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Remote treatment of intermittent central suppression improves quality-of-life measures

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KEYWORDS
Dyslexia;
Electronic rapid alternate occlusion;
Intermittent central suppression;
Quality of life;
Suppression;
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Abstract

BACKGROUND: Intermittent central suppression (ICS) is a repetitive intermittent ("on-and-off") loss of central visual sensation without strabismus or amblyopia. These repetitive seconds-long suppressions have been suggested to create visual confusion and instability that would cause vision symptoms, contribute to reading complaints, and even impair reading.

METHODS: Teacher-identified Job Corps students were diagnosed with ICS and then treated with 5-Hz electronic liquid crystal shutter alternate occlusion.

RESULTS: Twenty-six young adult students (19.7 ± 1.6 y) had their ICS treated over 5.9 ± 3.7 months. Suppression periods decreased in length ($P < 0.0001$) and "binocular" nonsuppressed periods increased in length ($P < 0.0001$). Overall, College of Optometrists in Vision Development (COVD) quality-of-life (QOL) scores improved ($P < 0.0001$), 16 reading behavior COVD QOL questions improved ($P < 0.0001$), and individual QOL questions improved. Posttherapy reading scores (N = 18) improved 3.7 (± 2.6) years ($P < 0.0001$).

CONCLUSIONS: Treating ICS with electronic alternate occlusion reduced suppression periods, increased binocular periods, and improved symptoms as measured in the COVD QOL questionnaire. Positive changes also occurred in reading scores. These data suggest ICS should be considered a probable cause for symptoms of reading problems.

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Treatment of the visual sensory defect of suppression has been part of optometric vision therapy since its beginning. Louis Jaques called for the treatment of nonstrabismic suppression in the 1950s.[1,2] Most of the early thought on suppression diagnosis, treatment, and neuropathology, however, comes from study of strabismus and amblyopia. For example, Bielschowsky used the term *diplopiaphobia* referring to a sort of "phobic" cortical response to diplopia that then produces suppression in strabismus.[3] In their seminal work, Hubel and Wiesel[4-7] discovered changes in visual neurology in kittens when their eyelids were sutured shut, providing insight into the deprivation and constant suppression of strabismus and amblyopia. However, the explanations and descriptions of strabismic/amblyopic suppression did not fully explain nonstrabismic, nonamblyopic, intermittent central suppression (ICS). Both types of suppression are visual sensory defects that suspend, at least for a short time, central

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Dr. Hussey is the primary inventor of the electronic rapid alternate occlusion goggles. No commercial version is yet available. Clinical studies continue. There are no other potential commercial conflicts of interest.

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visual sensation. Therefore, both represent a loss of intact central visual sensation. Beyond that, the 2 suppression conditions show almost as many dissimilarities as similarities.[8]

Strabismic/amblyopic (constant) suppression is viewed often as a constant cortically based inhibitory loss of central, and possibly paracentral, visual sensation.[9] In unilateral constant (strabismic/amblyopic) suppression, occlusion of the sighting eye will override the inhibition of the visual neurology and "force" the strabismic/amblyopic eye to see, at least while the normally sighting eye is covered. Some alternation occurs in alternating strabismus, but usually with a degree of patient volition.

ICS, on the other hand, is a repetitive, intermittent ("on-and-off") loss of central visual sensation. Although variable, a typical ICS "cycle" might consist of repetitive 2- to 3-second suppressions spaced by similar periods of bilateral sight. Eighty percent to 90% of ICS patients alternate.[10,11] While a strabismic patient might control an alternation, a typical ICS patient will very much act as an observer in a diagnostic examination, reporting the changes in visual sensation, including alternation, but not controlling them.

Other vision conditions that commonly accompany strabismic versus ICS illustrate additional differences between the 2 types of suppression. Strabismus and amblyopia, and the co-occurring suppression, often are associated with significant refractive errors.[8,9] ICS patients fit very normal refractive error distributions.[10] Amblyopia by definition is reduced acuity in 1 eye. ICS patients show very normal and equal acuities. Both strabismus and amblyopia reduce stereopsis scores, whereas ICS patients can show normal stereopsis scores.[10,11]

Although cortical inhibition can explain the constant suppression of strabismus and amblyopia, it fails to explain the intermittency and alternation of ICS. What cortical mechanism can explain a loss of sensation that switches eyes, is intermittently inhibitory (that is, actively inhibitory, then not actively inhibitory, then actively inhibitory on the opposite side), and all of that repetitively? Further, the genesis of ICS associated with whiplash cervical trauma has been documented, but without visual field defect.[12] What strictly cortical inhibitory mechanism is there that is triggered by trauma? What traumatic cortical damage has been documented that apparently is sufficient to intermittently interrupt visual sensation by traumatically producing inhibition but is insufficient to produce a field defect? The putative cortical explanation of suppression fails to explain ICS.[13]

Active therapies for suppression, and ICS in particular, almost always involve 2 components: a bilateral (bioptic) visual environment (e.g., a stereoscope) and visual motion.[14] Common techniques include cheiroscopic tracings, in which the bilateral stereoscope visual environment incorporates a moving pencil, a Brock string, in which plucking the string brings visual sensation back in a suppressed eye, and dissociated eye movements using a rotating visual target while looking through dissociating prisms.

Allen[15] advocated alternating flicker for strabismus suppression treatment using flashing lights alternating in a square-wave pattern at 9 Hz. The 9-Hz alternation rate was thought to make use of the 9-Hz Bartley phenomenon brightness enhancement, theorized to represent improved transmission of the visual signal to the cortex.[15] Similarly, electronically controlled liquid crystal shutter lenses (*see* Figure 1) can serve as the visual flicker-producing tool, producing a rapid alternate occlusion rather than bright flashing. The strongest, most efficient antisuppression alternate occlusion frequency, as determined empirically during a stereoscope drawing task, is approximately 5 Hz. Further, that 5-Hz alternation pace fulfills the 2 requirements for an antisuppression therapy: bilateral sight and motion. On-off flicker is motion in stimulus form.[16,17] Direct square-wave alternation between the eyes at that 5-Hz pace is fast enough that the central vision reads the signal as continuous, that is, as bilateral and with little central flicker. Paradoxically, then, electronic rapid alternate occlusion (or Allen's flashing lights) delivers a strong bilateral motion stimulus—strong enough for antisuppression therapy.

The treatment goal of decreasing suppression in, for example, intermittent exotropia is understandable, but what is the interest in nonstrabismic, nonamblyopic ICS? Some suggest a link to reading problems, possibly dyslexia. Strauss and Immerman,[18] Annapole,[19] Safra,[20] Miller et al.,[21] and Hussey[10,11] have suggested a diagnostic link to reading problems. In contrast, 1 study found little incidence of ICS as described above in a university student population with good reading skills.[22] Miller et al.[21] and Hussey[23,24] have also treated ICS and found improvements in reading, quality-of-life (QOL) measures, or other visual tasks, such as marksmanship. This current study updates a previous pilot study for treating ICS with electronic liquid crystal rapid alternate occlusion in isolation at a location remote from in-office treatment availability.[23]

Subjects

All subjects came from a Job Corps site in north central Washington state. According to the Job Corps Web site, "Job Corps is a free education and training program that helps young people learn a career, earn a high school diploma or GED, and find and keep a good job. For eligible youth at

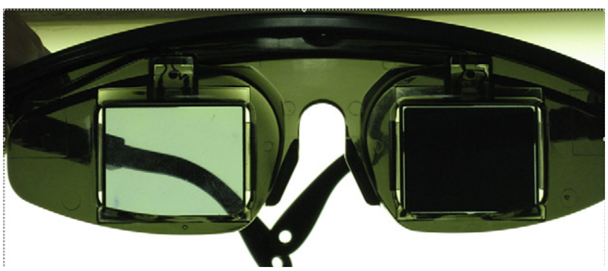

Figure 1 The alternate occlusion goggles show 1 liquid crystal lens occluded.

least 16 years of age, Job Corps provides the all-around skills needed to succeed in a career and in life."[25] The treatment group of students was, at the time of original examination and during any treatment, enrolled in Job Corps.

Twenty-six students who had ICS (absent strabismus and amblyopia) underwent treatment and returned for follow-up examination. This treatment group ranged in age from 17 to 23 years. Average age at the initial examination was 19.7 (SD, 1.6) years, making these students adults and virtually eliminating development as a causative factor for any changes in the group. Four of the 26 subjects in the treatment group were female.

This is a clinical group being treated for ICS with the hope of improving the chances of academic achievement. Bright visual flicker, most commonly between 15 and 25 Hz, has been implicated in triggering seizure.[26] In light of this, and to err on the side of caution, all students who had ICS diagnosed were screened for seizure history, then offered treatment if they reported no history of seizure.

Methods

Treating the ICS in this Job Corps group onsite at a 2.5-hour distance from the clinic required a method that could be used with minimal oversight by Job Corps staff. Using electronic rapid alternate occlusion with liquid crystal lenses alternating at 5 Hz provided antisuppression treatment while the students would sit and read. These Job Corps students alternate a week in academic education with a week in trade training. During those education weeks, they were to wear the alternating goggles, beginning with 5 minutes of wear and gradually working up to 30- to 40-minute sessions, while reading. Three to 5 treatment sessions were to be accomplished during the education weeks. The treatment goggles were not allowed to leave a specified treatment area on the Job Corps campus. (Although each student was asked to keep track of goggle use, precise logging of treatment times did not happen.) Follow-up examinations occurred as allowed by Job Corps scheduling and road conditions. Often, 3 or more months passed between examinations. In the treatment group, 9 of the 26 were seen more than twice (more than the initial and 1 follow-up examination). The time between the initial examination and the last examination—the study treatment time—averaged just less than 6 months (5.96 ± 3.7 months). Miller et al.[21] used a study treatment paradigm of 30 therapy-hours of treatment. Using estimations of treatment time based on student reports suggests a similar average treatment period in this current study.

Three measures were used to assess changes in the treatment group: timing of the on-off cycle of the ICS, the College of Optometrists in Vision Development (COVD) QOL Questionnaire[27,28] (*see* Appendix), and Tests of Adult Basic Education® (TABE®; CTB/McGraw-Hill,) reading scores.

At both the initial examination and subsequent examinations, each student was given a COVD QOL checklist to fill out. The COVD QOL checklist has repeatedly proven a valid and reliable symptom survey for pre- and posttherapy evaluations.[27,28] Occasionally, an accompanying Job Corps staff member helped if the reading demand of the checklist proved too great.

Next, each student underwent a vectographic analytical vision examination as described elsewhere and an eye health examination.[29] This routine vectographic examination was the tool for diagnosing ICS and has a number of subtest vectographic targets in which the diagnosis of ICS can be made. The diagnosis requires a suppression to fit the definition of ICS; that is, a repetitive intermittent suppression generally similar to the timing pattern described above. One of the targets, the bisected diamond target from the (modified) Borish Vectographic Nearpoint Card™ (Stereo Optical Co., Inc., Chicago, Illinois) is the easiest target to use to time the suppression (*see* Figure 2). The timing of suppression and nonsuppression periods serves as a measurement of the ICS. Changes in that timing from examination to examination provide a measurement of change in the suppression with therapy.[23,24] Those timing numbers were held with the records until compiled for this study.

Job Corps uses the TABE to assess reading in their education students. According to the CTB/McGraw-Hill Web site, "the Tests of Adult Basic Education®, are norm-referenced tests designed to measure achievement of basic skills commonly found in adult basic education curricula and taught in instructional programs. Reading, language, mathematics, and spelling are the areas measured."[30] All reading-level testing is done at Job Corps by Job Corps staff. These data have the limitation that education continues during the ICS treatment period, so the changes cannot be held to be purely from treatment of the ICS. However, it is the Job Corps educational staff that refers students for treatment. Therefore, prior education had not brought these adult students up to levels of reading ability anticipated by that educational staff. This is an ongoing treatment program that started in 2002. That program continuation speaks to the ongoing desire of the educational staff at Job Corps to have this additional help. Also, it would be very unusual in clinical practice to treat a child with ICS who was not undergoing concurrent educational reading training. TABE improvements

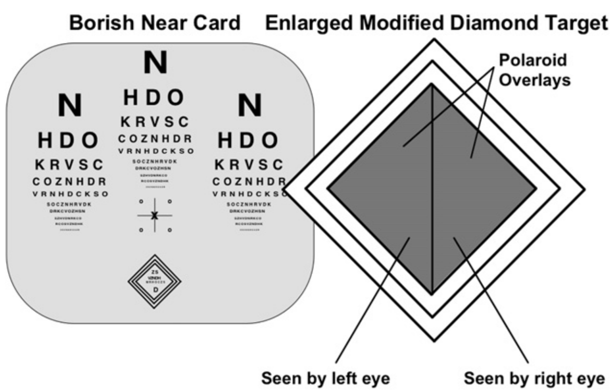

Figure 2 Schematic of modified Borish Vectographic Near Card.

beyond what we might reasonably expect in an average 6-month educational period would suggest that some of the positive change came from the ICS therapy. Although these results might suggest real help for reading scores from the therapy, the data on reading changes must be viewed as changes from a combined program of education and ICS treatment.

Paired, 2-tailed *t* tests were used to evaluate significance of changes. In addition, 95% confidence levels for pre- to posttherapy differences were calculated to help assess changes. For calculation purposes, the maximum nonsuppressed "visually on" period was considered to be 10 seconds, even for those students whose suppression was successfully extinguished.

Results

Pretherapy

At the initial examination, all students had normal, healthy eye health examinations. Corrected visual acuities ranged from 20/15 to 20/30. No student in this treatment group had strabismus. No student had more than 1 acuity line difference between eyes, fulfilling the ICS diagnostic distinction of no strabismus or amblyopia. Average fully corrected decimal visual acuity was 0.94 ± 0.13 in the right eye (OD) and 0.93 ± 0.14 in the left eye (OS), the equivalent of 20/21 OD, OS. Average refractive error spherical equivalents were OD −0.61 ± 1.8, OS −0.67 ± 1.98 dioptic spheres (DS). If we exclude 2 students with refractive errors at 2 SD or more from the means, the average spherical equivalent refractive errors are OD −0.17 ± 0.86 and OS −0.18 ± 0.74 DS. This closely agrees with 2 prior reports from 2 groups totaling 90 ICS patients showing refractive errors of −0.06 to −0.08 DS. spherical equivalent.[10,11]

Pretherapy stereopsis scores show a relatively normal group, although the scores vary enough to suggest some problems in testing in this group. Using the graded stereopsis circles of the Stereo Fly test (9 circles) and the AO/Reichert distance stereo ring test (4 circles) on the adult vectographic slide (both from Stereo Optical Co., Inc.), the students' scores averaged close to the maximum of 4 (90 arc seconds) at distance and 7 (60 arc seconds) at 40 cm. Probably the best conclusion from the stereopsis data is that stereoacuity as tested is not a valid, reliable diagnostic test for ICS. This conclusion is consistent with those of past studies on ICS in which stereoacuity was tested but says nothing about stereoacuity in other conditions.[10,11,31]

Pretherapy length of suppression periods and bilateral sight ("binocular") periods also agreed with prior reports. Suppression periods averaged 2.5 ± 1.1 seconds; bilateral periods were 2.8 ± 2 seconds. All but 4 of these 26 patients alternated (85%). These initial findings support the classic ICS description as a repetitive intermittent, usually alternating, suppression of about 2 seconds of suppression spaced by 2 to 3 seconds of bilateral sight.[11] If we look at the suppression and nonsuppression periods as a cycle and view 2 SDs on each as a boundary of significance, then as a clinical rule, if the suppression does not repeat in less than 11 or 12 seconds, it is probably not clinically significant.

Posttherapy

The first posttherapy result that must be reported is the complete lack of seizure activity. Often with visual flicker the suggestion is made that seizures will be triggered. An important distinction to be made here is that reports of photic-induced seizures often involve bright flashing images.[26] In contrast, with electronic rapid alternate occlusion, overall illumination is reduced because visual stimuli are alternately blocked. While prudence demands continued screening for seizure activity through patient history, and conservative use schedules when initiating therapy with alternating visual flicker, suggestions that 5-Hz alternating flicker produced by liquid crystal occlusion will trigger a seizure are unsupported in this group and have not occurred over the 8 years of treatment experience at Job Corps.

The therapy was successful in reducing suppression periods (*see* Figure 3). The pretherapy average suppression period reduced 1.48 (±1.36) seconds to just over 1 second (from 2.5 ± 1.1 seconds to 1.02 ± 1.04 seconds). This difference is significant ($P < 0.0001$; 95% confidence level lower limit = 0.9315, upper limit 2.0301). Bilateral-sight/binocular periods increased posttherapy more than the suppression periods decreased. These binocular periods increased from 2.8 to 6.8 ± 3.3 seconds (*see* Figure 4). This change is also highly significant ($P < 0.0001$, binocular period pre- to posttherapy = −3.94 ± 3.3055 seconds, 95% confidence interval lower limit = −5.2774, upper limit −2.6072). The 4-second increase in bilateral periods versus the 1.5-second decrease in suppression periods

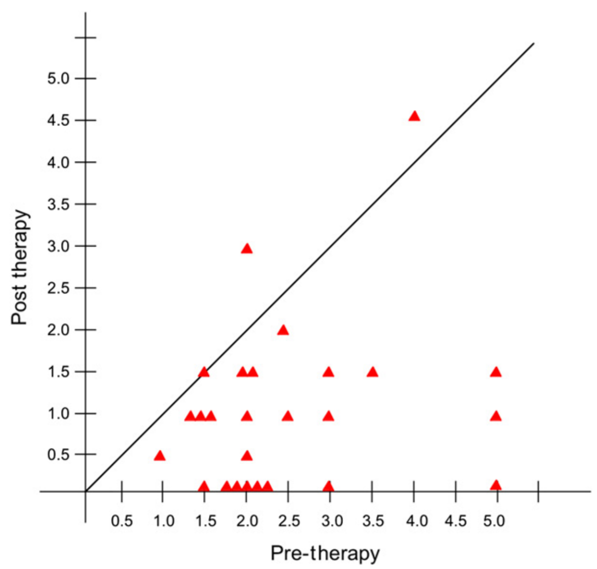

Figure 3 Length of ICS suppression periods in seconds.

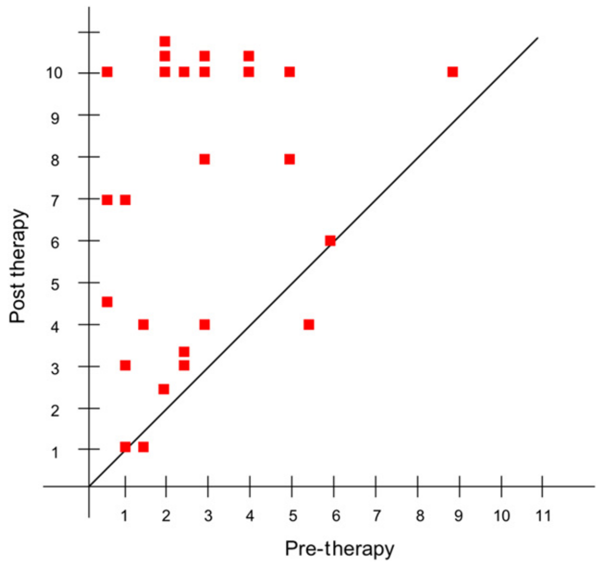

Figure 4 Length of binocular periods during ICS cycle in seconds.

suggests the treatment increased binocularity more than it decreased the inhibition thought to be the suppression. This finding presents another challenge to the strict inhibitory view of suppression.

The reduction in suppression and increase in binocular periods was accompanied by a decrease in overall symptoms as measured by the COVD QOL questionnaire (*see* Figure 5). The overall scores decreased 17.96 ± 17.65 points from 50.6 (±19.2) average to 32.7 (±14.1) average, significant at $P <$ 0.0001 (95% confidence interval of the difference lower limit = 10.834, upper limit = 25.089). Group scores for all individual QOL questions improved with reduction in ICS with different levels of significance. Significance levels are noted in the Appendix.

As a further exploration of symptomatology, 16 of the COVD QOL checklist questions were chosen that more directly reflected reading symptoms. Those questions are noted in the appendix. The reading-related QOL scores also changed significantly (from 30.4 ± 9.2 down to 17.4 ± 8.3, a change of 13.1 ± 11.5; $P < 0.0001$, 95% confidence interval of the difference lower limit 8.418, upper limit 17.736; *see* Figure 6).

Pre- and posttherapy TABE reading scores (*see* Figure 7) were obtained for some of the students (N = 18). With an average treatment period of just under 6 months, the average TABE reading level changed from the 4.9 ± 1.7 grade level to the 8.6 ± 2.4 grade level. This change is highly significant ($P < 0.0001$ [change test score 1 to test score 2 mean = −3.70, 95% confidence interval of the change lower limit −5.01, upper limit −2.39]). Those scores changed with concurrent education.

Discussion

By most measures, these adult students enrolled in Job Corps must be considered as having vision and reading difficulties in the absence of eye pathologies or traditional acuity issues. In this group of 17- to 23-year-old young adults, an average beginning reading level equivalent of fifth grade should be considered abnormal. In addition, these young adults started with a very high level of visual symptoms. Reduction of the suppression reduced symptomatology significantly. Because reducing ICS improved symptomatology, these data support ICS as a treatable cause of visual symptoms that can be (logically) associated with reading problems. Whether these symptoms, difficulties, and complaints constitute dyslexia is a definitional argument.

Reading levels as measured by the TABE test increased significantly. With many of these students, academic problems had prevented high school graduation. The average 3.5-year improvement in reading level occurred over an

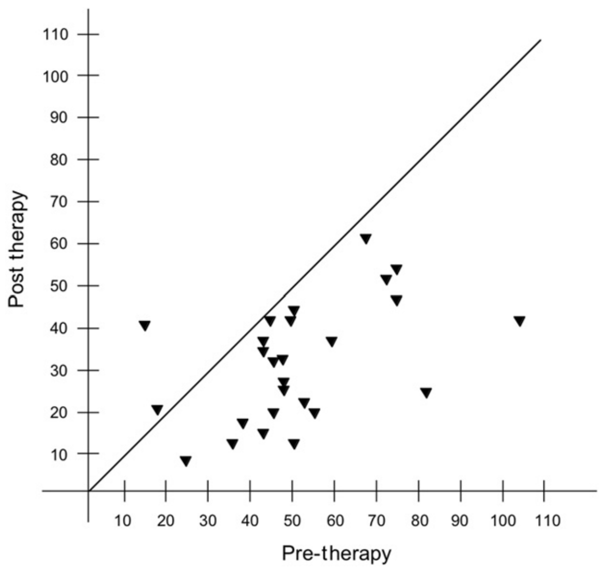

Figure 5 COVD QOL score, full checklist.

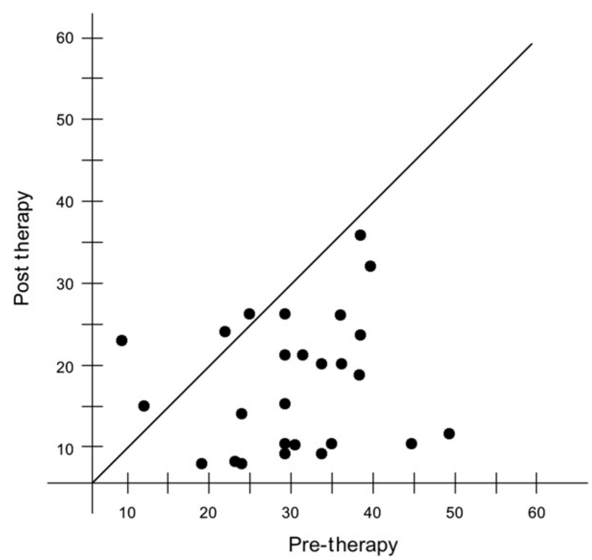

Figure 6 COVD QOL score, 16 reading questions.

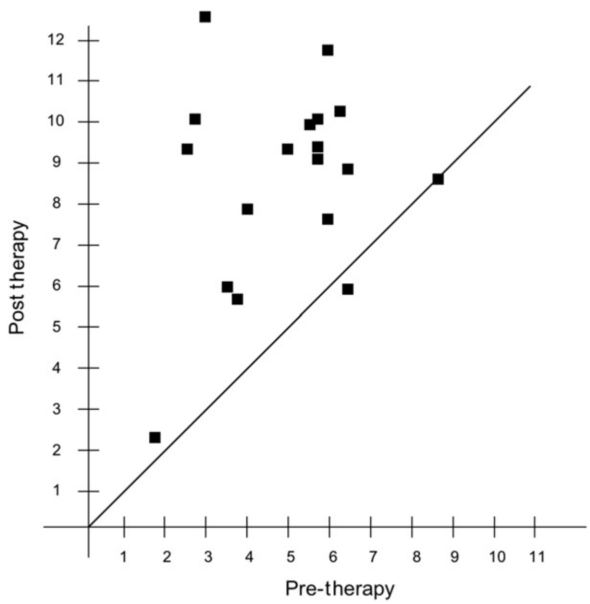

Figure 7 TABE reading scores by grade level.

average 6-month period that includes the standard student schedule of education weeks alternating with trade training weeks. ICS therapy occurred only during education weeks. During trade weeks, no ICS therapy occurred. Similarly, concurrent reading education happened on the same alternate week academic schedule. Seldom in clinical practice do we treat patients with vision problems that might affect reading success who are not also receiving reading education. So, this study, in part, reflects the reality of clinical practice. Perhaps the most accurate view of these improvements in reading level would be that we can logically expect increases in reading level, or maybe accelerated reading improvements, when we treat an ICS patient who is also in school. More studies and controlled studies need to be done.

An associated question is whether this particular therapy worked as intended to treat ICS. Suppression periods decreased and binocular periods increased. This was accomplished with no significant side effects. Seizures have not occurred, but we continue to monitor ongoing treatments. These data should not be taken to define the only available treatment for ICS. As discussed above, most therapies for suppression involve a visual motion stimulus presented in a bilateral/bioptic visual environment. So, cheiroscopic tracings (a moving pencil in a stereoscope) will help treat ICS. Dissociated rotations using the prism-induced diplopic visual motion of a rotator (bilateral visual environment) will help treat ICS. The bilateral stimulus of a Brock string can have motion added with head movement or by plucking to help treat ICS. All of these fulfill the stimulus-level demand of bilateral sight with a motion stimulus. Similarly, in this group, liquid crystal shutter lenses delivered a strong enough bilateral motion stimulus through 5-Hz square wave alternating occlusion to treat the suppression.

These data support the view that the presence of ICS increases visual symptoms and impairs reading performance. Further, this sensory deficit is treatable. Clinical measurements, symptomatology as measured by QOL checklists, and reading scores all changed significantly. Ninety-five percent confidence intervals of the changes show all changes pre- to posttherapy to be different from zero. However, "…without some understanding of the underlying physical mechanism, even several observations are of little or no use."[32] What is the mechanism by which ICS might cause these symptoms and disrupt reading?

ICS is a repetitive suspension of the central visual image. The "lock" for accurate binocular aim is 2 intact pictures. When the image from 1 eye or 1 side is lost during an ICS suppression period, that "lock" is gone. Some drift or inaccuracy in aim should occur with the suppressed eye. This is supported by the work of Collewijn et al.[33] who interleaved binocular and monocular conditions during eye movement recordings of saccades and associated vergence behavior. Under monocular conditions, the nonseeing eye's aim was not accurately linked to the seeing eye. The nonseeing eye lacked the proper information for target position. Vergence errors were not corrected during fixation periods. Collewijn et al.[33] refer to binocular vision as "essential" for bilateral saccade accuracy. That bilateral saccade accuracy is, of course, necessary for accurate reading when 2 eyes are involved.

Extrapolating to ICS, the patient would experience the same vergence errors during the suppression periods. Then as the suppression resolved and bilateral sight was restored, any aiming error would result in a confused image. The aim will be corrected, but accompanied by image motion during the vergence correction. Because ICS is repetitive, recurring after a 3-seconds-long binocular period in this group, this means these patients are repetitively experiencing visual confusion and motion. Using the ICS cycle timing as a guide in this group, we would expect, on average, every 5.5 seconds or so the vision system would be in a nonsuppressed vergence correction. Logically, we might expect the size of the aiming error and then the vergence correction would be affected by other conditions, such as size of the near phoria and length of the suppression period in the individual.

Other possible ramifications of this sensory defect might be suggested. But if this "mechanical" hypothesis accurately explains any of the visual consequences of ICS, is it any surprise that the treatment group had a high level of symptoms and that correction of the ICS improved those symptoms? Reduction of the aiming error, vergence correction, and the associated visual confusion period through that decrease in ICS should make reading easier, explaining some of the increase in reading level in this study. Again, these students were often undergoing remedial reading training. However, the reduction in visual confusion should make that remedial training more productive and probably faster.

Beyond the scope of this report is the meaning of the increase in binocular periods with treatment. Assuming the putative explanation for suppression as only a function of cortical inhibition, the decrease in suppression periods with treatment is understandable. But, a simultaneous and larger increase in the noninhibitory periods implies an explanation of ICS that is not strictly inhibitory but probably involves the patency of the afferent visual signal to the cortex.[13,31,34]

Conclusion

ICS must be considered a probable cause of symptoms of reading problems as measured by the COVD QOL questionnaire. Properly diagnosing ICS, then treating the ICS, improves QOL measures. Some positive effects can be expected on reading scores in students who have reading education in school. Because ICS is routinely diagnosable, and treatment of the ICS improves QOL and reading scores, vision therapy for intermittent central suppression as the only currently available treatment should be considered medically necessary and appropriate. These data cast doubt on cortical inhibition as the sole explanation for all suppression.

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References

1. Jaques L. *Corrective and Preventive Optometry.* Los Angeles: Globe Printing; 1950:4.
2. Jaques L. Synchronized optometry: A monograph. 1956:14-19. Located at: The Archives and Museum of Optometry, St. Louis, Missouri.
3. Bielschowsky A. *Lectures on Motor Anomalies*. Hanover: Dartmouth College Publications; 1943:32.
4. Wiesel TN, Hubel DH. Effects of visual deprivation on morphology and physiology of cells in the cat's lateral geniculate body. *J Neurophysiol* 1963;26:978-93.
5. Hubel DH, Wiesel TN. Receptive fields of cells in striate cortex of very young, visually inexperienced kittens. *J Neurophysiol* 1963;26: 994-1002.
6. Wiesel TN, Hubel DH. Single-cell responses in striate cortex of kittens deprived of vision in one eye. *J Neurophysiol* 1963;26: 1003-17.
7. Wiesel TN, Hubel DH. Spatial and chromatic interactions in the lateral geniculate body of the rhesus monkey. *J Neurophysiol* 1966;29: 1115-56.
8. Hussey ES. Use of visual flicker in remediation of intermittent central suppression suggests regionalization of vision. *J Behav Optom* 1999; 10:3-11.
9. Griffin JR. *Binocular Anomalies: Procedures for Vision Therapy.* Newton: Butterworth-Heinemann; 1982:43-132.
10. Hussey ES. Intermittent central suppression: a missing link in reading problems? *J Optom Vis Develop* 1990;21:11-6.
11. Hussey ES. Temporal characteristics of intermittent central suppression. *J Behav Optom* 2002;13:149-52.
12. Hussey ES. Intermittent central suppression caused by cervical trauma (whiplash). *J Behav Optom* 1997;8:31-6.
13. Hussey ES. Binocular visual sensation in reading: A unified theory. *J Behav Optom* 2001;12:119-26.
14. Hussey ES. The on-switch for seeing. *J Optom Vis Develop* 2003;34: 75-82.
15. Allen MJ. Understanding suppression. *J Optom Vis Develop* 1995;26: 50-2.
16. Hussey ES. Speculations on the nature of motion with optometric implications. *J Behav Optom* 2003;14:115-9.
17. Wallis TSA, Arnold DH. Motion-induced blindness is not tuned to retinal speed. *J Vision* 2008;8:1-7.
18. Strauss RJ, Immerman AS. The relation of macular suppression and other normal binocular visual functions to reading underachievement, Parts I-IV. *Rev Optom* (Part I) 1964;101:31-4. (Part II) 1964;101:25-32; (Part III) 1964;101:27-34 (Part IV) 1965;102:25-32.
19. Annapole L. Visual skills survey of dyslexic students. *J Am Optom Assoc* 1967;38:853-9.
20. Safra D. Die orthoptische Legastheniebehandlung (Abstract: The orthoptic treatment of legasthenia). *Klin Mbl Augenheilk* 1992;200:612-3.
21. Miller JE, Whiteaker J, Zolg C, et al. Identifying and reversing intermittent central suppression in students with low reading comprehension as a method of improving student performance in reading. *J Optom Vis Develop* 2000;31:131-7.
22. Zeri F, De Luce M, Spinelli D, et al. Intermittent central suppression, an evaluation of its presence using three instruments. *J Behav Optom* 2005;16:59-62.
23. Hussey ES. A pilot study on the geographically remote treatment of intermittent central suppression using electronic rapid alternate occlusion. *J Behav Optom* 2007;18:10-4.
24. Hussey ES. Correcting intermittent central suppression improves binocular marksmanship. *J Military Med* 2007;172:414-7.
25. Job Corps. Success lasts a lifetime! Available at: http://www.jobcorps.gov/home.aspx. Last accessed March 22, 2010.
26. Fischer RS, Harding G, Erba G, et al. Photic- and pattern-induced seizures: a review for the Epilepsy Foundation of America Working Group. *Epilepsia* 2005;46:1426-41.
27. Maples WC. Test-retest reliability of the College of Optometrists in Vision Development Quality of Life Outcomes Assessment. *Optometry* 2000;71:579-85.
28. Maples WC, Hoenes R. The College of Optometrists in Vision Development checklist related to vision function: expert opinions. *Optometry* 2009;80:688-94.
29. Hussey ES. Examination of binocular sensation over time with routine testing. *J Behav Optom* 2000;11:31-4.
30. CTB/McGraw-Hill. TABE 9&10. Available at: http://www.ctb.com/ctb.com/control/ctbProductViewAction?p=products&productFamilyId=608&productId=882. Last accessed March 24, 2010.
31. Hussey ES. Binocular visual sensation in reading II: Implications of a unified theory. *J Behav Optom* 2002;13:66-70.
32. Hoven R. "Terrorism and bathtubs" in American Thinker. Available at: www.americanthinker.com. Last accessed October 15, 2009.
33. Collewijn H, Erkelens CJ, Steinman RM. Binocular co-ordination of human horizontal saccadic eye movements. *J Physiol* 1988;404:157-82.
34. Hussey ES. An idealized experiment on the effect of decreasing Magnocellular signal on visual sensation. *J Behav Optom* 2005;16: 119-24.

Appendix

		0	1	2	3	4	Significance
*	Blur at near						*
*	Double vision						*
*	Headaches with near work						**
*	Words run together when reading						**
*	Itching, burning, watering eyes						**
*	Falls asleep reading						**
*	Sees worse at end of day						***
*	Skips /repeats lines reading						***
*	Dizzy/nausea with near work						
*	Head tilts closes one eye when reading						**
	Difficulty copying from chalkboard						
*	Avoids near work and reading						*
*	Omits small words when reading						**
	Writes up or downhill						**
	Misaligns digits or columns of numbers						*
*	Poor reading comprehension						**
	Poor/inconsistent in sports						
*	Holds reading too close						**
*	Trouble keeping attention on reading						**
*	Difficulty completing assignments						***
	Says “I can’t” before trying						*
	Avoids sports and games						
	Poor hand-eye coordination/handwriting						
	Poor distance judgement						*
	Clumsy/knocks things over						
	Doesn’t use time well						
	Doesn’t make change well						
	Loses things						
	Car/motion sickness						
	Forgetful/poor memory						

COVD checklist. Assign a value from 0 to 4 for each symptom. 0 = never; 1 = seldom; 2 = occasionally; 3 = frequently; 4 = always. Questions starred on the left are the 16 “reading symptoms” questions. Significance levels of improvements in individual questions are indicated in the far right column: ***$P < 0.001$, **$P < 0.01$, *$P < 0.05$ (*see* text).