Article

The VisionPrint System: A new tool in the diagnosis of ocular motor dysfunction

Janna Iyer, BS; Marc B. Taub OD, MS, FAAO, FCOVD
WC Maples, OD, MS, FAAO, FCOVD, FACBO
Southern College of Optometry

ABSTRACT

Purpose: An often-used procedure for assessing gross ocular motor functioning is the Northeastern State University College of Optometry (NSUCO) Oculomotor Test. The patient's pursuits and saccades are assessed by the clinician, making the test subjective in nature. These studies will determine if the VisionPrint system (VPS), an objective measure, can also be used to assess ocular motor function, helping to diagnose ocular motor dysfunction.

Methods: Study 1: Twenty adult students from the student population at Southern College of Optometry (SCO) were recruited and instructed how to use the VPS. They were then tested with the VPS and a minimum of 2 weeks later were retested to determine the reliability of the VPS.

Study 2: Twenty-two children (ages 6-13) from the clinic population at SCO were recruited and instructed how to use the VPS. In addition, they were explained testing procedures for the NSUCO test of saccades. These children performed both procedures and were retested a minimum of 2 weeks from their initial testing date on the VPS to determine the reliability of the instrument for younger patients.

Results: Study 1: The VPS was determined to have acceptable test-retest reliability ($p= 0.19$) in diagnosing whether someone was a "head mover" or an "eye mover."

Study 2: The VPS was determined to also have acceptable test-retest reliability with children ($p= 0.3233$). The VPS also showed a high correlation ($R= -0.8803$) with the NSUCO test of saccades.

Conclusion: The VPS can effectively be used to assess ocular motor function by objectively calculating a person's head versus eye movements. A head to eye movement ratio of greater than 0.5 means patients move their heads more than their eyes when reading. Since excessive head movement is a sign of ocular motor dysfunction, the VPS can assist practitioners in assessing eye/head movements, leading to a diagnosis of ocular motor dysfunction.

Keywords: Northeastern State University College of Optometry Oculomotor Test, Ocular motor dysfunction, Readalyzer, Saccades, VisionPrint System

Introduction

Ocular motor dysfunction (OMD) is defined as a sensorimotor anomaly of the oculomotor system whose characteristic feature is the inability to perform accurate, effective ocular pursuit, saccadic and/or fixational eye movement patterns.[1] It is a common condition that can be improved with optometric vision therapy.[2] Signs of this condition include frequently skipping words, especially small words, using a finger to help with tracking, transpositions, difficulty when copying from board to paper, a short attention span and excessive head and body movements while reading.[1,3,4]

Studies on the prevalence of OMD report 22.6% to 24% of children in a normal population exhibit saccadic dysfunction.[5,6] In children with reading and

Correspondence regarding this article should be emailed to mtaub@sco.edu or sent to Dr. Marc B. Taub at Southern College of Optometry, 1245 Madison Avenue, Memphis, TN 38104.

Iyer J, Taub M, Maples WC. The VisionPrint System: A new tool in the diagnosis of ocular motor dysfunction. Optom Vis Dev 2010;42(1):17-24.

learning difficulties, the prevalence is significantly higher.[3,7] Another study reported on children between the ages of 5 and 14 years with learning problems, and found that 95% had ocular motor inefficiency.[5]

The current methods used to diagnose OMD include psychometric, observational, and computer-based tests. Psychometric eye movement tests include the King-Devick (K-D)[8,9] and Developmental Eye Movements (DEM),[10,11] which are easily administered, have acceptable norms, and are reasonably objective, but are loaded with cognitive factors that may skew the results. These tests are difficult to administer in younger children and mentally challenged patients.[12]

The K-D test contains eight lines of five single digit numbers. The test becomes progressively more difficult as there are three separate test plates. In the first, the numbers have large spaces vertically between each line of numbers and have a black line connecting each number to the next in the line. The second plate also contains large spaces between each of the lines of numbers but the black lines connecting the targets are no longer present. The third and final plate has smaller spacing between each of the lines of numbers increasing the crowding effect. The numbers also become more randomly staggered as the patient progresses through the three charts. The patient is asked to read aloud each page of numbers as quickly as possible. A score is calculated based on the time to complete each chart and the total number of errors made. The calculations are compared to the mean and standard deviation of the test's developmental norms.[13] A criticism of the K-D test is that children with decreased number recognition will hesitate between the numbers' recognition and vocalization. If the child has decreased information retrieval skills or decreased visual verbal integration skills, they will display decreased performance on the K-D test even though their saccadic skills may be normal.[10,14]

The DEM evaluates saccadic eye movements by assessing the speed and accuracy in which a series of single digit numbers to be seen, recognized and verbalized.[14] This test compensates for the automaticity as it compares differences in time scores between vertical and horizontal responses. In this test, the child is first timed while reading two test plates, each composed of two separated vertical columns of numbers; the vertical time score is the sum of these two times. Next, the child reads the same quantity of numbers presented in a randomly spaced, horizontal array (16 rows of 5 randomly spaced single digit numbers).[11] The time for this section is adjusted if lines or digits are reread or skipped. Scoring is based on a ratio of the time taken to read the horizontal plate versus the time taken to read the two vertical plates. The vertical time score indicates the automaticity of a child's number calling without saccadic eye movements, while the horizontal time score reflects both automaticity of number calling and saccadic eye movement skill. Each score is compared to developmental norms and standard scores developed for the test.[13]

Table 1[12]: NSUCO Scoring Criteria, Direct observation of saccades

Ability

1. Completes less than two roundtrips
2. Completes two roundtrips
3. Completes three roundtrips
4. Completes four roundtrips
5. Completes five roundtrips

Accuracy

(Can the patient accurately and consistently fixate so that no noticeable correction is needed?)

1. Large over-or undershooting is noted 1 or more times
2. Moderate over-or undershooting is noted 1 or more times
3. Constant slight over-or undershooting noted (>50% of time)
4. Intermittent slight over-or undershooting noted (<50% of time)
5. No over or undershooting noted

Head Movement

(Can the patient accomplish the saccade without moving his or her head?)

1. Large movement of the head or body at any time
2. Moderate movement of the head or body at any time
3. Slight movement of the head or body (>50% of time)
4. Slight movement of the head or body (<50% of time)
5. No movement of the head or body

Body Movement

(Can the patient accomplish the saccade without moving his or her body?)

1. Large movement of the head or body at any time
2. Moderate movement of the head or body at any time
3. Slight movement of the head or body (>50% of time)
4. Slight movement of the head or body (<50% of time)
5. No movement of the head or body

An observational test, the Northeastern State University College of Optometry oculomotor test (NSUCO)[15] has the advantage of not being cognitively loaded by a knowledge of written symbols, but the disadvantage of being subjective.[12] The NSUCO standardizes the procedures and scoring criteria for observational pursuits and saccades. The targets used during testing, known as Wolff wands consists of ½ cm. gold and silver spheres attached to dowel rods. Since these targets do not involve letters, words, or numbers, no comprehension skills are involved for this task. Ability, accuracy of the saccades, the degree of head movement, and the degree of body movement has been normed into standard scores for age and grade levels. Each of the four parameters is rated with a score of 1 to 5.[12] (Table 1) The NSUCO has been shown to have good reliability between and within clinicians,[16] good test-retest reliability,[17,18] and good validity.[19,20] In one study, saccade exact agreement was 75% for 24 observers grading the test; intra-rater reliability (when the same observer grades the same behavior on two different occasions) was 83% for saccades.[21] Additionally, two studies showed that children with learning disabilities and children who were poorer readers had lower scores on the test than did normal children or children who were good readers.[19,20]

The computer-based reading eye movements tests, the Readalyzer and Visagraph, provide the most detailed clinical method of testing reading eye movements since it accounts for regressions, length of fixation, and span of fixation. The instrument is significantly more expensive and time consuming in comparison to the previously mentioned procedures.[12] The Visagraph and Readalyzer are computerized instruments that monitor the subject's eye movements, using infrared photocells, as a passage of age appropriate print is read. Subjects must be properly aligned in the instruments, and head and body movements must be minimized for accurate recordings. The Readalyzer and Visagraph objectively analyze the recordings, so subjective interpretation by the practitioner is minimal. These programs also calculate eye tracking components including fixations, regressions, directional attack (left to right tendency), average span of recognition, average duration of fixation, reading rate, grade equivalency, and relative eye movement efficiency. The actual eye movement recordings can be printed and analyzed. Limitations include difficulty of testing younger children (grade 3 and younger) and, if head movements occur, loss of proper recording alignment positioning can also be difficult with disabled or hyperactive children.[13]

New technology known as the VisionPrint System (VPS), designed by Essilor, objectively measures the patient's head to eye movement ratio (H/E) using the Polhemus FASTRAK system that tracks motion. The VPS is used to determine the individual physiological needs of those with presbyopia. Readings obtained with the VPS aid in the design of the Varilux Ipseo progressive addition lens which has several designs based on the patient's H/E ratio. Testing with the VPS consists of following a small light as it moves 25 times randomly[22] between the central fixation point and the fixation point on either of the two "arms," with maximum gaze rotation of 40°. The two arms-based lights are each located 38 cm from the central light on the same horizontal axis. The subject wears a pair of spectacles with a sensor (Figure 1) that is positioned approximately 40cm from the sensor on the base of the instrument. (Figure 2)

Figure 1: *VisionPrint System: The subject wears a headset with sensors (as shown) and sits approximately 40 cm from the machine.*

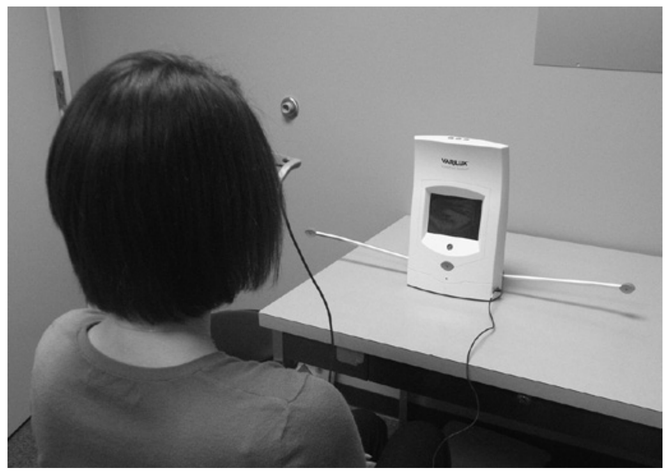

Figure 2: *Proper positioning occurs when the two crosshairs align. The subject then follows the light as it moves between three fixation points, at random.*

The VPS calculates the Gain (Gain = Head Angle/ Target Angle) separately for the right and left side,[23]

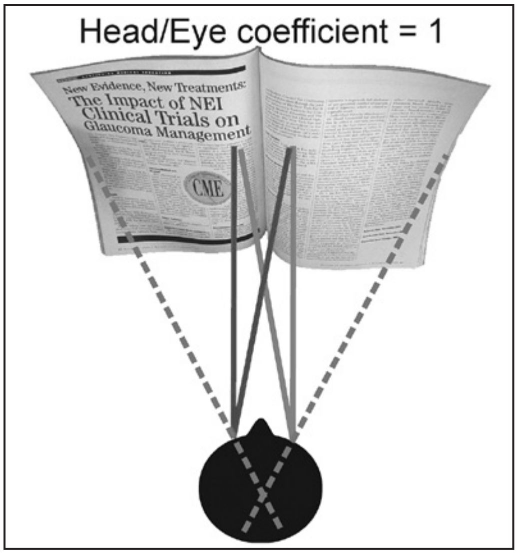

Figure 3: *The sight patterns of a "head mover."*

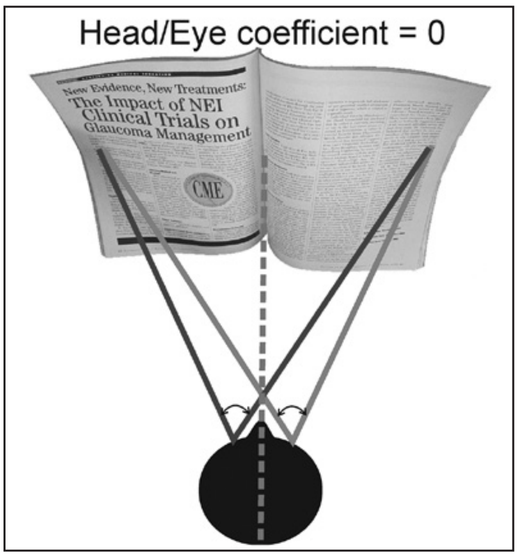

Figure 4: *The sight patterns of an "eye mover."*

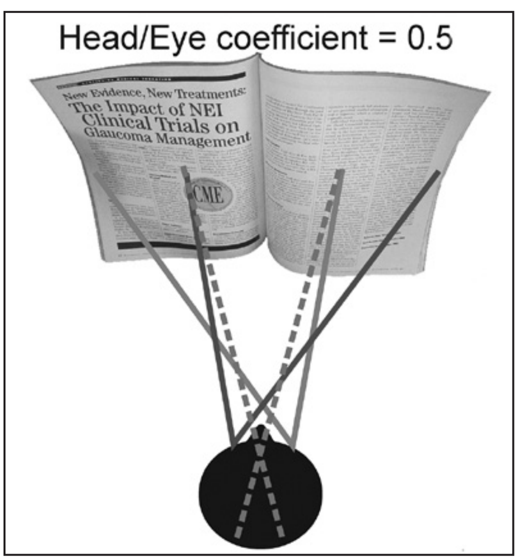

Figure 5: *The sight patterns of an equal "eye/head mover."*

and records the stability coefficient to ensure the accuracy of the reading.[24] A H/E ratio of "1" indicates that the patient views peripheral objects by rotating only the head. When reading a magazine, the patient's eyes remain relatively fixed while the head rotates across the page. (Figure 3) A H/E ratio of "0" indicates that the patient views peripheral objects by rotating only the eyes. While viewing peripheral objects, such as the pages of the magazine, the patient's head continues to face straight ahead while the eyes rotate across the page. (Figure 4) A H/E Ratio of "0.5" indicates that the patient views peripheral objects by rotating eyes and head equally. The patient with an H/E Ratio of "0.5" will rotate the head to the midpoint of each page and use rotation of the eyes to view the extreme edge of the page.[24] (Figure 5)

Potentially, the VPS could be used to aid in the diagnosis of OMD and help direct the optometric vision therapy plan to better suit the patient's needs. Two studies are discussed below. The first study examined whether the VPS was a reliable measure of H/E movement in a population of optometric students. The second study was conducted to determine if the VPS would also be reliable in children, as this population makes up the majority of vision therapy patients. Results from the VPS were then compared to the NSUCO-Saccades test, a reliable diagnostic procedure for ocular motor dysfunction, to determine if the VPS could be useful in assessing ocular saccades and diagnosing ocular motor dysfunction.

Study #1

Methods: Twenty students from the student population at Southern College of Optometry participated in this study. The subjects were required to have at least 20/25 vision at distance and near, and at least 30 seconds of arc stereopsis. Additionally, they could not be strabismic or amblyopic. The presence of a binocular, accommodative, or ocular motor dysfunction was not a disqualification factor in this study. Each subject was tested with the VPS on two visits separated by a minimum of two weeks. Each participant wore their habitual prescription for the duration of this study. A head/eye ratio (H/E) and stability coefficient (SC) were recorded at each visit. An H/E of .01 indicated that the subject is considered an "eye mover" while a ratio of 1.0 signified a "head mover." If the SC was above 0.16, the reading was considered unreliable and repeated.

Participants were instructed how to perform the VPS test prior to testing:

- With the subject seated, the VPS spectacles were properly positioned on the face and positioned approximately 40cm from the sensor on the base of the instrument.
- Participants were told they would see an orange light in the center position which will then move randomly

Table 2: Study 1: H/E Ratio in Both Test Administrations

Patient	H/E Test 1	H/E Test 2	Difference
1	0.05	0.05	0
2	0.03	0.01	0.02
3	0.04	0.04	0
4	0.03	0.1	0.07
5	0.04	0.06	0.02
6	0.05	0.02	0.03
7	0.01	0.01	0
8	0.02	0.04	0.02
9	0.05	0.05	0
10	0.06	0.05	0.01
11	0.08	0.05	0.03
12	0.02	0.02	0
13	0.01	0.01	0
14	0.05	0.04	0.01
15	0.09	0.16	0.07
16	0.02	0.07	0.05
17	0.09	0.06	0.03
18	0.02	0.06	0.04
19	0.01	0.07	0.06
20	0.03	0.04	0.01

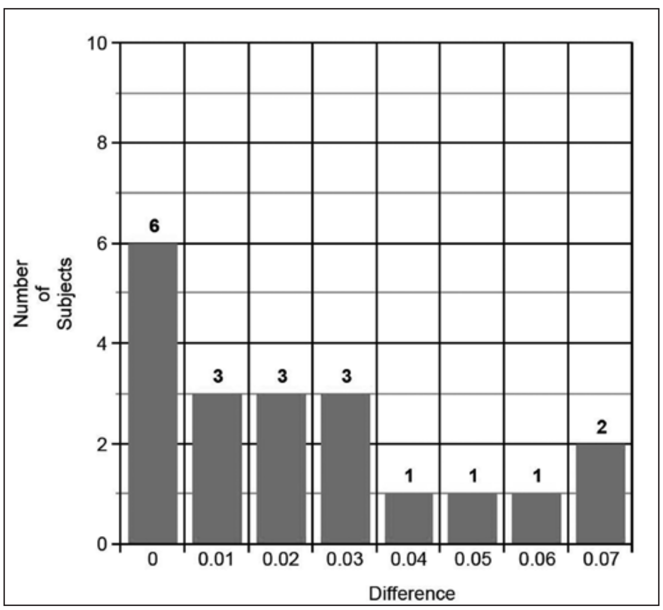

Figure 6: *Study 1: Difference in H/E Ratio between Test Administrations*

toward one of the two arms of the instrument or back to the center position.

- Participants were instructed to follow the light as they would normally. No further instruction was given regarding the movement of their eyes or head.
- After 3 minutes of following the light, the instrument calculates the individual's H/E ratio.

Table 3: Study 2: H/E Ratio in Both Test Administration and the NSUCO

Patient	NSUCO	H/E Test 1	H/E Test 2	Difference
1	20	0.08	0.13	0.05
2	20	0.11	0.06	0.05
3	12	0.73	0.76	0.03
4	18	0.23	0.23	0
5	20	0.06	0.03	0.03
6	11	0.94	0.91	0.03
7	19	0.17	0.14	0.03
8	11	0.82	0.51	0.31
9	15	0.24	0.31	0.07
10	17	0.31	0.35	0.04
11	20	0.02	0.06	0.04
12	20	0.07	0.05	0.02
13	19	0.18	0.15	0.03
14	12	0.73	0.7	0.03
15	20	0.05	0.08	0.03
16	20	0.07	0.06	0.01
17	14	0.6	0.61	0.01
18	13	0.4	0.19	0.21
19	19	0.07	0.03	0.04
20	19	0.03	0.13	0.1
21	19	0.1		
22	18	0.09		

Results: The mean H/E was 0.045 +/- 0.028 for the first presentation and 0.079 +/-0.108 for the second presentation. The mean of the difference between individual test administrations was 0.024 +/- 0.024 and ranged from 0 to 0.07. (Figure 6) No significant difference was found between the two presentations when analyzed with a paired t-test. (p=0.19) All trials were considered acceptable by the device as none registered a stability coefficient greater than 0.16. Of the 20 subjects that completed both test administrations, all were measured as "eye movers." (Table 2)

Study # 2

Methods: Twenty two subjects (14 males and 8 females) between the ages of 6-13 years (mean: 9.5 years) were enrolled. Patients were recruited from the clinic population at Southern College of Optometry.

Figure 7: NSUCO: The subject is standing comfortably and is asked to look at her reflection in either the silver or gold Wolff wand, until 5 roundtrips are completed.

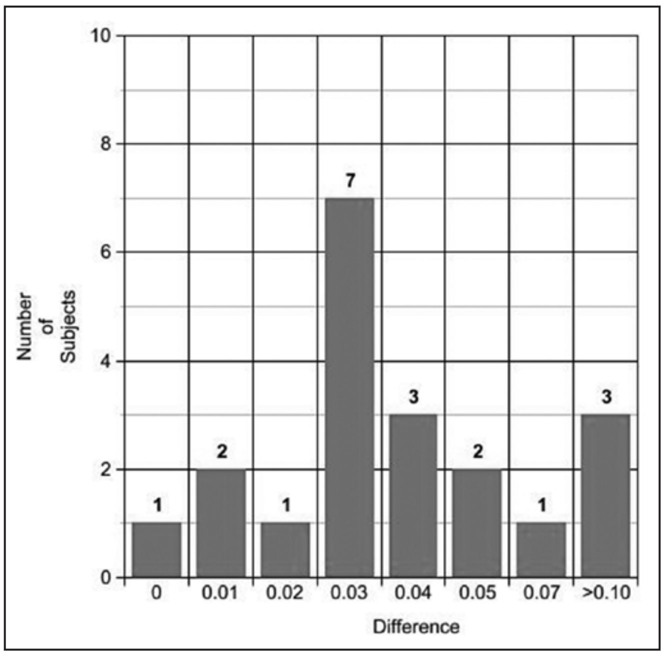

Figure 8: Study 2: Difference in H/E Ratio between Test Administrations

Participants with a diagnosis of strabismus or amblyopia were excluded. The presence of binocular, accommodative, or ocular motor dysfunction was not a disqualifying factor. All participants were tested with the VPS and the NSUCO on the first visit. Test order was randomized to reduce bias. Subjects (n=20) were then re-tested with only the VPS on a second visit, separated by a minimum of two weeks. Two subjects were not available for re-testing. Each subject wore their habitual prescription for the duration of this study.

Participants performed the VPS and NSUCO Saccades tests. The VPS procedure was identical to the first study.

Since the VPS only tests saccades, only the saccades portion of the NSUCO test was used for comparison:

- The NSUCO was administered with the patient standing comfortably, feet shoulder width apart.
- Two Wolff wands were held horizontally <20 cm apart at a test distance between 40cm and the individual's Harmon distance. (Figure 7)
- Participants were instructed to look at their reflection in the sphere of either the silver or gold Wolff wand and to fixate on one ball or the other when instructed for a total of ten times, or 5 roundtrips.
- No further instructions were given regarding the movement of their eyes or head.

Results: No significant difference was found between the two readings for the VPS when analyzed with a paired t-test (p=0.3233). The mean of the difference between individual test administrations was 0.058 +/- 0.074 and ranged from 0 to 0.31. (Figure 8) Additionally, a regression analysis showed an r value of -0.8803 (high inverse correlation) when comparing the NSUCO-Saccades test to the average of the VPS tests. Of the 20 subjects that completed both test administrations, 15 were measured as "eye movers" and 5 were measured as "head movers." (Table 3)

Discussion: The lack of significant difference between the test/retest findings from the first study (optometry students) and second study (children age 6-13) indicates that the VPS is reliable in the determination of H/E. Furthermore, a regression analysis performed comparing the NSUCO-Saccades and the VPS in children age 6-13 showed a strong correlation. Subjects with higher scores on the NSUCO-Saccades, generally showed lower H/E ratios on the VPS, meaning they were "eye movers", while those with lower scores on the NSUCO-Saccades, showed higher H/E ratios on the VPS, indicating these subjects as "head movers." The high correlation between the NSUCO-Saccades and the VPS shows that the VPS could be used as an effective objective procedure to help diagnose ocular motor dysfunction in children.

In looking closer at the data between the studies, there is a small difference in the means between the age groups for the VPS (0.034). This difference, when compared with a standard t-test, proves to be on the cusp of being significant statistically (p=0.055). Clinically, this difference is not likely to change the characterization of the VPS findings. It does not come as a surprise that there is a greater variability in testing when working with children. It is suggested that two measurements be made in children 13 years of age and younger and the results averaged. If there is a large difference between the administrations, a third test should be performed and all three results averaged.

Though there are a variety of ways to diagnose ocular motor dysfunction, the VPS provides a quick and accurate alternative to conventional methods. In comparison to current methods, the VPS has several benefits. With the VPS, the child is not required to verbalize numbers, as in the K-D or DEM, nor are they required to read a passage as in the computer-based eye movement tests (Readalyzer and Visagraph); therefore, the VPS could be used for children with difficulty verbalizing. Like the NSUCO, the VPS measures saccades, however, because this is a computer-based program, it does not depend on the practitioner's observations and interpretation. Since excessive head movement while reading is a sign of OMD, the practitioner can assume that a patient with a H/E ratio of greater than 0.5 might have OMD.

Similar to the Visagraph or Readalyzer, the patient does have to wear a head mounted unit, although it is not as cumbersome as the other two units. Patients with sensory issues may have difficulty wearing the head unit. While patients simply have to look at the targets as they are illuminated, they have to remain stationary on the "Y" or back/front axis for the test to be accurate. If the patient moves out of alignment, the stability coefficient can increase. A patient with physical disabilities that does not allow them to sit still or sit up properly would not be able to perform this test. While the VPS is significantly more expensive than Wolff Wands, an office that procures this instrument to primarily fit the Ipseo lens could potentially use the VPS for ocular motor testing.

Conclusion: The VPS represents a new tool for the diagnosis of ocular motor dysfunction. This information obtained from this device can aid in designing a therapy plan to address and alleviate each patient's specific issue. The VPS represents a reliable, objective method to evaluate eye movements in both children and young adults. Further studies will be aimed at comparing the initial H/E ratios of children enrolled in a VT program versus the H/E ratios after progressing through therapy, and whether the VPS results would differ based on if the patient was sitting, as in this study, versus standing.

References

Note: URLs are functional hyperlinks to Internet addresses.

1. Garzia R. Ocular Motor Dysfunction: Deficiencies of Pursuit Eye Movements. http://www.umsl.edu/~garziar/factsheets/factsheet_ompursuit.pdf. Last accessed 7/23/10.
2. Gallaway M, Boas MB. The impact of vergence and accommodative therapy on reading eye movements and reading speed. Optom Vis Devel 2007;38:115-20.
3. Scheiman M, Wick B. Clinical Management of Binocular Vision: Heterophoric, Accommodative, and Eye Movement Disorders. Philadelphia: Lippincott, Williams, & Wilkins, 2008,383.
4. Maples WC. Ocular Motility Therapy. In: Press L. (Ed) Applied concepts in vision therapy. Santa Ana, CA: Optometric Extension Program, 2008,120-136.
5. Hoffman L. Incidence of vision difficulties in children with learning disabilities. J Am Optom Assoc. 1980;51:447-51.
6. Lieberman S. The prevalence of visual disorders in a school for emotionally disturbed children. J Am Optom Assoc. 1985;56:800-03.
7. Sherman A. Relating vision disorders to learning disability. J Am Optom Assoc. 1973;44:140-41.
8. King AT, Devick S. The proposed King and Devick test and its relation to the Pierce saccade test and reading levels. Available from the Carol E. Shepared Memorial Library. Illinois College of Optometry: 1976.
9. Lieberman S, Cohen AH, Rubin J. NYOSA KD test. J Am Optom Assoc 1983;54:631-37.
10. Garzia R, Richman JE, Nicholson SB, et al. A new visual verbal saccade test: the Developmental Eye Movement test (DEM). J Am Optom Assoc. 1990;61:124-35.
11. Garzia R, Richman JE, Nicholson SB. A new clinical eye movement test compensating for automaticity of number calling. Am J Optom Physiol Opt. 1987;64:54-65.
12. Maples WC. Oculomotor Dysfunctions: Classification of Saccadic and Pursuit Deficiencies. In: Press L. (Ed) Applied concepts in vision therapy. Santa Ana, CA: Optometric Extension Program, 2008,120-36.
13. Vogel G. Saccadic eye movements: theory, testing, & therapy. J Behav Optom. 1995;6:3-12.
14. Richman J, Walker A, Garzia R. The impact of automatic digit naming ability on a clinical test of eye movement functioning. J Am Optom Assoc. 1983;54:617-22.
15. Maples WC. The NSUCO Oculomotor Test. Santa Ana, CA, Optometric Extension Program Foundation, 1995.
16. Maples WC, Atchley J, Ficklin T. Northeastern State University College of Optometry's oculomotor norms. J Behav Optom 1992;3:143-150.
17. Maples WC, Vaughan S, Ficklin T. Verification of the reliability of the King-Devick saccade test. In: Goss D, (Ed). Proceedings of the 1988 NSU Symposium on Theoretical and Clinical Optometry. Tahlequah, OK: Northeastern State University, 1988:33-43.
18. Maples WC, Ficklin T. Test-retest reliability of the King-Devick saccade test and NSUCO ocularmotor tests. J Behav Optom 1991;3:209-14.
19. Maples WC, Ficklin T. A preliminary study of the ocular motor skills of learning disabled, gifted and normal children. J Optom Vis Devel 1989;20:9-14.
20. Maples WC, Ficklin T. Comparison of eye movement skills between above and below average readers. J Behav Optom 1990:1:87-91.
21. Maples WC, Ficklin T. Interrater and test-retest reliability of pursuits and saccades. J Optom Assoc 1988:59:549-42.

22. Varilux Ipseo Information Booklet http://www.marketplacevision.com/content/eyeglasses/lenses/essilor/ipseo/IpseoVisionPrint.pdf. Last accessed 7/23/10

23. Wong J. New Progressive Addition Lens Design: Utilizing the Varilux Ipseo Lens for Non-Adapt PAL Wearers. 2006. http://www.opt.indiana.edu/students/case_rpt.pdf. Last accessed 7/23/10.

24. http://www.eyehealthvision.com/optical/varilux_ipseo.asp. Last accessed 7/23/10.