THE NEED FOR ADULT NORMS ON THE DEVELOPMENTAL EYE MOVEMENT TEST (DEM)

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Abstract

The Developmental Eye Movement Test (DEM) has several potential advantages for assessing saccadic performance of adults including those following acquired brain injury. However, it was developed and normed on children. This study investigated the performance of young adults on the DEM. We administered the DEM following standardized procedures to a convenience sample of 50 community-living young adults. Mean age of subjects was 25.0 years (range = 22.3-26.9); 90% were college students. We compared the performance of the young adults with that of the oldest DEM normative group (i.e., 13-year-olds). Mean vertical times ($p < 0.001$) and adjusted horizontal times ($p < 0.001$) were significantly different for the two groups. Ratio scores were significantly different ($p < 0.001$) for the two groups on a Chi-square goodness-of-fit test. These results indicate that the performance of young adults on the DEM differs from that of early adolescents. We recommend that further studies be done to establish age-specific norms.

Key Words

brain injury, Developmental Eye Movement Test (DEM), oculomotor, saccade, vision

INTRODUCTION

The Developmental Eye Movement Test (DEM) is a well-accepted clinical test of saccadic eye movements in children.[1] Administration of the DEM consists of first timing the child reading aloud two vertical arrays, each consisting of 40 single-digit numbers evenly spaced in two columns. This is followed by timed reading of a horizontal array consisting of the same numbers in the same order, but unevenly spaced within each row. After adjustment of the horizontal time for errors, the ratio of the adjusted horizontal time to the combined vertical times is calculated. Horizontal and vertical times, number of errors, and ratio scores are compared to standardized norms for eight different age groups, between 6 and 13 years, or for grades one through eight.

Saccadic eye movement impairment following acquired brain injury

While the DEM was developed and standardized for use with children, saccadic eye movement function is also of concern in adults with acquired brain injury (ABI), e.g., traumatic brain injury (TBI) and stroke. The full extent of oculomotor impairment following brain injury has not been determined; however, it appears that saccades, along with other primary visual functions, are vulnerable to brain damage. The cluster of vision problems occurring post-TBI described by Padula, Shapiro, and Jasin[2] includes saccadic impairments along with other oculomotor dysfunctions. In a study of a consecutive series of individuals with severe traumatic brain injury or cerebral vascular compromise living in a sub-acute extended care facility, Suchoff, Kapoor, Waxman, and Ference[3] found nearly 40% with oculomotor dysfunctions including impaired saccadic movements. Similarly, Schlageter, Bray, Hall, Shaw, et al.[4] reported saccadic impairment in 38% of rehabilitation inpatients with TBI who had recovered sufficiently to participate in a vision assessment. These findings appear to reflect a higher occurrence of oculomotor dysfunction than would be expected in a healthy adult population.[3,4]

Along with the growing evidence for oculomotor dysfunction following ABI, rehabilitation clinicians have begun to recognize the potential impact of impaired foundational oculomotor skills on higher-level function in this population.[5] Accurate input to the visual system underlies accurate perception and cognitive processing of visually based information and, subsequently, safe and efficient performance of everyday activities. In a British study of eye movements during tea making, Land, Mennie, and Rusted[6] found that saccades guided and monitored nearly every component of even this well-rehearsed activity. Throughout the task, saccades moved the center of gaze to objects about to be manipulated or to the place where the most valuable information for the next action could be obtained.

Accurate incoming visual information is even more critical for individuals with brain damage whose cognitive and/or physical capacities are compromised. Inadequate visual information may add to the functional problems that result from impairments in other body systems. At the same time, individuals with cognitive and/or physical impairments may have difficulty compensating for inadequate visual performance. In addition, interpretation of degraded visual information following brain injury may require a disproportionate amount of cognitive resources, leaving less processing capacity for remembering information, planning and executing appropriate responses, and other cognitive tasks.[7] Many rehabilitation activities following brain injury include a visual component and performance on these tasks can be negatively impacted by impaired oculomotor skills. Thus, it is possible that unidentified and untreated oculomotor impairments may hinder a client from fully benefiting from rehabilitation interventions and negatively impact the speed and extent of recovery.[8,9]

It would be useful for clinicians working with adults with brain injury to have assessment methods to assist in identifying individuals with impaired saccadic eye movement function. The DEM has several inherent advantages for this purpose. The ratio score compares the time required to read the unevenly spaced horizontal array, where demand for saccadic eye movement is high, to the time required to read the evenly spaced vertical arrays, where the saccadic eye movement demand is less. This comparison allows for adjustment for the potentially confounding effect of number-naming skill that may be associated with other visual-verbal saccadic assessments[1]. This feature would be particularly advantageous for testing people with brain injury where speech and language impairments are common. The time required for DEM test administration is relatively short which would be advantageous for a population where attention span and concentration can be limited. The DEM's use of scores based on timed performance and accuracy may provide more objective ways of comparing change over time than tests that rely on visual observation of saccades. In addition, the DEM test materials are inexpensive and easily portable.

However, as the DEM was developed for use with children, interpretation of the results of testing adults on the original DEM would be limited to comparison to the norms for the oldest childhood age group (i.e., 13 to 13.11 years). The DEM is a norm referenced test, i.e., it evaluates how test takers perform relative to others in a specific "norming" sample or specific group of test. While making test interpretations based on extension of norms to non-normed groups is *not* recommended, it is even more problematic given uncertainty over the precise nature of changes in saccadic eye movement function over the life span.

Sampredo, Richman, and Pardo[10] recently developed an adult version of the DEM, termed the Adult Developmental Eye Movement Test (A-DEM). However, this test was developed in Spain with Spanish speaking subjects; consequently, there is the possibility that these norms are potentially unsuitable for English speakers. In addition, the A-DEM used double-digit numbers rather than the single-digit numbers used on the original DEM. Thus, it is not possible to make conclusions regarding performance on the DEM based on the A-DEM norms.

Our purposes for the present study were to:

1. Obtain normative data for the DEM on a sample of adults aged 22 to 26 years.
2. Compare these data to previously obtained norms for children 13.0 to 13.11 years of age.

SUBJECTS

We recruited a convenience sample of 50 community-living, healthy young adults (25 females and 25 males). The subjects ranged in age from 22.3 to 26.9 years (M = 25.0 years, SD = 1.43). Ninety percent (n = 45) of subjects were college students. The educational level of the remaining five subjects was unknown. The included subjects were not screened nor excluded for pre-existing visual disorders and/or reading or learning disabilities. We did exclude subjects who: (a) were non-native English speakers; (b) had received medical care for TBI or stroke; or (c) had a history of loss of consciousness or alteration of consciousness resulting from injury to the head that resulted in hospitalization, emergency room visit, or physician visit. The University of Washington Human Subjects Review Board granted permission to conduct the study.

MATERIAL

The standard DEM test plates were used. These consist of two plates with 80 numbers arranged in two vertical columns and one plate with the same numbers arranged horizontally in rows.[1]

PROCEDURES

Following screening to establish eligibility per the criteria noted above and obtaining written consent, we administered the DEM to individual subjects following the standardized procedures. Times for vertical and horizontal readings were recorded. As per the instructions for DEM scoring, the horizontal time was adjusted for errors by multiplying the horizontal time by 80 divided by 80 minus the number of omission errors plus the number of addition errors. Ratios were calculated by dividing the adjusted horizontal time by the vertical time.[1]

DATA ANALYSIS

Data analysis included calculation of descriptive statistics for age, vertical time, adjusted horizontal time, ratio, and total errors. Vertical and adjusted horizontal mean times were compared to the mean times of the oldest original normative sample (i.e., 13.0-13.11 years) by using a t-test for one sample. For the purpose of comparing the ratio scores, the ratios for the young adults were divided into groups according to the quartiles of the normative sample of 13-year olds. Data that fell between the values of the original quartiles for 13-year-olds were placed in the next lowest quartile. The distribution of ratios for the young adults was compared to the distribution of ratios of the original normative sample by using Chi square tests for goodness-of-fit.[11]

RESULTS

The mean vertical time on the DEM for the young adults was 27.3 seconds (SD

Table 1. DEM Scores for Young Adults Ages 22 to 26 (N = 50)

	Mean	SD	Median	Minimum	Maximum
Age (years)	25.0	1.43	25.3	22.3	26.9
Vertical time (seconds)	27.3	4.28	27.0	19.0	38.0
Adjusted Horizontal time (seconds)	28.8	4.83	28.0	19.0	39.0
Ratio[a]	1.05	.098	1.04	.9	1.3

[a] Adjusted horizontal time divided by vertical time

Percentile	Vertical Time	Adjusted Horizontal Time[a]	Ratio Score[b]	Errors
	Seconds			
99	19.0	19.0	.90	0
95	21.0	21.0	.91	0
90	22.0	22.0	.93	0
85	22.0	23.7	.95	0
80	23.0	25.0	.97	0
75	24.0	25.0	1.00	0
70	25.0	26.0	1.00	0
65	25.9	26.9	1.00	0
60	26.0	27.0	1.00	0
55	26.0	28.0	1.04	0
50	27.0	28.0	1.04	0
45	28.0	29.0	1.06	0
40	28.6	30.0	1.08	0
35	29.0	31.0	1.08	0
30	29.0	31.0	1.10	0
25	29.3	32.0	1.11	1
20	30.8	32.0	1.12	1
15	33.0	34.4	1.14	1
10	33.9	36.9	1.22	1
5	35.0	37.4	1.27	2
1	38.0	39.0	1.30	2

Table 2.
Distribution of DEM Scores for Young Adults

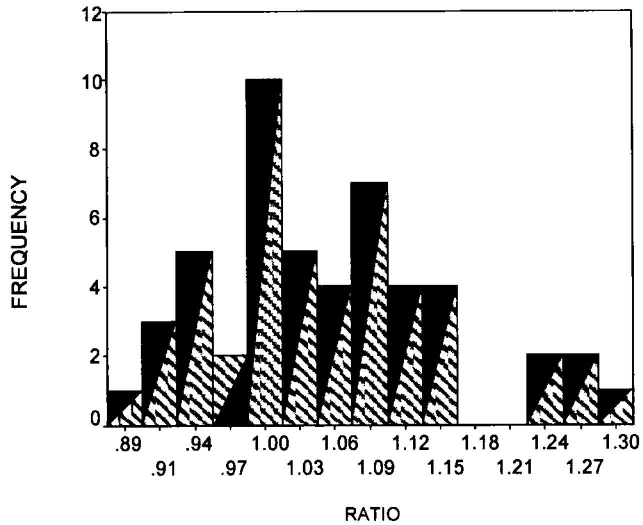
[a]Horizontal time multiplied by 80, divided by (80-omission errors + addition errors)
[b]Adjusted horizontal time/vertical time

Table 3. Relationship of Observed DEM Ratios for Young Adults to Original Normative Sample

Original Normative Sample		Young Adult Sample
Quartiles	Range of Ratio Scores	Observed Percentage of Young Adults[a]
1st	Lowest to 1.069	56% (n= 28)
2nd	1.070 to 1.105	18% (n=9)
3rd	1.106 to 1.160	15% (n=8)
4th	1.161 to highest	10% (n=5)
	Total	100% (n=50)

[a] 25% expected per quartile

Figure 1.
Distribution of DEM ratios for young adults 22 to 26 years.



= 4.28). See Table 1. Compared to the mean vertical time (33.7 seconds) for the original normative sample of 13 year olds, the performance of our sample was significantly different (p <0.001). The mean adjusted horizontal time for young adults was 28.8 seconds (SD = 4.83). This was significantly different from the mean (37.6 seconds) of the original normative sample of 13 year olds (p <0.001). Seventy two percent of our young adult subjects did not make any errors, 22% made one error, and 6% made two errors.

Table 2 provides the percentiles distribution of the DEM scores. As noted in the table, 99% of the subjects had a ratio of at least 0.90, and 75% had a ratio of at least 1.0.

Figure 1 shows the histogram of the ratios. Table 3 shows the distribution of the observed data for the young adults within the quartile groups. Under the assumption that the distribution of DEM ratios in 13-year-olds and young adults is the same, we would expect that 25% of all subjects would fall inside each category. A Chi-square test for goodness-of-fit found a significant difference in the distribution of quartiles for young adults compared to that of the normative sample of 13-year-olds ($\chi^2_{[3]}$, p <0.001).

DISCUSSION

We found that the young adults had significantly better performance on the DEM than the 13-year-olds in the original normative sample. The times for the vertical component and the adjusted horizontal component were more evenly matched for the young adults resulting in lower ratio scores. The overall shift towards lower (i.e., better) ratio scores for young adults can be seen with the 25th percentile ratio scores for those between 22 to 26 years corresponding to the 50th percentile for 13-year-olds.

The DEM test may be useful clinically to identify potential saccadic eye movement impairment in adults following brain injury. The results of this study suggest that using normative data for 13-year-olds to interpret findings from the assessment of young adults would result in under-identification of persons with impaired saccadic eye movements. The cut-off for normal range of performance on standardized assessments such as the DEM where higher scores indicate worse performance is typically set at two standard deviations (SD) below the mean. Using the existing 13-year-old norms, the cut-off point would be 1.36 (1.12 + 2 x .12). The cut-off for the ratio scores based on the results of this study would be 1.25 (1.05 + 2 x .098). Thus, persons with ratio scores between 1.26 and 1.35 would not be identified as having atypical performance on the DEM if the 13-year-old norms were used with a cut-off point of the 13-year-old mean plus two standard deviations (1.36), but would fall in the atypical range if the ratio scores from this study were used.

It should be pointed out that, clinically, those persons with ratio scores between 1.26 and 1.35 in this study would be in a category of <16th percentile or beyond 1 standard deviation from the mean based on the 13-year-old norms. This discrepancy focuses on the issue of what is the most suitable clinical criterion applied for the cut-off point and further supports the need for establishing age-specific norms for the DEM throughout the lifespan.

At the same time, we do not recommend using these study results as DEM norms for young adults. This study sample consisted of a small, fairly homogenous, group consisting almost entirely of college students. College students may develop faster and more accurate saccadic eye movements than young adults with less education experience as a result of increased time spent reading and increased demand for faster reading. Thus, the difference for the young adults and the 13-year-olds may reflect a certain degree of sample bias rather than true age-related performance. A study with a more educationally diverse sample should be conducted to establish normative data.

A direct comparison of these results with the A-DEM developed by Sampredo and colleagues[10] is not possible due to differences in the age ranges used for grouping and the different test constructions. However, it is of interest that the mean ratio score of 1.05 (SD = .10) for the 22 to 26 year olds in this study is very similar to the mean ratio score of 1.06 (SD = 0.11) for the 24 to 28 year old group on the A-DEM. For these ages, mean horizontal and vertical times on the A-DEM are longer (approximately 1.6 times) as might be expected for a comparison of reading double-digit numbers aloud in Spanish on the A-DEM to reading single-digit numbers in English on the DEM.

The results of this research point to the importance of establishing age-specific norms for the DEM throughout the lifespan. While it does not appear that saccadic function plateaus between early adolescence and young adulthood, it is possible that a plateau exists at a later age. Alternatively, it is possible that times on the DEM may either continue to improve throughout the life span or improve for a period of time and then decline as a consequence of normal aging as demonstrated by Sampredo and colleagues.[10] It is our recommendation that age-specific norms be established for all age groups. The two primary age groups of interest for clinicians working with individuals following brain injury would be late adolescents/young adults and elderly adults where the incidence of traumatic brain injury and/or stroke is highest[12] and there is a clinical need for objective and accurate assessment of saccadic eye movement. The present study is a step in this direction.

However, it is important to point out that while the present study focused primarily on the DEM's ratio, full clinical application of the test results depends on considering inter-relational factors in the test. Specifically, the ratio needs to be considered in relationship to the vertical and the horizontal adjusted times. Thus, if the vertical and horizontal times are in the expected range, the ratio will be close to one (1). This is considered normal performances in both rapid automatic naming (RAN) and saccadic ability respectively. When the vertical time is in the expected range, but the horizontal time is abnormally increased, the ratio will be significantly greater than one (1). This indicates compromised saccadic eye movements. When both the vertical and horizontal times are abnormally increased, the ratio will be close to one (1). This is indicative of a problem in RAN. Finally, when both the vertical and horizontal times are abnormally increased, with the horizontal time much greater than the vertical, the ratio will be greater than one (1). This indicates a problem of automaticity in RAN along with compromised saccadic eye movements.[13] Other factors such as attention function may also significantly influence the results throughout the life span.[14]

SUMMARY

The DEM is a test of saccadic eye movement performance with multiple advantages over other assessment methods. While it was developed for use with children with learning disabilities, it has the potential to be useful in identifying saccadic dysfunction in adults in general, and particularly in those adults with ABI. Such assessment could provide an inexpensive and easy to use assessment of an aspect of oculomotor functioning. Findings from this study support development of adult norms for the DEM. We recommend further investigation of saccadic eye movement on the DEM with a more diverse sample of young adults along with older age groups as a first step in that direction.

This study was completed in partial fulfillment of the second and third authors' requirements for the Master of Occupational Therapy degree in the Department of Rehabilitation Medicine, University of Washington, Seattle, WA.

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Date accepted for publication:
January 16, 2005