

THE DEVELOPMENTAL EYE MOVEMENT TEST:

A LITERATURE REVIEW

Abby Maus

Doctor of Optometry

Ferris State University

Michigan College of Optometry

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Ferris State University

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ABSTRACT

This literature review explores several research studies pertaining to the Developmental Eye Movement (DEM) Test in an attempt to determine their overall quality in investigating the usefulness of the DEM test in clinical practice. An analysis of their purposes, methodology, results, and interpretation of data is made. The literature reviewed emphasizes the assessment of clinical validity of the DEM test in optometric practice. In evaluating these studies, the overall ability of the DEM test to assess visual-verbal ocular motor function effectively is determined.

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INTRODUCTION

The Developmental Eye Movement (DEM) test is a clinical visual-verbal ocular motor assessment tool often used in optometric practices to evaluate school-age children's ability to efficiently perform saccadic eye movements used in reading.¹ The test attempts to offer clinicians an economical, effective, and practical alternative to electro-oculography in examining eye movements.²

The DEM test includes three subtests: two are vertical arrays of numbers, while one is horizontal. Before the test is administered, patient data including age in years and months and grade level in decimal form is recorded. The DEM test has standardized instruction and is meant to be performed in a quiet, controlled environment. The DEM test includes a pre-test in which number recognition and articulation is determined; if this initial assessment is not performed accurately and efficiently by the patient, the test is not to be administered. The patient is then instructed to read a column of numbers as quickly as possible and the time in seconds is recorded as Test A. A second vertical subset of numbers is then given to the patient and they are again instructed to read the column of numbers as quickly as possible and the time in seconds is recorded as Test B. Without significant delay, the patient is then asked to carefully read a horizontal subset of numbers spaced sporadically along several lines. Again, the time in seconds is recorded as Test C. The examiner records all substitution, omission, addition, and transposition errors. The Vertical time score is calculated by adding the time in seconds of both Test A and Test B. The horizontal time score is adjusted according to the number of omission and deletion errors using a designated formula. A ratio is determined by dividing the horizontal time by the vertical time. Total errors are calculated by adding the occurrence of all individual errors.² The examiner's booklet includes a manual of percentile ranks based on patient age and grade level in order to determine a patient's performance in comparison to the normal population.

The normative sample of students used to acquire this data range from age six to thirteen with even distribution of males and females.³

Overall, the vertical time allows the examiner to determine a baseline performance of automatic number recognition. On the other hand, the horizontal time allows the examiner to evaluate this same skill when the numbers are situated in such a way that a high level of oculomotor ability is involved. Children with reading deficiencies often have poor rapid automatic naming abilities as well.⁴ A deficiency in the skill of automatic naming will slow the performance of a visual-verbal oculomotor test, but it is difficult to determine whether the results are due to insufficient saccadic skills or poor rapid automatic naming.⁴ A benefit of the DEM test is that it measures rapid automatic naming and attempts to factor out its influence on horizontal saccadic eye movement testing.⁴ Also, since the saccadic skills required for success in this test are similar to those needed for reading, the ratio determined by the DEM test is meant to give some further clinical insight regarding the patient's ability to efficiently read text.

Reading the English language requires short, left-to-right saccades interspersed with fixations and longer right-to-left saccades.³ It is important to note that reading efficiently not only requires the integration of these eye movements; attention, memory, and the utilization and processing of this visual information is also important. Assessing oculomotor function in the clinical setting is certainly important in identifying possible interferences with reading and, ultimately, with learning. In order to better care for patients, it is certainly important to assess these processes in an effective way in the clinical setting. Since the DEM test is readily available, comparatively inexpensive, and easy to use, it is commonly incorporated into pediatric exams to give a better understanding of a patient's abilities.⁵ There have been several studies to help determine the DEM test's ability to give clear, reliable information regarding a patient's reading skills and oculomotor function. This paper discusses several documented studies and evaluates their methodology, content, and conclusions in an attempt to further understand

the reliability of the Developmental Eye Movement test in assessing oculomotor function and its role in optometric clinical practice.

EVALUATING THE LITERATURE

In order to better understand the DEM test and its usefulness in clinic, it is first important to study how certain aspects of a patient's physical and personality traits may affect the results of the test. One important patient trait that may influence DEM test results is attention. In a 2000 study by Coulter, RA, et al, experts attempted to determine the influence attention had on a patient's accuracy of horizontal DEM test results over time. When analyzing the results of a patient's performance on the DEM test, it is important to note the errors made by the patient. The investigators attempted to determine whether these errors were made due to oculomotor deficiency or lack of attention. The study used 22 patients, 12 boys and 10 girls between the ages of 6-11 years of age.² They divided the groups into two groups: those with abnormal DEM scores (below the fifteenth percentile) and those with normal DEM scores.² The researchers stated that if attention was not a factor in the accuracy of patient responses, but were in fact due to oculomotor dysfunction, errors would be evenly distributed throughout the examination.² However, if attention were a factor in errors made, the researchers stated that the number of errors would increase as the time of the examination proceeded.² The study found that more errors in accuracy occurred in the second part of the examination in those patients who had abnormal DEM test results. No differences in distribution of errors were found in patients with normal DEM results.² From these results, the researchers concluded that attention may influence accuracy of the DEM test responses over time in those patients that perform poorly on the test.²

This research project would be difficult to repeat precisely since it is not clear how many students were in each group. Also, one of the weaknesses in this study is the population used. Using a

small population not chosen at random in a study makes it difficult to generalize this information to a larger set of patients in an area of different socioeconomic class. In addition, although the conclusions may be true and have some value when interpreting DEM results, the research fails to incorporate the possibility of poorly sustained accommodative function or binocular performance rather than attention alone. Attention alone may not be the only factor in play in these patients. Also, the study deals with horizontal scores only. One of the benefits of the DEM test is its ability to cancel out poor automaticity skills by using both vertical and horizontal subscores to develop a ratio. Ultimately, this is not a study of the DEM itself, but of attention sustainability on a visual-verbal task. Downfalls of this study aside, it is important to note that attention may surely play some sort of role in DEM testing and a clinician must take this in consideration when evaluating the scores of a patient.

Other important aspects to consider when utilizing the DEM test in clinical practice are the overall visual functionalities of a patient. One study by Webber et al attempted to determine the functional impact of amblyopia in children. In this study, the eye movements of 39 amblyopic children and 42 non-amblyopic children were evaluated using the DEM test.⁶ The group of amblyopic students included only those patients who had undergone amblyopic treatment by surgical or other means.⁶ The group included children whose treatment was successful as well children who remained with greater than .2 logMAR difference in visual acuity between the two eyes.⁶ Although studies indicate binocular coordination of saccades is impaired in strabismic amblyopes,⁷ this particular study included several patients with deprivation amblyopia and refractive amblyopia as well. Previous studies also indicate that amblyopes also have poorer control of fixation and poorer fine motor control, especially in cases where speed and accuracy are relevant.⁸ Webber et al found that, under habitual viewing conditions, amblyopes had no significant difference on DEM outcome scores than the non-amblyopic control group.⁷ This study also determined that under habitual viewing conditions, DEM test measures were not significantly related to visual acuity of either eye, level of binocular function, history of strabismus, or

refractive error.⁷ It is unclear whether these conclusions expressed in the reported discussion were a result of the DEM ratio findings, horizontal time findings, vertical time findings, or total errors. According to the reported results in the table, more total errors as well as increased times on both horizontal and vertical DEM tests resulted in the groups with less stereoacuity. However, the ratios of the horizontal and vertical scores were similar among all patients. Since poor stereoacuity and refractive error would come into play equally between the horizontal and vertical subtests of the DEM test, it makes sense that the ratios would not be significantly affected by amblyopia. Overall, the researchers concluded from this study that the poor reading skills of amblyopes were not explained by poor saccadic eye movement efficiency.⁷ While it is important for clinical purposes to understand that DEM ratios may be unaffected by factors such as binocular function and refractive error, it is important to scrutinize the conclusive findings of this research. Many other studies show that the DEM test does not give a reliable assessment of saccadic oculomotor function at all.^{9, 10, 11, 12}

Ayton et al attempted to assess whether the DEM test is actually a way to quantify saccadic eye movements, reading performance, symptomology, and visual processing speed.¹⁰ Prior to this research, there was no empirical evidence that DEM test results were actually related to eye movements.¹⁰ This study compared DEM test scores with quantitative eye movement recordings by an infrared eye tracker, Convergence Insufficiency symptom survey answers, visual processing data, and reading performance data in a randomized order in an attempt to determine the DEM test's validity as a saccadic assessment tool.¹⁰ This study improved on previous studies in several ways: it used a detailed symptomology survey, used a large population, and focused on the median ages in which the DEM was intended. The study utilized 158 patients; the study did not include patients with poor visual acuity, amblyopia, behavioral disorders (such as attention disorders), history of ocular disease, or poor stereoacuity.¹⁰ The study determined that no significant correlation existed between any component of the DEM test scores and quantitative eye movements such as gain, latency, regressions, and asymptotic peak velocity as

measured by the infrared device.¹⁰ The researchers also determined that no correlation between the DEM and symptomology questionnaires existed.¹⁰ In order to better understand the relationship between DEM scores and visual processing speed (VPS), the researchers used rapid serial presentation of numbers and short, age appropriate words in a fixed location so no saccadic eye movements were required. There was a positive correlated between visual processing speed and verbalization to DEM findings.¹⁰ From this study, it is important to note that the Developmental Eye Movements test may be a better assessment of visual processing speed and verbalization rather than a reliable indirect measure of saccadic ocular control.

There are many other studies which concern the DEM test's ability to identify oculomotor abnormalities and relate them to reading ability. Webber et al attempted to determine the relationship between DEM test results and infrared eye movement records and how they corresponded to reading ability.⁶ The study included 59 children from the same elementary school. The children were evaluated using the DEM test, Visagraph, and standardized scores on the Reading Progress Test (RPT), a reading comprehension test with documented high repeatability and validity.¹² The research determined that there existed a positive correlation between the vertical/horizontal DEM adjusted times and Visagraph reading rates.¹² The study determined no significant correlation between the DEM scores and the standardized RPT scores. However, RPT scores were associated with duration of fixations and calculated reading rates using the Visagraph, but did not correlate to DEM scores.¹² From this data, the researchers concluded that the DEM can identify slow readers, not necessarily patients with poor reading ability.¹² These findings are important since they indicate that reading speed is determined by the duration of fixations and processing time rather than oculomotor control itself. Also, this research suggests that DEM test is a better indicator of reading speed rather that reading achievement and saccadic control. One limitation of this study is that its participants were not selected based on academic ability and PRT scores were skewed toward higher scores. Since the DEM test is often used for

struggling readers, further studies regarding patients with below average reading abilities are warranted.

Another study regarding the clinical application of the DEM test hypothesized that poor readers scored low on the DEM test due to insufficient training of left-to-right saccades. Medland et al conducted a study using 43 English speaking children and 20 English speaking adults as well as 6 Arabic speaking children and 5 adults fluent in both Arabic and English languages.⁹ To these subjects, the DEM test was administered twice, once in the habitual direction and once in the opposite direction. Since the Arabic adults were equally practiced in reading in both directions, the researchers hypothesized that these subjects' DEM scores for the two trials would not be significantly different.⁹ The results of the study were that significant differences did in fact occur only in those subjects who were practiced in a single direction. The researchers concluded that DEM should not be used to evaluate patient's saccadic eye movements with poor reading abilities in the first place.⁹ Although this study is interesting indeed, it is important to note that only 5 Arabic adults were used in this study, in comparison to 69 who were not equally practiced in reading in both directions. Also, in addition to the conclusion that results of the eye movement differences were the effect, not the cause, of poor reading ability,⁹ one must not ignore the inference that socioeconomical and cultural traits must be considered in regards to DEM testing. Also, while the researcher and location were kept constant throughout the English speaking subjects, the Arabic subjects were tested by a Kuwait teacher who was contacted via email and no information regarding the testing procedures was given in the article. In addition, Arabic subjects were given Arabic symbols and no appendix of this form of the DEM test was given. The details of this test format was not expressed and thus this study would be difficult to repeat. Were the Tests A and B of the DEM separated by the same degrees at 33 centimeters as the original DEM test? Were other factors of the DEM kept the same? When evaluating this literature, these may be important questions that could affect the validity of the results. Although it is important to keep the conclusions of this research project in mind

when utilizing the DEM test in clinical practice, one must be skeptical of this study's true validity. More research may be necessary before such conclusion can be made.

Since one of the initial purposes of the DEM test is to help identify oculomotor dysfunction, then the signs and symptoms of this condition should be related to the performance on the DEM test. There are six primary signs and symptoms found to be associated with oculomotor dysfunction: moving head excessively when reading, frequently losing place when reading or copying, skipping lines when reading, using finger to maintain place, rereading lines by mistake, and lacking comprehension of reading material.^{13,14,15,16,17} Tassanari et al designed a study to investigate the relationship between DEM performance and symptoms associated with oculomotor dysfunction.¹¹ The study found that symptomatic subjects had poorer DEM scores than subjects asymptomatic for symptoms associated with oculomotor deficiencies. Also, this study determined that a failing DEM ratio score identified 90% of subjects who were symptomatic.¹¹ While the actual ability of the DEM test to diagnose oculomotor dysfunction was not investigated in this study, it found that the DEM test was in fact successful in identifying patients who had symptoms associated with oculomotor deficiencies.¹¹ This information may be useful in clinical practice, but more testing is necessary to determine the underlying cause of the patient's symptoms.

The same study by Tassanari et al also investigated the test-retest reliability. Since poor repeatability may affect a clinician's ability to evaluate and monitor vision therapy progress, understanding this aspect of the DEM test is important.¹⁷ Many previous studies determined that the DEM has poor repeatability for vertical, horizontal, and ratio results due to improved vertical and horizontal scores on retest.¹⁸ The DEM test is most often used in a setting in which a symptomatic patient presents for a vision therapy workup. A limitation of previous studies is that they did not include such patients in their research populations; the subjects were chosen randomly from elementary

schools.¹¹ Tassinari et al determined that the DEM test was in fact repeatable when given to symptomatic patients presenting for a vision therapy evaluation.¹¹ The research regarding the DEM test's repeatability is useful but, since studies contradict its usefulness in measuring vision therapy progress, more investigation may be needed.^{17,18}

The study designed by Tassinari et al was useful in gaining further insight regarding the DEM's repeatability and connection to symptoms of oculomotor dysfunction. This research was performed using two separate groups. Group 1 included 53 patients who were participating in vision therapy evaluations at a private optometry practice; group 2 consisted of 13 subjects chosen randomly from a parochial school.¹¹ One to four weeks separated the test and retest for both groups.¹¹ The subjects for both groups also answered a symptoms questionnaire. While this study was useful, there were limitations in its design. A very small population was used to determine the test-retest reliability in the asymptomatic parochial schoolchildren of group 2. This fact makes generalization of these findings difficult. Also, the study states that a second test was given to subjects within one to four weeks of the initial test, but no explanation of the waiting periods among the groups was described. The retesting schedule used in the methodology of this study lacks consistency and reproducibility. Although it is important to keep the findings of this study in mind, one must understand the limitations on the DEM test repeatability and relation to oculomotor dysfunction symptomology.

CONCLUSIONS

Literature concerning subjects who have poor reading skills has repeatedly noted the abnormal eye movements associated.^{14,15,16} Evaluating oculomotor performance can range from simple gross observation to complex measures such as infrared recording systems, such as the Visagraph.¹² Gross observation lacks the capability to quantify clinical observation effectively leading to results that lack

repeatability. Infrared recording devices are expensive and not easily accessible to many optometric practices. Fortunately, the DEM test was formed. The DEM test was developed on the assumption that poor saccadic control is a major cause of reading difficulties. Assessing saccadic function aims mainly at identifying vision problems which may interfere with learning. Not only is it economical, but its ease of use makes it a readily available and widely used way of assessing oculomotor control. Because of its widespread use in clinical optometry, it is important to understand the relationship between DEM test scores and direct forms of oculomotor function. In addition, understanding how these measures of eye movements relate to reading ability. In evaluating DEM scores, a clinician must also be aware of what patient traits may affect the results, repeatability of the measurements, and what these results are measuring in the first place.

There have been many studies that have focused on the DEM test and its effectiveness in assessing oculomotor control and reading ability. It is important as a clinician to evaluate these studies with scrutiny to determine the validity and clinical applicability of their conclusions.

Based on recent research, it can be determined that many factors can influence the results of DEM test scores. For example, attention deficiencies can result in increased errors as the test goes on. If the errors increase over time, it may be due to fatigue rather than oculomotor dysfunction alone. Also, when using the DEM test to assess a patient with poor reading skills, it is important to understand what the test is actually measuring. There are several studies that suggest that the DEM is not as effective at assessing oculomotor saccadic function as previously thought.^{9,10} Many other factors come into play in regards to successful scores on the DEM test. Studies show a positive correlation between visual processing speed and verbalization skills.¹⁰ Since these skills are also used in reading, the DEM test may indicate a child who is at risk for academic delay and also offer evidence to support possible treatment of coexisting conditions, not just saccadic function. Because of this evidence, clinical use of the DEM

test on patients is certainly beneficial in clinical optometric practice, but it is important to understand its suggested lack of ability to diagnose oculomotor dysfunction alone.

REFERENCES

1. Garzia RP, Borsting EJ, Nicholson SB, et al. *Optometric clinical practice guideline: care of the patient with learning-related vision problems*. St. Louis: Am Optom Assoc 2000:13-6.
2. Coulter RA, Shallo-Hoffman J. The Presumed Influence of Attention on Accuracy in the Developmental Eye Movement (DEM) Test. *Optometry and Vision Science* 2000;77:428-432.
3. Richman JE, Garzia RP. *Developmental Eye Movement Test, Version 1, Examiner's Booklet*, 1987.
4. Lowther AH, Rainey BB, Goss DA, et al. The Developmental Eye Movement Test as a predictor of word recognition ability. *J Optom Vis Develop* 2001;32:9-14.
5. Kulp MT. Survey of perceptual testing among binocular vision/pediatrics faculty. *J Optom Vis Develop* 2001;32:93-98.
6. Webber AL, Wood J, Gole GA, Brown B. Effect of Amblyopia on the Developmental Eye Movement Test in Children. *Optometry and Vision Science* 2009;86:760-766.
7. Kapoula Z, Bucci MP, Eggert T, Garraud L. Impairment of the binocular coordination of saccades in strabismus. *Vision Res* 1997;37:2757-66.
8. McKee SP, Levi DM, Morshon JA. The pattern of visual deficits in amblyopia. *J vis* 2003;3:380-405.
9. Medland C, Walter H, Woodhouse JM. Eye movements and poor reading: does the Developmental Eye Movement test measure cause or effect? *Ophthalm Physiol Opt*. 2010;30:740-747.
10. Ayton LN, Abel LA, Fricke TR, McBrien NA. Developmental Eye Movement Test: What is it Really Measuring? *Optometry and Vision Science* 2009; 86:223-230.
11. Tassinari JT, DeLand P. Developmental Eye Movement Test: reliability and symptomology. *J Optom*. 2005;76:387-399.
12. A, Wood J, Gole G, Brown B. DEM Test, Visagraph Eye Movement Recordings, and Reading Ability in Children. *Optom Vis Sci* 2011;88:295-302.
13. Griffin JR, Christensen GN, Wesson MD, et al. *Optometric management of reading dysfunction*. Newton, Mass.: Butterworth-Heinemann, 2002.
14. Griffing JR, Grisham JD. *Binocular anomalies diagnosis and vision therapy*, 4th ed. Boston: Butterworth-Heinemann, 2002.
15. Scheiman M, Wick B. *Clinical management of binocular vision*, 2nd ed. Philadelphia: Lippincott, Williams, and Wilkins, 2002.

16. Richman JE, Garzia RP. Eye movements and reading. In: Garzia RP, editor. *Vision and reading*. St. Louis: Mosby, 1996:133-48.

17. Rouse MW, Nestor EM, Parot CJ, DeLand PN. A Reevaluation of the Developmental Eye Movement Test's Repeatability. *Optom Vis Sci*. 2004;81:934-938.