The Adult Developmental Eye Movement Test (A-DEM)

A Tool for Saccadic Evaluation in Adults

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ABSTRACT

The Developmental Eye Movement test (DEM), is standardized and designed for evaluating oculomotor behavior in children, under 14 years of age. In this study we sought to create a version to be used above the age of 14 by using double rather than single digits. This resulted in twice the amount of numbers to be called out during the test. We administered this modified version for adults (A-DEM) to 520 normal Spanish-speaking subjects ranging from 14 to 68 years of age. They were divided into 11 age groups. The subjects were assessed to be cognitively intact with no known neurological or ocular disease. All subjects had corrected visual acuity of 20/20 or better at near and viewed the targets binocularly. The times (in seconds) to call out the numbers in Spanish in for the vertical and horizontal subtests were recorded. Errors were also recorded. A horizontal/vertical (HV) ratio was determined based on these results.

The mean (HV) ratio for the sample was 1.04(0.10) with no significant difference due to age . A significant increase in time for vertical performance was found in subjects older than 38 years ($p<0.05$) and for horizontal performance in subjects older than 43 years ($p<0.05$). There was no significant difference in the ratio as a function of age. We present the age-based normative values for our sample. We also found changes in horizontal saccade ability with an apparent tendency to take longer as age increased in later decades of life. The potential affect of ageing on visual-verbal and eye movement processing are discussed. Further studies are needed for this adult level oculomotor test in English-speaking populations as well as selected elderly populations.

KEY WORDS

Developmental Eye Movement Test (DEM), Adult Developmental Eye Movement Test (A-DEM), Saccade, Horizontal to Vertical Ration (HV), Spanish sample population

Introduction

The act of reading is a highly complex, integrated function involving both physiological and psychological processes. Reading requires efficient sacaddic eye movements enabling the reader to rapidly redirect the line of sight so that the point of information stimulates the fovea. Measurement of eye movements supplies the clinician with useful information of how the reader processes visual information during reading. [1,2]

A variety of assessment procedures has been developed to evaluate saccades. Based on this need, procedures using a visual-verbal format were established. [3] Visual-verbal format tests are inexpensive, easily administered and provide quantitative evaluation of eye movements in a simulated reading environment. Their main advantage is ease of administration without the need for sophisticated instrumentation.

These visual-verbal tests purport to assess oculomotor function on the basis of the time required to attend, perceive and rapidly name a series of numbers (single digits). Reading and naming require lexical access and retrieval in the context of rapid scanning, sequencing and processing of serially presented material.

The Developmental Eye Movement (DEM) test is a clinical oculomotor test of a visual-verbal format which has been standardized and its reliability and validity have been shown. [4,5]

In this test, oculomotor performance is judged by verbal naming speed and accuracy. There are two parts of the DEM test requiring rapid, continuous naming. The Horizontal Test assesses rapid naming in a format requiring horizontal saccadic eye movements, whereas the Vertical Test does not. By comparing and contrasting the Vertical Test and Horizontal Test time results, oculomotor skill can be differentially assessed.

However, the DEM is designed for evaluating oculomotor behavior in children, and is currently standardized for patients under 14 years of age. It would beneficial to have an adult form of this well accepted test . The purpose of this study was to design an adult visual-verbal format oculomotor test based upon the DEM test principles.

Subjects

The test was evaluated in a sample of 520 subjects ranging in age from 14 to 68 years from a Valencian population (East-

Table 1. Age Ranges in Subject Goups		
Group	Age range (years)	N
1	14-18	48
2	19-23	52
3	24-28	60
4	29-33	45
5	34-38	45
6	39-43	45
7	44-48	45
8	49-53	45
9	54-58	45
10	59-63	45
11	64-68	45

ern Spain). They were patients in an optometric clinic and were randomly chosen volunteers. The gender distribution was relatively balanced (53.2% male and 46.8% female) . The sample population was divided into eleven groups, each spanning five years (Table 1). No subject had a history of neurological or ocular disease, were reportedly free of any anticonvulsant or sedative-hypnotic medication, and were considered cognitively intact, as assessed by a brief examination of mental status.

All subjects had corrected visual acuity of 20/20 or better at near and viewed the targets binocularly. All the subjects were inexperienced in the method. Saccadic movements were recorded individually using the Adult DEM (A-DEM) by four optometrists experienced in the use of the DEM test.

Materials

In this study, the DEM was modified by using double rather than single digits. This resulted in twice the amount of numbers to be called out during the test as well as increasing the cognitive visual-verbal retrieval demand on rapid number calling. The Adult DEM (A-DEM) consists of three sub-tests with the same distribution of the established DEM: vertical test-1 (V1; Figure 1), vertical test-2 (V2; Figure 2) and horizontal test (H; Figure 3). V1 and V2 each contains 40 double digit numbers while H contains 80 double digit numbers. The subject views the test cards at 33 cm (VA 20/60).

Procedure

The procedure is the same as the DEM test with the exception that a pre-test card to assess the ability to call out the numbers was not included in this adult version of the DEM. Further, the subjects were instructed to call out the whole number as opposed to single numbers, e.g., 29 as opposed to 2, 9.

The subjects read the first two vertical tests (V1 and V2) and the total completion time is measured in seconds (V). The completion time and number of errors for the third test (H) are recorded. Because of the incidence of errors in this sub-test, a corrective formula is used in order to obtain the horizontal adjusted response time (HA):HA = HT x 80 / (80 - O + A). being: HT = horizontal time, O = omissions and A = additions.

A ratio is obtained by dividing the horizontal adjusted time by the vertical time: Ratio = HA/V. This allows for comparisons of the automaticity of naming the numbers to the effectiveness of the saccades.

TEST V_1

32	43
71	56
54	21
96	14
81	75
25	54
53	39
74	72
43	43
67	81
14	76
49	47
76	62
62	59
37	93
73	23
67	34
35	67
78	41
91	18

Figure 1 : Vertical test-1 of the M-DEM.

Figure 1. Vertical A-DEM (1)

TEST V_2

61	76
34	92
26	33
93	95
12	24
71	19
46	44
65	72
58	61
29	36
57	25
35	58
76	74
44	47
84	66
43	31
41	76
56	56
29	97
18	85

Figure 2: Vertical test-2 of the M-DEM.

Figure 2. Vertical A-DEM (2)

TEST H

32		74	53			96			82
25	51			74		43			65
18			45		75		62		38
71		93		36		94			21
44	54				21			16	73
57			36		78		47		86
70	47		63	51					29
93		20			39		63		42
66	30	21		94					15
79				47		63	51		28
52		33	72			48			81
43			54		23			16	74
76	93	36			91				27
19			46			76		65	30
22		59		71			43		63
35	76		54			94			86

Figure 3: Horizontal test of the M-DEM.

Table 2. Means (SD) for Vertical Score Time		
Group	Vertical time (secs)	
	Mean	±SD
1	50.50	8.64
2	45.23	6.60
3	44.93	7.22
4	47.43	7.46
5	47.18	7.88
6	51.24	7.64
7	54.58	10.01
8	57.64	11.18
9	57.04	12.46
10	64.37	8.43
11	66.00	10.44

Figure 4 :Horizontal Time vs. Vertical Time (Secs) for each Age Group with Trend Lines

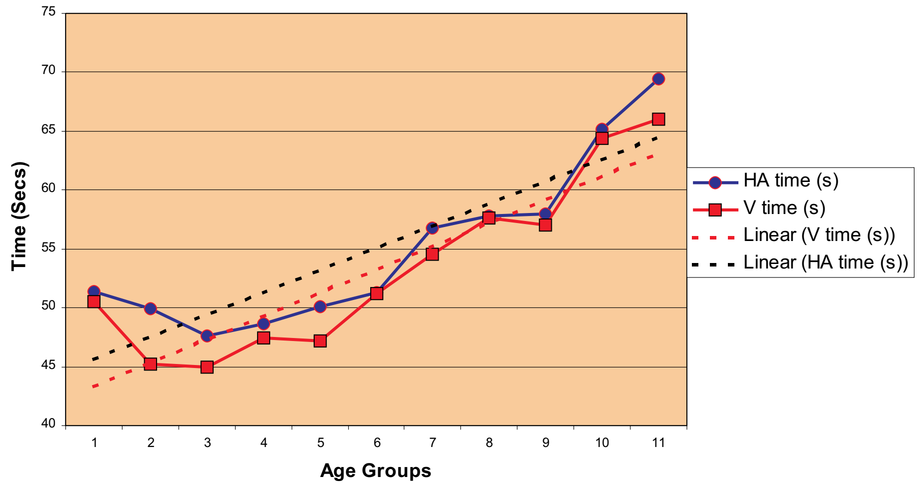

Table 3. Means (SD) for Horizontal Score Time		
Group	Horizontal time (secs)	
	Mean	±SD
1	51.21	12.85
2	49.93	8.23
3	47.63	7.32
4	48.61	7.73
5	50.09	10.47
6	51.34	6.92
7	56.80	10.78
8	57.82	9.45
9	58.01	10.95
10	65.18	10.87
11	69.46	10.14

Figure 5: Horizontal / Vertical Ratio for each Age Group with a Linear Trend Line for all age Groups

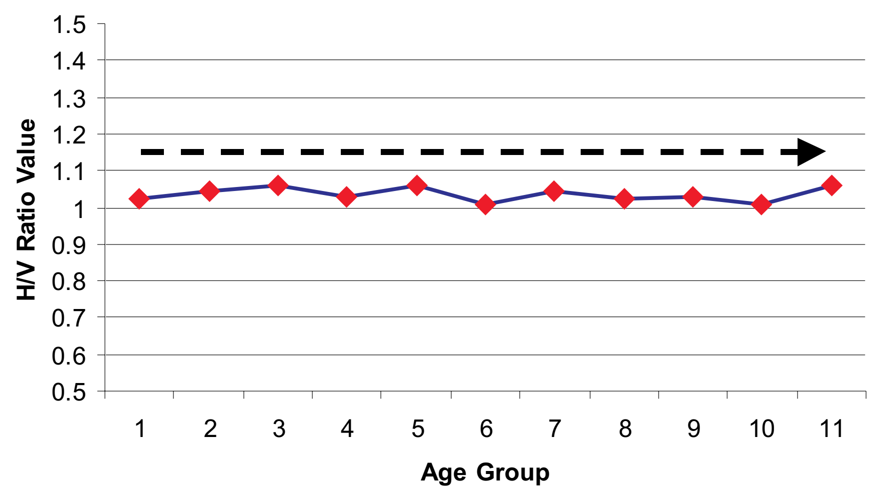

Table 4. Means (SD) for Horizontal/Vertical RatioScore		
Group	Ratio	
	Mean	±SD
1	1.01	0.10
2	1.08	0.12
3	1.06	0.13
4	1.03	0.11
5	1.06	0.11
6	1.01	0.09
7	1.05	0.11
8	1.01	0.11
9	1.03	0.10
10	1.01	0.08
11	1.06	0.10

RESULTS

Means and standard deviations for the values obtained were calculated for horizontal adjusted time, vertical time, errors in horizontal and in vertical tests, and ratios for all groups. Tables 2 and 3 present the results obtained in each age group, from 14 to 68 years, with the A-DEM for horizontal adjusted and vertical times and horizontal and vertical errors. These results represent the average values with their respective standard deviation (SD) values that we take as normative for each age group.

The results for the time values were plotted in order to make an easy comparison of time versus age. The results obtained in horizontal and vertical sub-tests are shown in Figure 4. The mean values for the vertical and horizontal scores were significantly related (Pearson r= 0.98; P<.001). These results indicate that subjects required more time to complete the horizontal task in relation to the vertical task, except in group 6. In order to compare the differences between horizontal and vertical times, a paired t-test was performed between data of both times at each age group tested . There was a significant difference in the scores as a function of age (P<.005). As age increased, the horizontal and vertical times increased. These results are better observed in Figure 4, where linear trend lines were calculated for the vertical and horizontal scores. By inspection, it can seen in this graph that there is a consistent, yet clear difference between the two scores as they show an increased slope due to the increased time to respond during the test.

The Mean (HV) ratio for the total sample was 1.04 (0.10) with no significant difference due to age as shown in Table 4. A significant increase in time for vertical performance was found in subjects older than 38 years ($p<0.05$) and for horizontal performance in subjects older than 43 years ($p<0.05$). Yet, there was no significant difference in the ratio as a function of age. This is exhibited in Figure 5.

DISCUSSION

It is important to note that the results were obtained with Spanish-speaking subjects. If numbers were named in other language, the results could vary, However, Velazquez et al asked the question, "Do DEM test scores change with respect to the language?"[6] In their study, the authors provided normative data for a Spanish speaking sample from ages 6 to 11 years for the DEM . Their results indicated that the test does not appear to be linguistically related since the Spanish norms were in agreement with the established English based norms.

Statistical analysis revealed significant differences in vertical A-DEM results for groups 6 and higher, i.e. ages 39 to 68 yrs., ($p<0.025$). For younger adults (groups 1 to 5) there were no significant differences in vertical A-DEM scores, ($p>0.05$). There was an average of 2.13% increase in the vertical time change in the younger group, while the older group had an average increased change of 29.29%.

We analyzed vertical A-DEM results for determining the cause of horizontal A-DEM differences. Vertical A-DEM times were increased for subjects older than 38 years old and horizontal A-DEM times were increased for subjects older than 43 years. However, since the A-DEM ratios were normal in these groups and there was a correlation of $r=0.98$ between the vertical and horizontal scores, it is unlikely that impaired saccades were the primary cause for higher horizontal A-DEM times. Rather, impaired language processing automaticity would appear to be the major influence on the horizontal and vertical A-DEM scores, i.e., not a decrease in saccadic efficiency. This is consistent with the original DEM where an increase in vertical subtests time is indicative of a delay in automaticity and language processing skills.

Throughout our lifespan, there are noticeable age differences in the speed of information processing. These differences are consistently related to performance on measures of higher-order cognition. As people age, there are clear reductions in visual-verbal processing speed, lexical access, and other mental processes.[7-13] Studies have suggested that longer response times in older adults could be partly due to increased caution in responding, with a propensity to emphasize accuracy to the detriment of speed.[14] Other studies examined the role and effect of age differences in perceptual speed, accessing and retrieving information. In older adults, the perceptual speed in accessing and retrieving information was slower than younger adults at feature extraction, lexical access, and accessing category information.[15,16]

As a result, the vertical A-DEM performance, as evidenced in our results, would be appear to be affected by these various age related language processing changes. In addition, it is reasonable that other variables, such as health issues, also contribute to a reduced processing efficiency as one ages.

These changes were not observed in the original DEM test for ages 6 through 14 years. Indeed, here the trend was for increased speed of processing as the child aged. Therefore, it appears most likely that automaticity reduction and reduced processing speed are the underlying factors for the increased A-DEM scores.

Assessing developmental changes in visual function is not new to optometry. The original DEM assesses language processing and eye movement changes in the growing child. Tests that probe visual perceptual skills are age normed and administered to children during their pre-school and school age years on a routine basis by many optometrists.

Generally, we tend to limit our consideration of such changes primarily within the domain of the growing child. Yet, the child does grow up and becomes an adult. As the adult grows, there are further developmental changes in the visual system. For instance, evaluating and treating the developmental changes of accommodation is a basic component in the examination of adults as they approach pres- byopia. The results of this study indicate the developmental changes that occur in saccadic eye movements over the adult years. This A- DEM test may serve as a clinical tool in numerous areas of vision care for the adult patient.

Further studies are needed to elaborate on these findings. We intend to investigate the use of the A-DEM : (1) to test normal healthy adults in an English speaking sample, (2) to test adults with known neurological, and cognitive restrictions, (3) to test adults with known saccadic and other oculomotor dysfunctions with A-DEM test and (4) evaluate adults older than 68 years old to determine whether A-DEM ratio is not affected by age in older groups.

CONCLUSIONS

We present a normative study and values for an adult form of the DEM test in a Spanish-speaking sample. Distinct developmental changes in horizontal reading-type saccades after age 13 years were found with an apparent tendency to take longer in visual verbal processing speed as age increased, especially in later decades of life. The potential affect of ageing on visual-verbal processing speed and automaticity and the associated eye movement performance has been discussed. Further studies are needed for this adult level oculomotor test in English-speaking as well as selected elderly samples. Additionally the validity and reliability of the test should be determined.

Acknowledgements

An earlier version of this study was presented at the annual meeting of the American Academy of Optometry poster session in San Diego, California, December 2003.

Disclosure

Dr. Richman is a consultant to Bernell Corporation which publishes and sells the DEM Test.

References

1. Solan HA. Models of reading disability and their implications. In: Hung GK, Ciuffreda KJ eds. Models of the visual system. NY: Kluwer Acad/Plenum Pubs, 2002:679-710.
2. Rayner K. Eye movements in reading and information processing: 20 years of research. Psychol Bull 1998;124(3):372-422.
3. Kulp MT, Schmidt PP. Effect of oculomotor and other visual skills on reading perfor-

mance: a literature review. Optom Vis Sci 1996;73(4):283-92.
4. Garzia RP, Richman JE, Nicholson SB, Gaines CS. A new visual-verbal saccade test: the development eye movement test (DEM). J Am Optom Assoc 1990;61(2):124-35.
5. Santiago HC, Perez A. Test-Retest Reliability Of The Developmental Eye Movement Test. Scientific Poster, American Academy of Optometry, December 1992.
6. Fernandez-Velazquez FJ, Fernandez-Fidalgo MJ. Do DEM test scores change with respect to the language? Norms for Spanish-speaking population. Optom Vis Sci 1995;72(12):902-6.
7. Rastatter MP, McGuire RA. Some effects of advanced aging on the visual-language processing capacity of the left and right hemispheres: evidence from unilateral tachistoscopic viewing. J Speech Hear Res 1990;33(1):134-40.
8. Rastatter MP, Lawson-Brill C. Reaction times of aging subjects to monaural verbal stimuli: some evidence for a reduction in right-hemisphere linguistic processing capacity. J Speech Hear Res 1987;30(2):261-7.
9. Salthouse TA. Aging and measures of processing speed. Bio Pychol 2000;54(1-3):35-54.
10. Kail R, Salthouse TA. Processing speed as a mental capacity. Acta Psychol 1994;86(2-3):199-225.
11. Myerson J, Hale S, Chen J. Lawrence B. General lexical slowing and the semantic priming effect: the roles of age and ability. Acta Psychol 1997;96(1-2):83-101.
12. Wingfield A, Poon LW, Lombardi L, Lowe D. Speed of processing in normal aging: effects of speech rate, linguistic structure, and processing time. J Gerontol 1985;40(5):579-85.
13. Gorman MF, Fisher DL. Visual search tasks: slowing of strategic and nonstrategic processes in the nonlexical domain. J Gerontol Series B-Psychological Sciences & Social Sciences 1998;53(3):P189-200.
14. Brebion G. Language processing, slowing, and speed/accuracy trade-off in the elderly. Experimental Aging Research 2001; 27(2):137-50.
15. Perceptual speed in adulthood: cross-sectional and longitudinal studies. Psychology & Aging 1989; 4(4):443-53.
16. Petros TV, Zehr HD, Chabot RJ. Adult age differences in accessing and retrieving information from long-term memory. J Gerontol 1983;38(5):589-92.

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Date accepted for publication:
July 14, 2003