodative Facility*
Vectograms (Clown) Computer Orthoptics (RDS) Aperture Rule Eccentric Circles	Loose Lens Accommodative Rock Letter Chart Accommodative Rock
Home Vision Therapy	
Random Dot Card Eccentric Circles HTS (base out, base in, and autoslide vergence)	Loose Lens Accommodative Therapy Letter Chart Accommodative Therapy

Phase Three

Jump Fusional Vergence and Binocular Accommodative Facility Techniques	
Jump Fusional Vergence	*Binocular Accommodative Facility*
Vectograms (Clown) Computer Orthoptics (RDS) Aperture Rule Eccentric Circles Loose Prism Facility	Binocular Accommodative Facility
Home Vision Therapy	
Eccentric Circles Binocular Accommodative Facility HTS (base out, base in, and jump vergence)	Loose Prism Jumps Random Dot Card

The NPC and PFV were used as the subjective clinical outcome measures. A normal NPC was defined as less than 6 cm, and an improved NPC was defined as a reduction (i.e., decrease) in NPC of more than 4 cm from baseline to the 12-week outcome examination.[7] To be classified as having normal PFV, the child had to pass Sheard's criteria[10] (i.e., PFV blur, or if no blur, then break value at least twice the near phoria magnitude) and have a PFV blur/break of more than 15Δ.

Objective Outcome Measures of Vergence and Accommodation

Accommodative step responses were obtained objectively in the right eye under both monocular and binocular viewing conditions using the WAM-5500 infrared, open-field autorefractor (Grand Seiko; Hiroshima, Japan). It was used in the continuous data mode obtaining approximately 5 samples per second. This sampling rate was sufficient to satisfy the engineering-based Nyquist criterion.[14] The spherical dioptric range is -22D to +22D, with a manufacturer reported resolution of 0.01D. Up to 10D of cylindrical refractive error can be measured with a manufacturer reported resolution of 1 degree. This refractor and accompanying test stimuli have been used in a recent laboratory study[15] and have FDA clinical approval. The subject viewed a line of high-contrast (~80%) 20/30 Snellen letters having a luminance of 36 cd/m^2 positioned at 50 cm (2D) on a white background and a high-contrast (~80%) 20/60 word with a luminance of 36 cd/m^2 at 25 cm (4D) on a transparent background. The subject was instructed to respond as rapidly as possible to the new target and maintain it in focus. Accommodative outcome measures obtained with this device included peak velocity (i.e., maximum response velocity), time constant (i.e., time for the exponential response to reach 63% of the final amplitude), total response time (i.e., from the response onset to its completion), steady-state response variability, and mean steady-state level. Three measurements of increasing and decreasing accommodation were obtained and averaged at each test session.

Dynamic horizontal vergence eye movements were obtained objectively using the Plusoptix Power Refractor (PRII) (Plusoptix; Nuremberg, Germany) based on the principle of infrared videography and dynamic retinoscopy. It concurrently measures horizontal and vertical eye position, refractive state, and pupil diameter, all in each eye. In the present experiment, binocular horizontal position of the eyes was recorded objectively and continuously using the PRII with a sampling rate of 12.5Hz, an effective resolution of ≤ 0.9 degree, and a horizontal linear range of at least ± 20 degrees, which was well within the tested range. This sampling rate was sufficient to satisfy the engineering-based Nyquist criterion.[14] Targets comprised the contiguous red and green fixation LEDs (angular size: 0.28 degrees) located on the measuring head of the PRII at 1m and a white LED (angular size: 0.86 degrees) placed at 0.3m, with both being aligned along the midline. The stimulus amplitude was 6.5 degrees for both symmetric

convergence and divergence. Since the target LEDs were not in the field-of-view of the PRII camera, a second small LED was placed at 0.3m. It was directed towards, and visible to, the video recorder of the PRII system to depict and record the time of target change on the frame of the video image to obtain a measure of response latency. This device and these test stimuli have been used in several laboratory studies[16] and have FDA clinical approval. The subject was instructed to respond as rapidly as possible to the new target and to maintain clarity and single vision. Vergence outcome measures obtained included peak velocity, time constant, total response time, and steady-state response variability. Three measurements of convergence and divergence were obtained and averaged at each session.

Treatment

Office-Based Vision Therapy with Home Reinforcement

The child received a weekly 60-minute, in-office vision therapy visit with additional prescribed procedures to be performed at home for 15 minutes per day, five days per week. The vision therapy procedures are described in detail elsewhere.[17] Those performed during the weekly office-based vergence/accommodative therapy sessions are listed in Table 2. At each office-based therapy session, the patient performed 4-5 procedures with constant supervision and guidance from the therapist. The therapist was a 4th year SUNY intern working under the direct supervision of one of the authors (BT). There were no diagnostic tests performed during these sessions. The therapist followed a detailed and specific protocol from the CITT Manual of Procedures (accessed at http://bit.ly/CITT_MOP). This document describes each procedure, amount of time used, expected performance, and criteria for ending the procedure and advancing to a more difficult level. The patient passed through each of the three phases as the respective criteria were attained, usually in about 5-6 weeks per phase.

Results

Clinical Measures

KL attended fourteen 60-minute sessions of office-based vision therapy from August 2011 to November 2011. The results of her outcome examination in December 2011 are compared to her pre-treatment values in Table 1. KL attained our criteria for successful treatment with a large and significant 26-point reduction in her CISS score, along with considerable improvement in both her positive fusional vergence range at near and the near point of convergence.

Objective Measures

With regard to dynamic changes in vergence following the vision therapy, nearly all parameters either considerably improved or normalized (Table 3). For convergence, total response time decreased nearly 300%, steady-state variability at near decreased by approximately 20%, peak velocity increased by nearly 50%, and the time constant decreased by nearly 300%. For divergence, total response time decreased by approximately 40%, steady-state response variability at distance remained about the same, peak velocity increased by over 100%, and the time constant decreased approximately 250%. Figure 1 presents objective recordings of pre-/post-vision therapy responses of convergence and divergence.

Table 3: Pre-/Post- Objective Measures of Vergence

Convergence		
	Pre-training	**Post-training**
Total response time (secs)	1.12	0.4
SS response var @ near (degrees)	1.02	0.89
Peak velocity (degrees/sec)	26	38
Time constant (millisecs)	509	153

Divergence		
	Pre-training	**Post-training**
Total response time (secs)	0.88	0.56
SS response var @ dist (degrees)	0.76	0.8
Peak velocity (degrees/sec)	13.5	29
Time constant (millisecs)	415	171

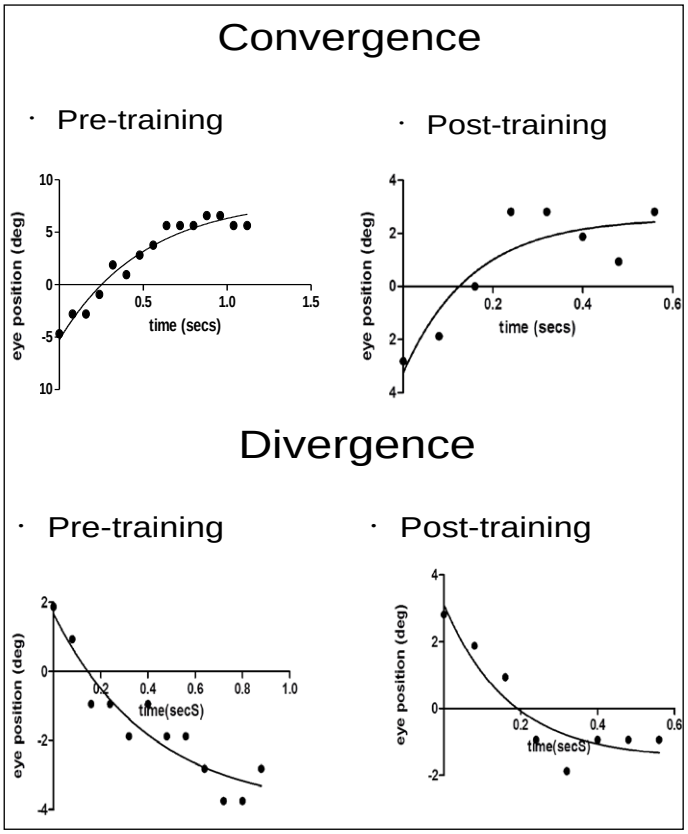

Figure 1: *Pre-/post-vision therapy convergence and divergence responses as a function of time. Single response profile.*

Table 4: Pre-/Post- Objective Measures of Accommodation

Binocular Viewing Increasing Accommodation

	Pre-training	Post-training
Total response time (secs)	1.4	1.2
SS level 4D stimulus (D)	2.87	3.12
Peak velocity (D/sec)	6.03	7.06
Time constant (millisecs)	414	333

Binocular Viewing Decreasing Accommodation

	Pre-training	Post-training
Total response time (secs)	1.2	1.1
SS level 2D stimulus (D)	0.85	1.2
SS response var @ 2D level (D))	0.1	0.16
Peak velocity (D/sec)	6.22	6.54
Time constant (millisecs)	373	298

Monocular Viewing Increasing Accommodation

	Pre-training	Post-training
Total response time (secs)	1.5	1.3
SS level 4D stimulus (D)	3.14	3.01
SS response var @ 4D level (D)	0.5	0.38
Peak velocity (D/sec)	4.4	5.03
Time constant (millisecs)	639	414

Monocular Viewing Decreasing Accommodation

	Pre-training	Post-training
Total response time (secs)	2.2	1.5
SS level 4D stimulus (D)	1.02	1.3
SS response var @ 4D level (D	0.23	0.22
Peak velocity (D/sec)	7.8	5
Time constant (millisecs)	406	418

With regard to dynamic changes in accommodation following the vision therapy, most parameters either improved or normalized, but to a lesser frequency and/or percentage than found for vergence. Changes were similar under monocular and binocular viewing conditions (Table 4). Figure 2 presents objective recordings of pre-/post-vision therapy responses of accommodation under binocular viewing conditions, whereas Figure 3 presents the same under monocular viewing conditions. Responses were faster following vision therapy in both viewing conditions.

Discussion

Recent evidence from randomized clinical trials has demonstrated that the most effective treatment for symptomatic CI in children is office-based vergence/

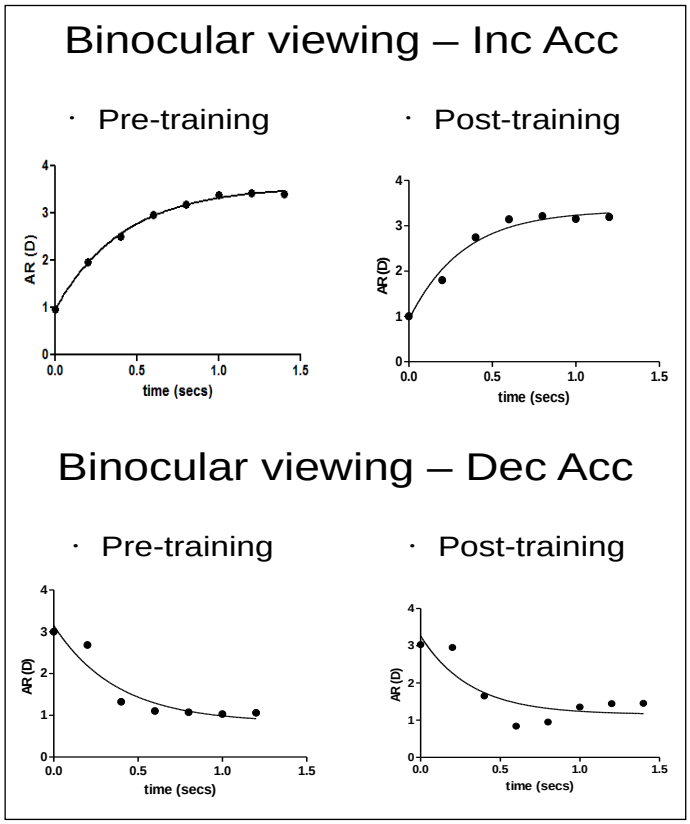

Figure 2: *Pre-/post-vision therapy increasing and decreasing accommodative responses as a function of time. Binocular viewing. Single response profile.*

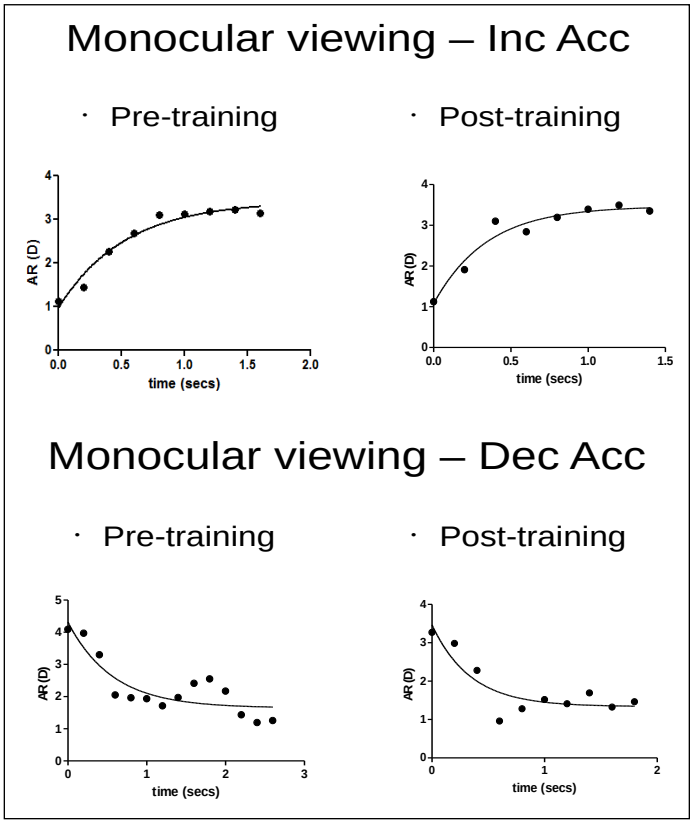

Figure 3: *Pre-/post-vision therapy increasing and decreasing accommodative responses as a function of time. Monocular viewing with the right eye; right eye fully occluded. Single response profile.*

accommodative therapy with home reinforcement.[7] In this case study, the child was treated with the same vision therapy program used in the CITT studies.[7] The significance of this case report is that it demonstrates the concurrent improvements in clinical and objective measures of both vergence and accommodation. Although similar improvements in objective measures of vergence have been reported for a small sample of adult patients,[18, 19] as well as in a small sample of children, we believe that this is the first report of changes in vergence and accommodation in a child.

While randomized clinical trials can be designed to minimize the effects of confounding variables and other sources of bias using control groups and masked investigators, it is valuable to be able to use objective assessments of physiological functions for a number of reasons. First, changes in objectives measures cannot be attributed to a placebo effect.[20, 21] Second, this case report illustrates the ability to obtain these objective data on a young child, and furthermore suggests that such measures could and should be used in future randomized clinical trials as objective outcome measures. Third, it demonstrates correlation of subjective and objective measures both before and after vision therapy.

The present findings have important neurophysiological implications with respect to the oculomotor system. They demonstrate objectively the presence of considerable oculomotor plasticity in a young child. This is consistent with the tenets of perceptual and motor/oculomotor learning, which are the underlying mechanisms for all vision therapy.[22] This is somewhat remarkable in light of the oculomotor system not being fully developed at this age.[23, 24] Lastly, these findings provide additional objective support of the value of office-based vision therapy with home reinforcement.

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