COMPARISON OF THE DEVELOPMENTAL EYE MOVEMENT TEST, THE VISAGRAPH NUMBERS TEST WITH A TEST OF THE ENGLISH LANGUAGE ARTS

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Abstract

The data from Developmental Eye Movement Test (DEM), the Visagraph Numbers Test (VGN) and the English Language Arts (ELA) section of the Test of New York State Standards were compared in a group of sixth grade students. The results indicated that temporal (timed) scores of the DEM and VGN were the most predictive of ELA scores. Further, the DEM and VGN scores were more likely to be significantly correlated if the timing scores were used. DEM vertical errors were also predictive of ELA scores and two VGN scores. The results support the link between reading ability and temporal processing speed and they call into question the omission of normative data for DEM vertical errors.

Key Words

Developmental Eye Movement Test, Visagraph, Test of New York State Standards, Rapid Automatic Naming

INTRODUCTION

Many behavioral optometrists utilize several tests to assess the oculomotor skills of their patients. Maples has classified these into categories of: electrodiagnostic, psychometric and free space testing. He further points out the importance of this type of testing because of potential neurological implications.[1] Another significant use of these tests relates to the role of saccades in reading and more general academic achievement. There is a body of research indicating that faulty saccades are a characteristic of individuals who are reading disabled.[2]

In the present study the overall goal was to determine the relationship of two tests that assess saccadic eye movements to a test that measures several areas of academic achievement.

THE TESTS

Developmental Eye Movement Test (DEM)[a]

This test was devised by Richman and Garzia in 1987.[3] The DEM consists of two sections: A vertical section (Test A and Test B) in which the patient reads aloud a total 80 numbers arranged in four evenly-spaced columns and a horizontal section (Test C) in which the patient reads aloud a total of 80 numbers that are unevenly spaced in 20 rows. The times required to complete the vertical and horizontal tests are recorded. Tests A and B measure visual-verbal automaticity. This patient's performance is further analyzed by dividing the horizontal time by the vertical time. Ideally, the quotient should be slightly greater than one (1). In general, a larger quotient indicates an oculomotor inefficiency in the absence of an automaticity deficiency; a small quotient indicates an inefficiency in automaticity in the absence of an oculomotor deficiency. The DEM is also scored on the number of horizontal errors. Normative data have been established for grades 1 through 8 and for ages 6 years, 0 months through 13 years, 11 months.

Visagraph Numbers Test (VGN)[b]

The Visagraph is an eye movement recording device. It detects the reflection of infra red light from the limbus that is transmitted through goggles that the patient wears while silently reading a short grade appropriate paragraph. This information is transmitted to a computer where the data are collated. Normative data at various grade levels have been established regarding oculomotor measurements such as the number of fixations, regressions, reading rate, average duration of fixation and saccades in return sweeps.

These measurements can also be obtained for patients, who have difficulty with 1st grade prose, by silently reading a series of nine rows comprising 62 single digit numbers that are horizontally arranged and connected by dots. This is the VGN used in the present study. Normative data have not been developed.[4]

Test of New York State Standards (TONYSS)[c]

This test is a series of criterion referenced sub-tests that measure 2nd, 3rd, 5th, 6th and 7th grade students' mastery of English Language Arts (ELA) and Mathematics.[5] The ELA is divided into three sections: (1) Information and Understanding (IU) in which the student must read several passages and answer multiple choice questions; (2) Literary Response and Expression (LRE) in which the student reads passages and writes short answer responses to questions; (3) Critical Analysis and Evaluation (CAE) in which the student writes an essay on a topic related to the content of a passage. The maximum number of ELA points is 46 (20 from IU, 12 from LRE, 14 from CAE). Children with total scores less than 30 require academic intervention.

There were three goals of this study: (1) To establish normative data on the VGN for 6th grade students. (2) To determine relationships between the DEM and VGN scores due to the apparent similarity of their test pages i.e. numbers; (3) To determine relationships between reading ability and oculomotor skills by using the ELA and DEM/VGN scores.

METHOD

Subjects

Parental consent forms were distributed to 378 sixth graders at the Miller Junior High School in Lake Katrine, New York. The students resided in and around Kingston, New York, a city with a population of approximately 24,000 and located 100 miles north of New York City on the west bank of the Hudson River. Seventy-one forms were returned from parents and students who consented and 67 subjects participated in the study. Four students were rejected: one was non-verbal, one had a severe learning disability due to removal of parts of her left parietal and occipital lobes, one moved out of the school district after completing the consent form and one was unable to follow the instructions on the tests.

There were 31 males and 36 females. 55 were Caucasian and 12 were African-American. All children were 11 years, 0 months old to11 years, 11 months old except for one who was 10 years old and seven who were 12 years old. The mean age was 11 years, 7 months with a standard deviation of 5 months. A total of 60 students who participated in the research project had taken the TONYSS during May 2004. The DEM/VGN data from the seven students who did not take the TONYSS were included in the statistics.

Table 1.
6TH Grade DEM Scores of 1987 Standardization[3] and Present Study (2004)

	1987 Mean	2004 Mean	1987 Std. Dev.	2004 Std. Dev.
Vertical Time	36.52	34.54	5.51	6.57
Vertical Errors		0.74		1.51
Horizontal Time	40.88	41.78	7.55	11.30
Horizontal Errors	1.28	2.85	1.67	3.57
H / V Ratio	1.12	1.20	0.12	0.15

Procedures

The DEM and VGN testings were conducted over three weeks during November/December 2004 by the author. At that time he was unaware of the results of the TONYSS that had been administered in May 2004. The school administration provided the use of a conference room illuminated with fluorescent lighting. The subjects were told that they were going to take two tests of tracking or eye movements. A quick screening was done to determine binocular near acuity by viewing a Snellen nearpoint card at 16 inches. In order to reduce the effect of practice, the DEM was the first test administered to 32 subjects and the VGN was administered first to 35 subjects.

Each subject was comfortably seated and viewed the DEM test book that was placed on a 15 degree slant board. The instructions for DEM Tests A and B were, "I want you to read the numbers down the two columns aloud as quickly as you can. When you get to the bottom of the first column, go right to the top of the second column and continue reading until you are done." The instructions for DEM Test C were, "Now I want to read the numbers aloud across as quickly as you can. When you get to the end of the row, go to the beginning of the next row and continue reading until you are done." Subjects were timed with a Radio Shack LCD quartz stopwatch and the times and errors were noted on a recording form.

Page 99 of the Visagraph test book[b] was photocopied and placed on the slant board. The goggles were placed on the patient's head and the pupillary distance was properly adjusted. The instructions were, "I want you to look at each number and read it to yourself as quickly as you can, as if you were reading a book. Tell me when you are finished. Look at the circle at the top of the page until I say to start." The results were electronically transferred to a SONY VIAO laptop computer.

After all testing was completed the examiner opened the files containing the ELA scores from the TONYSS that had been administered in May, 2004. These were used in the calculations as described in the next section.

RESULTS

Near binocular visual acuities were mostly 20/20 followed by 20/40 (6 students), 20/30 (5 students) and 20/60 (1 student).

The DEM scores (Table 1) fell within one standard deviation of the 6th grade scores found by Richman and Garzia in 1987,[3] confirming their reliability. The 1987 data did not list vertical errors because they were rare. The 2004 vertical results are listed in Table 1.

The VGN mean scores and standard deviations are listed in Table 2. They include: the number of fixations and regressions, the fixation duration in seconds, the numbers read per minute, saccades in return sweeps, cross correlation (fraction of the time that right eye and left eye horizontal movements were equal), fixation anomalies (the number of times that one eye moved to the right while the other eye moved less than 1% of the average line length), regression anomalies (the number of times that one eye moved to the left while the other eye moved less than 1% of the average line length) and both anomalies (the number of times in which the eyes moved in opposite directions).

There were four subjects for whom the Visagraph did not register information despite normal appearing graphs on the computer while the numbers were read. This occurred for unexplained reasons

Table 2.
6th Grade VGN Findings

	Fixations	Regressions	Fixation Duration	Numbers Per Min.	Saccades In Return Sweeps	Cross Correlation	Fixation Anomalies	Regression Anomalies	Both Anomalies
Mean	140.92	17.18	0.29	163.71	12.52	0.89	1.45	1.85	6.48
Std. Dev.	33.34	17.42	0.05	72.32	3.85	0.21	1.30	1.97	8.40

Table 3.
Comparison Of ELA Scores & DEM Scores - Pearson Correlation & Significance (P)

	VGN Fixations	VGN Regressions	VGN Fixation Duration	VGN Cross Correlation	VGN Nos. Per Min.	VGN Saccades in Return Sweeps	VGN Fixation Anomalies	VGN Regr Anomalies	VGN Both Anomalies	DEM Vertical Time	DEM Vertical Errors	DEM Horiz. Time	DEM Horiz. Errors	DEM H / V
ELA Total Points Correlation	-.085	-.055	-.343	.128	.198	-.175	-.009	.041	-.078	-.393	-.304	-.262	-.242	.025
P	.536	.690	**.010***	.353	.147	.202	.950	.769	.572	**.002***	**.018***	**.043***	**.063****	.850
IU Points Correlation	-.077	-.075	-.320	.153	.195	-.161	-.023	.002	-.106	-.350	-.238	-.248	-.234	-.032
P	.576	.588	**.017***	.263	.154	.240	.867	.990	.441	**.006***	**.067****	**.056****	.071	.808
LRE Points Correlation	-.039	.007	-.277	.079	.136	-.077	-.051	.119	-.028	-.308	-.210	-.179	-.168	.083
P	.775	.960	**.040***	.569	.323	.577	.712	.389	.542	**.017***	.108	.172	.201	.526
CAE Points Correlation	-.090	-.044	-.263	.065	.154	-.182	.046	.024	-.035	-.343	-.333	-.226	-.197	.056
P	.513	.750	**.053****	.639	.260	.183	.737	.862	.797	**.007***	**.009***	.083	.131	.672

*** = statistically significant at the .05 level or better. ** = near statistical significance.**

Table 4.
Comparison of DEM and VGN Findings– Pearson Correlation & Significance (P)

	VGN Fixations	VGN Regressions	VGN Fixation Duration	VGN Cross Correlation	VGN Nos. Per Min.	VGN Saccades in Return Sweeps	VGN Fixation Anomalies	VGN Regression Anomalies	VGN Both Anomalies
DEM Vertical Time Correlation	.280	.177	.540	.028	-.213	.328	.069	.170	.020
P	**.027***	.170	**.000***	.833	.097	**.009***	.592	.188	.878
DEM Vertical Errors Correlation	.042	-.100	.159	.138	.021	.305	.100	.269	-.009
P	.745	.441	.217	.288	.872	**.016***	.439	**.035***	.944
DEM Horizontal Time Correlation	.350	.179	.496	-.009	-.259	.291	.163	.179	.120
P	**.005***	.163	**.000***	.944	**.042***	**.022***	.205	.165	.354
DEM Horizontal Errors Correlation	.060	-.042	.042	-.002	-.122	.148	-.092	.193	.193
P	.646	.743	.748	.988	.344	.250	.477	.134	.133
DEM H / V Correlation	.260	.086	.151	-.080	-.180	.115	.175	.130	.235
P	**.042***	.505	.242	.540	.163	.375	.174	.315	.066

*** = STATISTICALLY SIGNIFICANT AT THE .05 LEVEL OR BETTER**

even after a conversation with a representative of Taylor Associates. These subjects' DEM and ELA results were included in the statistics.

A statistical analysis was performed using the Pearson Correlation and the significance of each correlation was determined.

A comparison of the DEM and VGN results (Table 4) showed the following statistically significant correlations at the $p<0.05$ level: DEM Vertical Time with VGN Fixations, VGN Fixation Duration and VGN Saccades in Return Sweeps; DEM Vertical Errors with VGN Saccades in Return Sweeps and VGN Regression Anomalies; DEM Horizontal Time with VGN Fixations, VGN Fixation Duration, VGN Numbers/Minute and VGN Saccades in Return Sweeps; DEM H/V Ratio with VGN Fixations.

A comparison of the ELA scores with the DEM and with the VGN (Table 3) showed the following statistically significant negative correlations at the $p<0.05$ level: ELA total score with VGN Fixation Duration, DEM Vertical Time, DEM Vertical Errors and DEM Horizontal Time; IU score with VGN Fixation Duration and DEM Vertical Time; LRE score with VGN Fixation Duration and DEM Vertical Time; CAE score with DEM Vertical Time and DEM Vertical Errors.

Negative correlations between ELA and DEM scores that approached statistical significance were: ELA total score with DEM Horizontal Errors ($p=.063$); IU score with DEM Vertical Errors ($p=.067$) and DEM Horizontal Time ($p=.056$); CAE score with VGN Fixation Duration ($p=.053$).

DISCUSSION

Comparison of the DEM AND VGN (Table 4)

Temporal measurements were involved in most of the statistically significant correlations. Students with longer DEM vertical and horizontal times had significantly more VGN fixations, longer VGN fixation durations and more VGN saccades in return sweeps. Students with longer DEM horizontal times also had significantly more VGN numbers per minute.

The DEM protocol also calls for dividing the horizontal time by the vertical time to determine if the student's slow horizontal time is solely due to slow visual verbal automaticity (low ratio) or if poor oculomotor skills are also a factor (high ratio). Students with high H/V ratios had significantly more VGN fixations. More fixations meant that more time was expended moving the eyes from left to right during the test.

The vertical error rate was low but it was a very sensitive test in identifying those students with oculomotor inefficiency as measured by the VGN. Students with high DEM vertical errors had significantly more VGN saccades in return sweeps and VGN regression anomalies. There were no significant correlations between DEM horizontal errors and any VGN measurements that were not related to the time factor. Horizontal DEM errors can be due to rereading numbers (addition errors), skipping numbers (omission errors), transposition errors in which consecutive numbers are switched and substitution errors due to naming mistakes. A child with excessive DEM addition errors may be more likely to have more VGN fixations and regressions. A child with excessive DEM omission errors, who skips several lines, may be more likely to have fewer VGN fixations and regressions. Excessive DEM substitutions may have no effect on VGN fixations and regressions. Therefore it is not surprising that there was no significant correlation between DEM horizontal errors and VGN fixations or regressions.

In general the number of VGN fixations, regressions or saccades in return sweeps had little relationship to non-temporal DEM data. This was probably due to the important differences between the DEM and VGN although the two tests appear to be superficially similar. DEM numbers are 3 mm. high (20/100 reduced Snellen acuity at 40 cm.) while VGN numbers are 33% larger at 4 mm. high (20/140 reduced Snellen acuity at 40 cm.). The spacing between lines is 5 mm. in the DEM and 6 mm. in the VGN. The DEM includes the numbers 1 through 9 while the VGN uses numbers 1 through 5. There are 5 digits per row in the horizontal DEM while the number of digits per row in the VGN varies from 6 to 8 with an average of 6.9 letters per row. The horizontal DEM has 16 rows and a total of 80 numbers while the VGN has 9 rows and a total of 62 numbers. The DEM requires pronunciation aloud of each number which involves motor activity of the larynx, lips and tongue while the VGN does not. The most important difference is that the spaces between DEM numbers are unfilled while the spaces between VGN numbers are connected with dots, making it very difficult to lose one's place. From this information we can conclude that the VGN test pattern is easier to fixate and identify due to the larger number size, closer horizontal spacing, the presence of the connecting dots, the smaller variation in the numbers presented and the lack of oral expression.

Comparison of ELA and DEM/VGN (Table 3)

ELA scores were most likely to be correlated with VGN and DEM results that were related to time factors. VGN fixation duration was significantly negatively correlated with three out of four ELA measurements and it approached significance with CAE. DEM horizontal time was significantly negatively correlated with ELA total points and it approached significance with IU points. DEM vertical time was significantly negatively correlated with all ELA measurements.

The DEM vertical test time has been found to be significantly related at the $p<0.001$ level to a test of Rapid Automatic Naming (RAN).[6] RAN, which is slow in reading disabled children, involves many factors including visual processing, phonological access and motoric processes and slow RAN can be due slowness in any one of them, slowness in their integration or a general timing deficit.[7] The results of the findings presented in this paper support the observation that a child, who processes information more slowly, is more likely to score lower on reading tests.

The importance of the DEM vertical test was also confirmed by Lowther, et al; they found a correlation of -0.37, significant at the $p<0.001$ level, between the DEM vertical time and the Woodcock Reading Mastery Test-Revised, a word identification test, in 1st grade children.[6]

DEM vertical errors were significantly negatively correlated with ELA total points and CAE points and they approached significance with IU points. The majority (71.5%) of vertical errors were addition errors followed by substitution and omission errors (12.25% each) and transposition errors (4%). Garzia and Richman's decision to exclude an analysis of vertical errors is not supported by the

data which shows that 6th graders, who make significantly more vertical errors than the mean, are more likely to have low reading scores.

Garzia and Richman found negative correlations between the reading subtest of the Wide Range Achievement Test and all DEM measures other than vertical errors, significant at the $p<0.001$ level.[3] DEM horizontal errors almost achieved significant negative correlation with ELA total points at the $p<0.05$ level in this study. This study did not find a significant correlation between the H/V ratio and reading scores. The mean age of students in the Garzia/Richman study was 8 years 9 months which was 2 years 10 months younger than the sample in this study. This may provide an explanation for any differences between their results and the statistics from this research. The older child, with almost three more years of reading experience, may be more likely to infer the meaning of a reading passage from some key words despite having deficient oculomotor skills.

CONCLUSIONS

More temporal factors than non-temporal factors were correlated with reading scores, supporting the contention that slow processing speed is a factor in reading disability. More DEM and VGN temporal factors than non-temporal factors were correlated when comparing those two optometric tests. This can be explained by the fact that it is more difficult to lose one's place on the VGN due to the design of the test page. DEM vertical errors were predictive in reading scores and two VGN measurements. DEM horizontal errors approached statistical significance with the ELA total score and probably would have reached significance at the $p<0.05$ level with a larger sample size.

FURTHER SUGGESTED RESEARCH

The establishment of VGN normative data for students in grades K through 5 would allow professionals to administer the VGN to illiterate elementary students and make meaningful conclusions about their oculomotor performance. A re-design of the VGN test page, using numbers 1 through 9, 3 mm. high with no connecting dots, would create a test more comparable to the DEM.

DEM normative data for ages 6 years 0 months to 13 years 11 months and grades 1 – 8 should be re-established, including statistics for the rare but significant vertical errors.

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