

Outcome Measures of In-Office Optometric Visual Rehabilitation Intervention on Oculomotor Function, Visual Processing Skills, and Reading Efficiency Scores in Children with Formally Identified Academic Difficulties

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ABSTRACT

Background

Oculomotor dysfunction (OMD) and visual information processing (VIP) deficits are often seen in children with reading difficulties. Prior published

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evidence has shown statistically significant correlations between several metrics, in particular vergence facility and reading efficiency at baseline within an office based vision therapy (OBVT) setting supported by home vision therapy (HVT). However, data on the effects of OBVT on OMD, VIP deficits, and reading performance is currently lacking. The purpose of this study is to investigate whether vision therapy improves VIP deficits in children diagnosed specifically with a dyseidetic based reading problem with confirmed concurrent oculomotor dysfunction.

Methods

Exam records of 143 pediatric patients (age 6-18 years old, 56% male) diagnosed with a dyseidetic based reading problem and who successfully completed OBVT re-enforced with HVT were included in the study. All patients were seen at a practice in Ontario, Canada. All dynamic visual skills and visual processing skills were tested at baseline, and again after every 10 sessions of OBVT. An independent test of reading fluency (TOWSRF-2), and standardized symptom scores using the COVD QoL Questionnaire and CISS symptom survey were also performed.

Results

All patients successfully completed vision therapy between 30-40 sessions. By 10 sessions, OMD and VIP results had significant improvement ($p < 0.001$), while vergence facility and TOSWRF-2 scores showed significant improvement after 20 sessions ($p < 0.01$ and $p < 0.05$ respectively). At the end of treatment, significant improvements were seen in COVD QoL scores (58 start / 19 finish, $p < 0.001$), CISS score (19 start / 6 finish, $p < 0.001$) and TOSWRF-2 reading fluency scores (20th percentile start / 47th percentile finish, $p < 0.001$).

Conclusion

Office-based vision therapy re-inforced by home vision therapy is an effective treatment method for

improving monocular and binocular visual skills, visual information processing skills, and reading fluency in children with dyseidetic reading problems.

BACKGROUND

Oculomotor dysfunction (OMD) occurs when there is an absence or delay in the brain's ability to coordinate the eyes to fixate, follow, or move fixation from one target to another accurately and efficiently. Signs and symptoms for OMD primarily involve poor reading stamina, frequent loss of place on a page, unstable fixation, skipping words, re-reading words, or reading one word slowly at a time.¹⁻³ OMD is closely associated with accommodative and vergence anomalies^{1,3,4} such as accommodative insufficiency (AI) and convergence insufficiency (CI), and can be referred to collectively as visual skills deficiencies (VSD) in order to differentiate from pathology related visual losses. In addition to signs and symptoms associated with reduced reading efficiency and ability, other symptoms associated with VSD include headaches, loss of attention, rapid visual fatigue, decreased copying speed, and reduced ability to retain what has been seen, a skill commonly referred to as visual memory or in the educational realm "orthographic mapping" related skills.⁵⁻⁸

Published estimates of the prevalence of VSD in children with reading based learning problems range from 19% to 86%^{1,3,9} depending on the specific aspect examined. Of interest, the general population has reported incidences for example of accommodative dysfunction in the 8-10% range^{10,11} and convergence insufficiency (CI) in the 5-7.5% range.^{3,12,13} In terms of attention based connections, the prevalence of CI alone in attention deficit hyperactivity disorder (ADHD) has been found to be as high as 15.9% with over 55% of the DSM symptoms overlapping to the point where significant potential for diagnostic confusion has been highlighted.¹⁴ In addition, the prevalence of accommodative and vergence disorders combined has been estimated to be 9.7 times greater than the prevalence of ocular disease in children ages 6 months to 5 years old, and 8.5 times greater

than the prevalence of ocular disease in children ages 6-18 years old.⁷ However, despite the high prevalence rate, VSD has received relatively little attention in early learning literature.^{1,12,15}

For example, studies by Hoffman¹⁶ and Metsing & Ferreira⁸ have reported that learning disability populations have a very high incidence of visual skills deficiencies (>90%), but neither study discussed any treatment options to eliminate or reduce VSD issues to foster more consistent sensory visual input. Similarly, while studies have shown uncorrected hyperopia as low as +1.25DS with poor accommodative function or higher Convergence Insufficiency Symptom Scores (CISS) with hyperopia >+2.00DS (non-cycloplegia) being associated with poorer academic performance, the correlation between hyperopia and VSD is often overlooked.^{1,17} Although research has highlighted high discriminatory testing methods for VSD in children with reading difficulties,¹ it remains to be examined whether the relationship between VSD, visual processing skills and reading efficiency is based on association, or if a causal relationship exists. While VSD directed Optometric vision therapy treatments does not directly treat reading problems per se, the treatment of critical dynamic visual skills such as tracking, accommodation, and vergence control, have been shown to improve reading performance and efficiency.^{2,12,18,19}

In 2022, the Ontario Ministry of Education's (MoE) "Effective Early Reading Instruction Guide"²⁰ used the term "Orthographic (derived from the Greek words "correctly written") Mapping" when discussing how children transition from a laboured pattern of single word/letter decoding to a more fluent pattern of "sight word" reading. The MoE statement correctly connects a child's visual skills, including visual memory skills, to their ability to retain "sight words" in order for fluent reading to occur: *"How do children move from slow decoding of words letter by letter, to being able to read words quickly and easily? Thank orthographic mapping, the process competent readers use to store written words, so they can automatically recognize them on sight. The more words we have stored in this sight word bank, the easier reading becomes"*.²⁰

To provide academic supports for children in school, the MoE and the child's school, in conjunction with educational psychology, often develop a formal "Individualized Educational Plan" (IEP) for children struggling with academics. According to the Learning Disability Association of Canada, in 2002 approximately 1 in 10 children (in Canada) required an Individualized Educational Plan (IEP) in school to support their academic learning¹; with approximately 86% of IEPs in place primarily for reading.^{1,21} The number of IEPs continues to increase by 0.3-0.6% per year; 10% in 2002 to 16.7% in 2018 in elementary school-age children.²²

Children with a formal IEP in place for reading are often provided additional aids such as assistive technology (i.e., text to talk devices) to help support reading comprehension, since children tend to often understand text better when visual input is removed. More specifically, children with dyseidetic reading problems often have improved comprehension when read to (i.e. auditory input) versus the child having to read print directly themselves. Because reading to a child with primarily dysphonetic difficulties can also be of benefit, it is essential to determine whether the child primarily has a dyseidetic or dysphonetic difficulty. Using the Dyslexia Screening Test (DST), for example, will exclude primarily dysphonetic cases to avoid a concurrent phonetic awareness confounder. However, to truly examine reading, VSD issues and visual information processing (VIP) skills such as visual memory should be examined in detail.^{1,2,5,16,23-28}

Visual memory is the ability to recall visual information, and is important when reading and subsequently retaining "sight words" or words with letter sequences that cannot be recalled using phonetic rules or patterns,²⁷ often referred to as "jail words" in phonemic/speech-language circles. The term "jail" is used to imply no conventional phonetic rules can be applied to decode the word and word must be memorised, therefore, the word is a "rule breaker". The ability to read sight words relies on the child's ability to remember eidetically what a word looked like for recall when seen and when asked to spell (the word) from memory., This

is a critical step to connect the visual image to both pronunciation and meaning. For example, the word "know" should phonetically be spelt "no". When learning to read, a child is taught to ignore the "k" and "w". Over time, as reading fluency increases, sight words are recognized via visual memory as part of the overall orthographic mapping process.^{5,20,29} This often overlooked but critical skill in educational circles is referred to as "selective intention", a term which describes the ability to remember a word although it looks different to its phonetic pronunciation.²⁸ In the absence of consistent visual input, such as intermittent blurred or double vision, visual memory fails to engage, resulting in difficulties with sight word acquisition, stunting the overall orthographic mapping process. Hence, challenges with reading, specifically with eidetic (i.e. symbol based, and worse with smaller print) encoding, are essentially rooted to a large extent in poor visual memory (VM) skills. This connection has also been recently recognized in the dyslexia research community. Several publications in this field have suggested that vision, specifically refractive error (mainly hyperopia) and binocular vision (vergence and accommodation) deficits, should be investigated and corrected *before* a diagnosis of dyslexia can be considered.^{23,24,30}

Therefore, to further examine the effect of VSD and VIP deficits on reading performance, the purpose of this study was to retrospectively investigate whether office based vision therapy (OBVT) re-enforced with home therapy improved visual skill deficiencies, visual information processing (in particular visual memory) with any impact on reading fluency in children with a specific dyseidetic based reading issue who were formally diagnosed with concurrent VSD concerns prior to OBVT.

METHODS

A retrospective review of 143 patient files (6-18 years; 56% male) seen in an Optometric Clinic in Ontario (Canada) from January 2017 to January 2021 were reviewed. Files were selected based on the following criteria: best corrected visual acuity of 20/20 in each eye, no history of strabismus or amblyopia, no prior history of vision therapy,

a dyseidetic reading disorder using the dyslexia screening test (DST, with an eidetic score $\geq 70\%$ and dysphonetic score $< 30\%$), Type II (Oculomotor) Developmental Eye Movement (DEM) pattern cases if saccades affected, IEP status formally present (accommodated or modified type), which requires reading performance to be in the 10th percentile or less (on provincial testing) and completion of the in-office vision therapy program (OBVT) prescribed. The Type II DEM pattern describes saccadic test results whereby the horizontal saccadic performance test is abnormal and the vertical saccadic performance test is normal compared to DEM normative data. Completion of the program was defined as no clinically significant changes to symptoms and clinical data seen after two consecutive progress evaluations (PEs), and the overseeing doctor formally indicating a successful graduation of the child from the OBVT program. Patients with formally diagnosed ADHD/ADD and Autism Spectrum Disorder (ASD) were excluded from review.

Consent and study process received ethics clearance from the University of Waterloo, Office of Research Ethics and followed the tenets of the Declaration of Helsinki for Human Research.

Clinical Tests:

Files were reviewed for the following clinical data (baseline and all subsequent progress evaluations): near point of convergence, saccadic function, fusional reserve amplitudes (positive and negative break points) at near, vergence facility at near, monocular accommodative facility and near stereopsis. In addition, Visual Information Processing (VIP) tests as outlined below, and symptom scores from both the Convergence Insufficiency Symptom Survey (CISS) and COVD Quality of Life Questionnaire (COVD QoL) were also reviewed. All clinical data was obtained and recorded by registered Optometrists in Ontario (PQ, DC, HM) in the course of clinically administered OBVT therapy. Data for VIP testing and symptom scoring was obtained independently of the overseeing doctor by a team of certified vision therapists.

Symptom Scores Used

Convergence Insufficiency Symptom Survey (CISS, 0-60 scale): This questionnaire was validated as part of the Convergence Insufficiency Treatment Trial (CITT).³¹ This questionnaire contains 15 questions each of which have five answers (Never, Infrequently, Sometimes, Fairly often, Always), which are totalled with the final symptom score ranging from 0-60. Any score over 15 is considered a concern and is indicative of significant symptomatology from a VSD standpoint. The CISS score has been accepted as a reasonable symptom scale for VSD generally, despite being developed specifically for convergence insufficiency.¹⁵

COVD Quality of Life (QoL) questionnaire: This questionnaire contains 31 questions each of which has five answers (Never, Seldom, Occasionally, Frequently, Always), which are totalled with the ultimate symptom score therefore varies from 0-24, with any score higher than 24 being considered a concern and indicative of a significantly symptomatic patient.^{15,31}

Oculomotor and Binocular Integration Skills examined:

Near Point of Convergence (NPC): This was assessed using an accommodative target, letter E on a "budgie stick" with VA equivalent to 20/30, with the measurement being recorded as the average distance in centimetres (cm) from the bridge of the nose at which the patient reported double vision or at which point one eye was visibly noted to drift out of alignment. Average of three successive measurements were taken using a ruler for the final value in cm. NPC receded more than 8cm was considered abnormal.^{31,32}

Vergence Facility at 40cm: Normal clinical value accepted as approximately 15 cycles per minute (cpm) at 40cm with testing described elsewhere.^{1,33} If the patient remained diplopic at any point (i.e. fusion broke down) the number of cycles to that point was noted. This test is both subjective and objective as the responses of the patient are listened to, but given the prism power difference used (i.e. 15 PD relative difference between 12BO/3BI), the eyes can also be observed

DISCUSSION

This study sought to investigate whether dynamic visual skills, visual processing, and/or reading fluency improved in children diagnosed with visual skills deficiencies (VSD) and treated with an office based vision therapy (OBVT) program. Although the study was a retrospective review of patient files, results were found to be consistent with previously reported findings,^{1,3,8,14-16,23} and should be considered in future study designs. Specifically, this study found a high frequency of VSD and VIP deficits in children (age 6-18 years) with a dyseidetic reading disorder measured using the DST suggesting a relationship may exist between visual skills, visual processing and reading efficiency. In addition, results found reading ability, as measured using the TOWSRF-2 reading efficiency test battery, as well as several visual processing indexes, improved while being treated with an OBVT program, supported by home re-enforcement; however, it is unclear whether additional metrics (i.e. concurrent reading program at school) also contributed to the overall finding. While most metrics such as OMD and VIP changed by the first progress evaluation (PE), reading outcome measures and vergence facility did not show gains until the second PE assessment (i.e. after 20 sessions). The fact that improvements in reading efficiency were seen mid-way through the vision therapy program is interesting, especially since vergence facility also appeared to follow the same time course.

These results were similarly reported by Quaid & Simpson (2013), who demonstrated vergence facility testing at near was the strongest dynamic visual skill measurement correlated to reading performance.¹ Therefore, the results presented in this paper taken with prior research,¹ suggests that in dyseidetic reading difficulty cases, reading fluency may be correlated with vergence facility, and also appears to improve in parallel with vergence facility outcome measures. This finding suggests that vergence function and reading scores may be associated, as seen in studies by Dodick *et al.*,² Husseindeen *et al.*¹² and Scheiman *et al.*¹⁸ More specifically, results from this study showed

that in addition to vergence facility, base-in prism break points also did not improve until PE #2; a pattern not yet reported in the literature with base-out prism data and warrants further investigation.

In addition to the correlation between vergence facility and reading efficiency in children,¹ it has also been reported that visual memory may be predictive of reading and math performance.^{5,6} Applying these connections, it can be assumed that if a word appears different due to visual fluctuations (i.e., diplopia or intermittent blur), visual recall will be challenging since there is no consistency in visual and an almost “overly phonetic” pattern of spelling, i.e., “fucher” for FUTURE or “stashun” for STATION will be depicted (Figure 14). Therefore, if a child cannot recall what a word *looks like* and proper phonemic awareness is present, the educational default will be to spell the word based on how it sounds. This results in a noticeable lack of reading fluency due to poor sight word or rapid “jail word” recognition, potentially leading to a stunted and laboured reading pattern^{26,29} due to failure of the visual component of the orthographic mapping process.²⁰

This study also explored whether commonly reported symptoms using the COVD QoL and CISS questionnaires were associated with abnormal binocular findings (Figures 3-7).

When comparing symptoms associated with binocular vision dysfunction to data-base findings, it was found commonly reported symptoms such as “words sometimes move on the page when I try to read”; “words come in and out of focus when I am trying to read”; “the words look funny when I am trying to read”; “sometimes I think the word is written twice on the page”; “I lose my place a lot when I read and have to use my finger to keep my spot” were recorded in patient files who also had a receded NPC and/or reduced accommodative or vergence facility. This is likely because children have difficulty understanding what is meant by “normal vision” but appreciated the clarity and comfort in vision when lenses and therapy were introduced. Similar to the findings in this study, the Convergence Insufficiency (CI) Treatment Trial (CITT)³¹ reported symptomatic

You can still see “20/20” and see like this. If a child has always “seen this way”, they don’t actually know any different and typically will not complain. In order to detect these visual issues, the eye doctor has to do very specific testing and pay attention to how the eyes move and team together in order to determine whether there is a problem. If your wish to get more information on eye teaming or eye focusing issues that can cause problems with reading, visit www.covd.org or www.vuetherapy.ca for more details. If your child skips lines when reading, avoids reading or gets frustrated quickly with reading, it is very likely a smart idea to have them assessed for eye teaming problems. If these issues are missed and left untreated, the effects on your child over time in terms of their academics can potentially be devastating.

Normal View

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Blurry and Double Image

Figure 14. Comparing single, clear vision to what a child would see if vergences and accommodation were a problem, causing double vision and blurred vision. This perception of print, which is purely a visual phenomenon will affect orthographic mapping by significantly impairing a child’s ability to “recall what has been seen. Although phonetic awareness and teaching instruction are also vital, a child’s ability to see clearly and consistently is a key aspect to developing visual memory, which is a requirement for sight word development to occur. The child will often prefer larger font despite attaining “20/20” acuity due to the “crowding effect” of smaller print.

children with CI can be successfully treated with office-based vision therapy (OBVT) re-enforced by home therapy. Several other studies such as those by Dodick *et al.* in 2016² and Scheiman *et al.* in 2011¹⁸ also report improvements in accommodative function and reading outcomes with OBVT.^{10,12} It should be noted, however, that while the above mentioned studies including this one, showed gains in reading performance following an OBVT program, it is unclear how much of the gains were due to a placebo effect or other factors such as

as concurrent reading program at school. While it can be speculated that reading performance improves following an OBVT program as noted in this study, a prospective randomized control trial would need to be carried out to confirm results.

Similarly, other research has shown that reading based outcomes as measured by the Wechsler Individual Achievement Test (WIAT-II) and Grey Oral Reading Test (GORT) methods reveal significant gains in performance in 57% of the sample size by 16 sessions, with and a further 25% show significant gains by 24 sessions,¹⁸ suggesting the TOSWRF-2 may require more sessions to show gains by virtue of how it is administered (i.e. TOSWRF-2 uses crowded lines of letters with no gaps, therefore likely requiring better figure-ground and visual discrimination skills). The greatest gains seen in the study by Scheiman *et al.* in 2018¹⁸ was attained using WIAT-II test in terms of reading comprehension subtest. Of particular interest as seen in this study, Scheiman *et al.* found that the children with more significant degrees of convergence insufficiency and the lowest TOSWRF-2 scores had more significant gains in therapy, and concluded that improvements in reading comprehension and reading speed were seen to a greater degree

in a children who were poor readers with more severe convergence problems following therapy. Although the limitation to this study was the lack of a control group, the conclusion is in agreement with the data presented in this paper. Specifically, the TOSWRF-2 reading level in the cohort examined in the research presented here at baseline was in the 20th percentile, and the overall baseline convergence was almost 13cm, with horizontal saccades being in the 25th percentile at baseline. This data indicates that the “average” child at

baseline in the current study could quite reasonably be classified as having “significant VSD concerns”. Therefore, it appears that the results in this study are in agreement with both the study by Scheiman¹⁸ when several factors are taken into account. Of all factors discussed however, ensuring that primarily dyseidetic cases, and not disphonetic cases are used, and ensuring appropriate diagnosis from a VSD aspect, appear to confer the maximum benefit from OBVT. In addition to DST testing, tests such as the Test of Word Reading Efficiency (TOWRE) and the Weschler Individual Achievement (WIAT) Pseudoword Decoding Test could also be used to further clarify the underlying etiology.

The involvement of vision in the reading acquisition process cannot be understated. Visual skills are required in conjunction with several other sensory areas to set the foundation for overall reading skills to emerge. Although the orthographic mapping process also requires important factors outside of vision such as intact phonological awareness, proper hearing ability, and proper instruction strategies, consistent visual input of what is seen on the page is vital for success in the literacy acquisition phase. Without appropriate oculomotor and binocular integration skills, it is a reasonable assertion that the “automaticity of sight word recognition” required for fluent reading ability will be difficult, if not impossible to attain.^{29,40} Symptoms such as intermittent blurred vision, double vision, tracking issues, and as a result reduced visual memory, will all lead to significant challenges when reading. Left untreated, VSD issues would logically lead to persistent dyseidetic reading issues, despite the administration of more traditional interventions such as tutoring, speech language pathology (SLP) intervention in terms of phonological training, or technology specific interventions such as “Fast-Forward” or “Empower” programs or similar computer screen based (i.e. text to talk) interventions. Outcome data presented in this study suggests that OBVT is a critical component in treating children with persistent dyseidetic based reading issues when significant VSD issues are formally diagnosed.

This conclusion is in agreement with several other studies concluding that VSD issues should be ruled out or treated in children with poor reading performance.^{1-3,8,11,12,15,16,18,23,30,39}

Limitations of the Study

Due to the retrospective nature of this study (data gathered from direct patient examinations), participants/patients were not masked and clinician bias must be considered when reviewing the results. Similarly, although the same clinician did examine the patient at baseline and during the PE exam, different clinicians were involved in the overall treatment of the patient (three total) and therefore inter-clinician variability must also be taken into account when reviewing data. Although data from this study does suggest that OBVT may be effective in improving areas of VSD and 490 VIP, the limitations of the study design cannot confirm this association. To confirm the results of this study, a future study should be a prospective, double-blind, randomised trial with similar subject recruitment criteria and treatment approaches.

CONCLUSION

Data presented in this paper confirms that treating appropriately diagnosed visual skill deficiencies (VSD) in children with dyseidetic reading problems with at least 20 office based vision therapy (OBVT) sessions improves reading fluency and efficiency as measured using TOWSRF-2 testing. More specifically, OBVT was found to improve several visual processing skills, in particular visual memory and visual discrimination ability, in addition to improving saccadic function, accommodation and vergence facility. Vergence facility in particular, in line with prior research¹ highlighting significant association, appears to improve in parallel with gains in reading fluency. This finding highlights the need to detect and treat VSD issues in children with dyseidetic reading difficulties, in particular those that appear to have persistent sight word acquisition and retention difficulties despite traditional interventions being undertaken.