

Article

The Impact of Vergence and Accommodative Therapy on Reading Eye Movements and Reading Speed

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ABSTRACT

Background: Most studies investigating the impact of optometric vision therapy on reading speed and reading eye movements utilize ocular motility and visual processing procedures. Only one study has reported the impact of accommodative and vergence therapy alone on reading speed, but only with three subjects.

Methods: Six patients with symptomatic accommodative/vergence anomalies received vision therapy along with objective eye movement recordings before and after therapy. Therapy consisted of procedures to treat accommodative and vergence skills – no saccadic or ocular motor procedures were utilized.

Results: Each of the patients showed clinically significant improvements in reading speed and eye movement efficiency.

Conclusions: Accommodative and vergence therapy alone has the potential to improve reading speed and reading eye movements. Ocular motor therapy may not be necessary for some patients with accommodative/vergence disorders who also demonstrate reduced reading speed and poor reading eye movements.

KEY WORDS

reading eye movements, reading speed, vision therapy, accommodation, vergence, Visagraph II, ReadAlyzer

INTRODUCTION

Patients who have undergone optometric vision therapy for accommodative and vergence disorders sometimes report improvements in various aspects of reading, including speed, fluency, and comprehension. Several studies have documented improvements in reading comprehension and/or word recognition after accommodative and vergence therapy.¹⁻³ Several other studies have reported improvements in reading comprehension using monocular occlusion, presumably to circumvent binocular disorders that were affecting reading.⁴⁻⁵ A study by Stavis et al found increased reading speed and comprehension after wearing BI prism among subjects with convergence insufficiency.⁶ Other studies have reported changes in word recognition and/or reading comprehension after vision therapy that utilized a combination of procedures involving ocular motility, vergence, accommodation, and visual processing.⁷⁻¹⁰

Studies that have investigated the impact of vision therapy on reading speed and reading eye movements have generally incorporated only ocular motility and tachistoscopic procedures.¹¹⁻¹⁹ An objective infrared eye movement recording device was used to assess reading speed and eye movement variables during reading. The earlier studies used the Eye Trac,¹¹⁻¹³ while the later ones used the Visagraph or Visagraph II¹⁴⁻¹⁸ or Ober2.¹⁹ Results of these studies have shown that tachistoscopic and saccadic therapy can reduce the number of fixations and regressions while increasing span of recognition, resulting in improved reading speed and comprehension.

Other studies investigating the impact of vision therapy on reading speed and reading eye movements used a combination of therapy procedures, including ocular motility, accommodative, vergence, and visual

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Table 1. Visual findings pre- and post-therapy

Subject (Age) #Visits	Diagnosis	Cover Test (16 inches)	Step vergence (16 inches)		NPC (inches)		Accommodative facility (cycles per minute)		DEM (sec)	
			Pre	Post	Pre	Post	Binocular	Monocular	Pre	Post
#1 JB (16) 19	CE Acc. infac.	4 EP	BI X/10/6	BI X/16/12	1/4	NA	6.5 w/ suppression >5 sec (+)	12 15	31	29
#2 SB (24) 14	CI AE	6 XP	BI 14/20/12 BO 16/30/20	BI 20/25/18 BO 35/>40	16/24	1/2	>5 sec (+) Fails (+)	11 NA	45	41
#3 LM (17) 13	CE	6 EP	BI 8/10/6 BO >30	BI 12/25/16	1/2	1/2	Fails (-) >10	8 NA	26	NA
#4 RE (15) 16	CI AI	Ortho	BI 8/12/8 BO X/30/18	BI X/14/10 BO >40	10/16	.5/1	>5 sec (-) >5 sec (-)	10.5 NA	36	NA
#5 MF (11) 12	CE	Ortho	BI 6/10/6 BO 18/35/18	BI X/16/12 BO NA	2/4	NA	5, diplopia (-) >10	16 NA	36	NA
#6 TA (14) 15	CI DE	7 XP, 18 IXT at dist	BI X/16/10 BO X/8/2 BO dist X/4/0	BI X/25/18 BO >40 BO dist 18/35/18	6/10	1/2	Fails (-) NA	13 NA	39	33

processing techniques.^{10,20-24} Each of these studies reported improvements in reading speed, but it was not possible to determine the relative contributions of each type of vision therapy to the final outcome.

There is limited research investigating the effectiveness of vision therapy incorporating only accommodative and vergence therapy on reading speed and reading eye movements. The only published study involved three patients with binocular and accommodative dysfunction, which showed improved reading rate with a word list after vision therapy.²⁵ Reading eye movements were not measured. A study reported by Peters in 1942 found improved reading speed in a group of college students using orthoptic therapy, primarily vergence training.²⁶ But this group also had reading therapy, as did a similar untreated group who also showed marked changes in reading speed with reading therapy alone.

This paper is a retrospective report of a series of patients with documented accommodative and vergence anomalies along with reduced reading speed and efficiency who received only vergence and accommodative therapy. We wanted to determine if this type of therapy alone would result in improvements in

reading speed and eye movement efficiency using an objective eye movement recording device.

METHODS

Six cases were selected from vision therapy case files over a 4-year period in one of the author's practice (MG). Each of the patients received standard accommodative and vergence testing including cover test at distance and near, near point of convergence, step vergence ranges with a prism bar, accommodative amplitude, accommodative facility with +2/-2 flippers, MEM retinoscopy, and the Developmental Eye Movement Test (DEM). Table 1 lists the pertinent findings. An objective assessment of reading eye movements was performed using the Visagraph II or the ReadAlyzer. The ReadAlyzer is very similar to the Visagraph II and uses the same normative data. Both are goggle mounted infrared eye movement recording devices that assess a group of eye movement variables during reading. The number of fixations and regressions are measured and reading rate, span of recognition and duration of fixation are calculated. Changes in these measures follow a developmental continuum, and subject performance is reported in the form of grade level equivalents.²⁷ Ten true/false questions are asked at

Table 2. Eye movement findings pre- and post-therapy

Subject (Age) #Visits	Number of fixations/ 100 words		Number of regressions/100 words		Fixation duration (seconds)		Average span of recognition (words)		Reading rate words/min.		Grade level equivalent		Comprehension %	
	pre	post	pre	post	pre	post	pre	post	pre	post	pre	post	pre	post
#1 JB (16) 19	128	74	26	2	.28	.33	.78	1.35	166	241	6.6	Adult	80	100
#2 SB (24) 14	136	87	22	11	.27	.23	.73	1.15	160	291	4.5	Adult	100	90
#3 LM (17) 13	109	79	13	5	.26	.26	.91	1.25	211	286	8.7	13.5	70	100
#4 RE (15) 16	112	75	23	6	.27	.30	.89	1.32	199	261	7.3	13.4	80	80
#5 MF (11) 12	257	131	42	12	.30	.23	.39	.84	74	197	1.0	6.4	80	90
#6 TA (14) 15	104	87	16	8	.34	.28	.95	1.15	167	239	6.7	12.7	80	100

the conclusion of the recording to ensure the subject is reading with comprehension.

Multiple eye movement recordings were performed on each subject to minimize the learning effect.²⁸ An independent reading level was estimated by having the patient read a passage orally. A reading level was chosen for the first recording where the patient was able to read fluently without noticeable hesitation. Then the reading level was dropped three or more grade levels on subsequent recordings to further deemphasize the impact of word recognition on reading eye movements. The last recording made was the one reported, unless subsequent recordings showed a decreasing reading speed. This was interpreted as a sign that the patient was fatiguing. In two of the six cases this pattern was evident, and in these cases the recording with the best reading speed was used.

Diagnosis of accommodative and vergence dysfunction was made using the classification schema of Scheiman and Wick.²⁹ Vision therapy consisted of vergence and accommodative activities including Vectograms, Tranaglyphs, Brock string, Aperture Rule, Eccentric Circles, loose prisms, computer random dot stereograms, stereoscope with jump vergence targets, and monocular and binocular accommodative rock with lenses. No saccadic or pursuit activities were performed. Patients were seen for in-office treatment 45 minutes once a week, with a recommendation of 15 minutes of daily home therapy. Home therapy consisted of one or more of the following: Brock string, accommodative rock with loose lenses or flippers, Eccentric Circles, and Home Therapy System (HTS) software.³⁰

When the patients met their vision therapy goals (elimination of symptoms and completion of the therapy sequence), they were re-evaluated using the same clinical testing measures. The Visagraph II or ReadAlyzer was re-administered using the same grade level material as before treatment but with different passages. Post treatment testing was performed with the same instrument used for pretreatment testing.

RESULTS

Table 1 lists the pre and post therapy visual findings, along with diagnosis, age and number of office visits completed for each patient. The ages ranged from 11 to 24 with an average of 16.2. Therapy visits completed ranged from 12 to 19 with an average of 14.8 visits. Because this was a retrospective study, complete data were not available for all subjects. However, the data demonstrate that following treatment all subjects had clinically normal NPC, step vergences, and accommodative facility.

Table 2 lists Visagraph II or ReadAlyzer eye movement data for each subject. Clinically significant reductions were seen in the number of fixations and regressions, as well as increased reading speed. Improvements in reading speed ranged from 62 words per minute (wpm) to 131 wpm, with an average increase of 89.6 wpm. Span of recognition also increased from an average of .78 words to an average of 1.18 words. Reading comprehension after treatment improved in four patients, remained stable in one patient, and was slightly reduced in one. Of the 3 patients where pre and post therapy DEM data were available, relatively small increases in speed were noted.

Although a formal symptom questionnaire or quality of life survey was not administered, each of the patients reported an elimination of all presenting complaints of asthenopia, headache, blur or diplopia. They also all reported subjective improvements in reading speed and fluency.

DISCUSSION

Although numerous studies have reported improvement in reading eye movements and reading speed after vision therapy, most have used either a "shotgun" approach to therapy including vergence, accommodative, ocular motor and visual perceptual/processing procedures,^{10,20-24} or only ocular motor and tachistoscopic training.¹¹⁻¹⁹ We believe that the cases described in this study are the first to objectively document increased reading speed and eye movement efficiency after vergence and accommodative therapy alone.

In clinical optometric care, it is likely that patients receiving vision therapy with multiple diagnoses of ocular motor dysfunction and binocular dysfunction will receive ocular motor therapy either prior to or coincident with vergence and accommodative therapy. This approach was not used with the six cases reported in this study. Interestingly, significant improvements were seen in reading speed and reading eye movements without ocular motor therapy procedures.

Over 15 years ago, Garzia et al³¹ showed that visual stress in the form of reading through -2.00 lenses resulted in slower reading with the cloze procedure in which readers have to guess at key missing words in the text. The reader attempts to fill in the missing words using context clues to demonstrate comprehension of the passage. They proposed that attention is a limited resource, and visual stress reduces the attentional capacity available for reading comprehension and language processing. The limited attention model in reading was initially proposed by Laberge and Samuels³² and led Garzia et al to suggest that visual stress inhibits lexical access, resulting in poor reading recall and comprehension. If the reading task requires comprehension, one strategy would be to reduce speed to ensure comprehension, which is apparently what happened with their subjects. It is possible that the six subjects reported here experienced an increase in reading speed after their accommodative/vergence function improved as more attention was available for reading and comprehension. This idea is also supported in a study by Ludlam which showed decreased comprehension among adults wearing BI prism while reading.³³ It is interesting to note in the current study that comprehension improved for four of the six patients, 1 stayed the same, and 1 decreased, but only from 100 to 90% (Subject#2). Thus, these patients were not reading faster at the expense of comprehension.

Binocular dysfunction and its negative effect on attention may also interfere with eye movement function. Binocular and accommodative instability can affect the

speed and span of recognition during fixation, and reduce fixation stability.^{34,35} This may result in more regressions and fixations as well as reduced reading speed. It is conceivable that even in the absence of diplopia and blur, accommodative and vergence stress can disrupt the sequencing of reading saccades. A recent study reported longer saccadic latencies in subjects with intermittent exotropia.³⁶

The eye movement data from the six patients in this study show fixations and regressions were both significantly reduced and span of recognition increased after vision therapy. Interestingly, there was not a consistent effect on duration of fixation. Three of the patients showed a faster average duration of fixation, but one remained the same and two had slower duration of fixation despite increased reading speed. This may be because the range of normative values for this parameter is quite narrow²⁷ and thus less susceptible to training effects, as was shown by Calef et al.¹⁹

The importance of attention in programming saccades is well accepted.³⁷⁻⁴⁰ Visual attention prioritizes visual processing during reading by first emphasizing central information to provide for word recognition, followed by diminishing central attention and increasing attention to peripheral information to help plan the next saccade. The magnocellular (M-cell) pathway carries this information about spatial positioning of letters, and along with attentional mechanisms, is crucial in guiding saccades during reading.^{38,41} Magnocellular deficits have been identified in children with reading disabilities, and subsequent therapy to improve temporal visual processing resulted in improved reading comprehension.⁴² Richman⁴⁰ summarizes the neuropsychological research in this area and argues that the same areas of the brain contribute to both attentional and eye movement processes, and it may be impossible to functionally separate them. Thus, stressors such as accommodative/convergence disorders that disrupt attentional processing also have the potential to disrupt reading eye movements.

The impact of binocular dysfunction on attention and reading may be thought of as acting on both macro and micro levels. On a macro level, visual stress reduces attentional capacity for language processing and reading comprehension.^{31,33} On a micro level, diminished attention disrupts eye movement control and fluency³⁷⁻⁴⁰ and reduces reading speed. Functionally, the impact of visual stress operates simultaneously at both macro and micro levels. As attention is reduced for language processing and comprehension, further disruption of eye movements could occur due to higher cognitive inputs into eye movement control. This may explain our clinical observation that many slow and inefficient readers are aware that they frequently reread to obtain comprehension even when word recognition is automatic.

The cases reported in this study suggest it may not always be necessary to incorporate eye movement procedures in vision therapy programs for patients with symptomatic accommodative/vergence dysfunction and poor reading eye movements. This approach may shorten the duration of therapy in some cases, as well as hasten the improvement of symptoms. Eye movement therapy can be done after accommodative/vergence therapy when improved vergence and accommodative function alone does not lead to improved reading speed and reading eye movements. Hoover and Harris⁴³ describe the use of ReadFast software after completion of a vision therapy program that included some eye movement procedures. They report significant additional improvements in reading speed beyond what was achieved in the initial vision therapy. ReadFast uses tachistoscopic and guided reading procedures. Current software programs such as Track and Read,⁴⁴ Vision Builder,⁴⁵ Ace Reader,⁴⁶ and PAVE⁴⁷ use similar procedures. It is possible that these programs will be more effective once accommodative/vergence problems are resolved and fixational stability is improved.³⁴⁻³⁵ In addition, attentional resources may be more effectively allocated to reading and reading eye movements once accommodative/vergence stress is eliminated.

Although this study provides preliminary data that accommodative/vergence therapy alone may lead to increased reading speed and eye movement efficiency, additional research is required because of a number of limitations in our study design. These limitations include small sample size, retrospective design, and the use of unmasked examiners. As more research is performed to study the impact of vision therapy on reading and learning, eye movement data would be useful in understanding the transfer of improved visual function to improved reading efficiency.

Conclusions

Accommodative and vergence therapy can result in improved reading speed and eye movements even in the absence of ocular motility therapy. The ReadAlyzer and Visagraph II are useful, objective computerized tools for monitoring changes in eye movements and can aid in our understanding of the effects of vision therapy on reading efficiency.

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August is National Children's Vision & Learning Month

On August 1st, COVD launched its public awareness campaign for National Children's Vision & Learning Month 2007. Since then, greater national and regional public awareness on the connection of vision and learning has been achieved than in any prior campaign. This multi-faceted success is the result of a new national marketing strategy, and also the efforts of numerous people on national and local levels.

Starting with the first day of the campaign launch, one of our greatest successes so far has been in raising awareness in – and through – the news media about the connection between vision and learning. Within the first four hours of the campaign launch press release being distributed, COVD's tracking service showed it was read by 210+ key subscription journalists. As of this writing, the launch announcement has been selected, run and posted by editors of major broadcast,

print, and internet news outlets, e.g., NBC (and various affiliates), Yahoo News, AOL News, Breitbart, Forbes.com, SmartMoney.com, etc., with a combined audience of 67,000,000+ visitors and viewers. It also has appeared and was syndicated on social network sites including Digg, Del.icio.us, Newsvine, as well as numerous blogs and dialogue boards. To leverage these results and add to them, we continue to develop new ways to re-purpose and continue syndicating information related to National Children's Vision & Learning Month 2007.

Of great interest, state and city proclamations supporting Children's Vision & Learning Month were also markedly increased from 2006. COVD state coordinators, local ODs and other COVD members have been successful in achieving 18 proclamations to date, including Arizona, California, Colorado, Florida, Iowa, Massachusetts,

Missouri, Nevada, New Jersey, New York, and South Carolina.

August, however, is only the start of a year-long continuation of the National Children's Vision and Learning campaign. This change will enable us to sustain momentum and continue to broaden awareness of developmental and behavioral vision therapy and vision care, both within the public sector and the professional optometric community.

The National Children's Vision & Learning campaign strives to further the dialogue within the optometric community about the benefits of vision therapy. This effort is also designed to educate and empower members of COVD to make an impact in their communities while benefiting the business success of their practices.

Excerpt from an article appearing in the October issue of *VISIONS*, written by Michael Draznin, COVD Marketing & Communications Consultant.

For regular updates on relevant information and content, new marketing tools, case studies, and more, visit www.covd.org.