A COMPARISON of the DEVELOPMENTAL EYE MOVEMENT TEST (DEM) and a MODIFIED VERSION of the ADULT DEVELOPMENTAL EYE MOVEMENT TEST (A-DEM) with OLDER ADULTS

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Abstract

The Developmental Eye Movement Test (DEM) is a standardized test for evaluating saccadic eye movements in children. An adult version, the Adult Developmental Eye Movement Test (A-DEM), was recently developed for Spanish-speaking adults ages 14 to 68. No version yet exists for adults over the age of 68 and normative studies for English-speaking adults are absent. However, it is not clear if the single-digit format of the DEM or the double-digit A-DEM format should be used for further test development.

The DEM and a modified version of the A-DEM were administered to 50 community-living older adults (mean age=79.2 years; 58% female). The average ratio scores for the DEM (1.05) and the modified A-DEM (1.06) were not significantly different (p=0.19). Individual scores on the DEM and modified A-DEM were significantly, but not strongly, correlated (r=0.42, p=.002) suggesting that differences in test format may preclude using the DEM and A-DEM interchangeably. Further work with larger groups of subjects will be necessary to determine norms for DEM-like tests for older adults.

Key Words

Adult Developmental Eye Movement Test (A-DEM), Developmental Eye Movement Test (DEM), modified A-DEM, oculomotor, older adult, saccade

INTRODUCTION

Saccadic eye movements are the rapid, jumping movements that serve to bring the image being viewed onto the fovea of the eye. These eye movements allow us to obtain maximum clarity of visual detail and contribute to efficient flow of processing of visual information. In addition, saccadic eye movements appear to play an important role in the cognitive and motor processes used in the performance of daily tasks,[1, 2] as shown in studies of food preparation[3,4] and driving.[5-7] Saccadic eye movements contribute to efficient and accurate reading with movement of the eyes along the lines of print.[8-10] They are important in how we recognize words and how we process larger units of printed language.

Evaluation of saccadic eye movements can require the use of complex and expensive objective measuring devices.[11] A simpler assessment method that has gained widespread acceptance involves measuring the speed of reading numbers aloud. Unfortunately, there is a fundamental problem with this number-naming testing approach. Impairments in the motor and cognitive components of speech and language can impact performance on a verbal task and potentially confound the assessment of saccadic eye movement dysfunction. Adding to this concern is the possibility that a majority of individuals with reading disabilities, regardless of the presence of other types of processing dysfunctions, may have difficulty retrieving a verbal label during rapid scanning, sequencing, and processing of serially presented material.[12-14] All such issues are further confounded with aging persons.

The Developmental Eye Movement Test (DEM)[15] is a number-naming saccadic eye movement test that was developed to address such concerns in children. Test administration of the DEM consists of timing the child reading aloud 80 single-digit numbers arranged vertically and the same numbers arranged horizontally. The vertical subtest uses two test plates with two columns on each page and 20 evenly spaced numbers in each column. The test plate for the horizontal subtest is comprised of 16 rows with five unevenly spaced numbers in each row. After adjustment for errors, the horizontal time is divided by the vertical time. The resulting ratio score is a comparison of the speed of reading material that compares performance of a number-naming task with a higher saccadic eye movement component (i.e., the horizontal test results) to performance of the same number-naming task with a lower saccadic eye movement requirement (i.e., the vertical test results). This comparison allows for adjustment for number-naming speed and results in a measurement of the efficiency of horizontal saccadic eye movements. An individual's performance on the DEM is assessed in comparison to norms for children ages 6 to 13 years. Overall, the reliability of the DEM has been shown to be reasonably good,[15,16] especially with those with symptoms indicative of oculomotor dysfunction.[16] However, others have raised some concerns about the reliability of DEM scores with a likely need to do repeated testing on an individual to attain better reliability.[17]

Clinicians have found the DEM to be an easy, practical, and inexpensive method of assessing saccadic eye movements in children. The approach represented by the DEM also has the potential to be useful with adults, especially in screening for impaired saccadic eye movement following acquired brain injury (i.e., traumatic brain injury or stroke).[18,19] However, at present, age-specific adult norms have not been developed.[20] While saccadic eye movement performance appears to improve from early adolescence to young adulthood[20] and decrease in late adulthood,[21,22] the exact nature and timing of the changes and the impact on a test such as the DEM are not known. The results of studies investigating eye movement and cognitive changes in the aging adult further underscore the potential value of knowing more about the performance of adults on such tests.[22-26]

In response to the need for development of adult norms on a test such as the DEM, Sampedro and colleagues[27] recently developed an adult version called the Adult Developmental Eye Movement Test (A-DEM). This version was developed with norms for Spanish-speakers aged 14 to 68 years. The A-DEM is similar to the DEM with two exceptions: First, the A-DEM uses double-digit numbers as test stimuli rather than the single-digit numbers on the DEM. Second, the numbers used for the horizontal array are not the same as those in the vertical array as they are on the DEM.

If the ratio scores were the only DEM scores of interest, it might be possible to extend the Spanish-speaking norms on the A-DEM to English-speaking adults. Velazquez and colleagues[28] found similar performance on the DEM for 6 to 11 year old Spanish-speakers when compared to the norms for English-speaking children. Additionally, a study of multilingual migrant children found that language barriers in this population are reflected in lower automaticity with number naming, but not eye movement dysfunction as measured by the DEM.[29] However, the differences in the time required to pronounce number names in the two languages, along with possible cultural differences in speaking rates, may affect horizontal and vertical times and preclude comparisons of those aspects of test performance without language-specific norms.

It is clear that studies to establish norms for English-speaking adults on a test such as the DEM or A-DEM would be beneficial. However, it is not clear which number format, i.e., the single-digit or double-digit numbers, should be used. It is not known if the difference in number format changes performance and, if so, what the nature of the effect would be. Information about the comparability of the performance on individuals on the two test versions could assist with a decision about how to proceed with normative studies.

The purpose of this study was to gather data on adults over the age of 68 on the DEM and a modified version of the A-DEM in order to determine whether differences in performance exist in older subjects on the two formats. A secondary purpose was to begin collection of normative data for adults ages 69 years and older. This age group is of particular clinical interest because of the higher risk of acquired brain injury in late adulthood[30] and the subsequent need for assessments of oculomotor function.

METHODS

Subjects

A sample of 50 independent community-living persons 69 years and older was recruited. Sites for recruitment and testing included senior centers and retirement living facilities. Potential participants were screened via a questionnaire. Individuals who were not native English speakers and who reported (a) previous acquired brain injury, (b) previous eye injury or disease, (c) reading difficulties such as dyslexia, and/or (d) inability to read the newspaper with or without current lenses were excluded. Permission to conduct this study was granted by the University of Washington Human Subjects Review Board. Written consent was obtained prior to data collection.

Procedures and material

A basic visual screening was administered for those who met the initial study criteria. The visual screening included tests or observations of (a) near visual acuity, (b) ocular motility, (c) peripheral visual fields, and (d) central vision fields. Participants were excluded if they demonstrated: (a) near visual acuity with present lenses less than 20/50, (b) nystagmus, (c) impairments or restrictions in ocular motility (d) peripheral field loss, and/or (e) central field loss. Participants were also administered the Mini Mental State Examination (MMSE)[31] to identify major cognitive deficits. Individuals scoring less than 25/30 on the MMSE were excluded from the data analysis.

Following the vision screening and MMSE, the DEM and a modified version of the A-DEM were administered. The order of test administration was randomized to control for order effects. Randomization was done by five-year age groups consistent with the age groupings on the modified A-DEM to allow for use of the first test for each participant as part of a subsequent study developing adult norms.

The tests were administered according to the DEM standardized procedures[15] with a few exceptions. More specific instructions to read the numbers as quickly as possible were given. This change was made to account for older adults' tendency to focus on accuracy over speed.[32] Attempts were made to conduct all tests in a quiet area or room to minimize visual and auditory distractions as per instructions, although this was not always possible when testing in busy senior center environments.

The test materials for the A-DEM were also modified. The original A-DEM vertical test plate was used. However, a new horizontal test plate was created using the same numbers as the A-DEM vertical plate. This change was made so that the only difference between the two test versions was reading double digits for the modified A-DEM versus reading single digits for the DEM. This allowed for comparison of the ratio scores with the different number formats on the two tests (i.e., single-digit and double-digit) without the possible confounding effect of one test version having the same numbers on the vertical and horizontal arrays and the other having different numbers.

Ratio scores were obtained per the standard scoring procedures described above with the following exception. We noted that the older adults were making increased errors on both the vertical and horizontal tests compared to descriptions of errors in younger age groups. The standard DEM procedures do not call for recording of vertical errors as they typically occur so infrequently in children that they are not considered essential for scoring purposes.[15] However, we decided to record the substitution, omission, addition, and transposition errors in the vertical arrays, as well as to adjust the vertical times for addition and omission errors, in the same manner that the horizontal errors are recorded and time adjusted. This is in keeping with others who have noted the need for normative data for DEM vertical errors in children.[33]

Data analysis

Descriptive statistics were calculated. ANOVA and chi-square tests were performed to examine whether the characteristics and test results of participants who were randomly assigned to receive the DEM test first were similar to those who received the modified A-DEM test first. The distribution of the DEM and modified A-DEM ratios was examined by visual inspection. The mean DEM and modified A-DEM ratios were compared using a paired t-test. The relationship between the DEM and modified A-DEM ratio scores was examined with a scatter plot and computation of Pearson's correlation coefficient. Differences in test order were examined by visual inspection. The scores on the two tests were divided into quartiles and the number of participants with scores in each quartile was calculated. The analyses were performed using Stata 8.1[34] or SAS 9.1.[35]

Results

Participant demographics and test results by overall sample and test order group are presented in Table 1. Overall, the randomization appears to have resulted in balanced samples for the test order groups. While there were slight differences for those who received the DEM first versus those who received the modified A-DEM first, the differences were not statistically significant.

Table 1. Descriptive Statistics of the Sample (N=50)

Variable		Mean (SD) or N(%)			
		Overall	Stratified by the order of the tests: DEM first (n=24)	ADEM first (n=26)	p-value
Age		79.2 (5.9)	80.0 (6.2)	78.5 (5.7)	0.40
Gender	Female	29 (58%)	16 (67%)	13 (50%)	0.23
	Male	21 (42%)	8 (33%)	13 (50%)	
DEM	Ratio	1.05 (0.10)	1.05 (0.10)	1.04 (0.09)	0.81
	Vertical Error	0.40 (0.8)	0.38 (0.9)	0.42 (0.7)	0.84
	0	37 (74%)	20 (79%)	18 (69%)	0.72
	1	8 (16%)	3 (13%)	5 (19%)	
	2+	5 (10%)	2 (8%)	3 (12%)	
	Horizontal Error	0.64 (1.10)	0.58 (1.21)	0.69 (1.01)	0.73
	0	31 (62%)	17 (71%)	14 (54%)	0.34
	1	13 (26%)	4 (17%)	9 (35%)	
	2+	6 (12%)	3 (13%)	3 (12%)	
ADEM	Ratio	1.06 (0.07)	1.05 (0.06)	1.08 (0.07)	0.14
	Vertical Error	0.42 (1.16)	0.21 (0.59)	0.62 (1.50)	0.22
	0	40 (80%)	21 (88%)	19 (73%)	0.36
	1	5 (10%)	1 (4%)	4 (15%)	
	2+	5 (10%)	2 (8%)	3 (12%)	
	Horizontal Error	0.98 (1.62)	0.71 (1.43)	1.23 (1.77)	0.26
	0	29 (58%)	16 (67%)	13 (50%)	0.382
	1	11 (22%)	5 (21%)	6 (23%)	
	2+	10 (20%)	3 (13%)	7 (27%)	

** None of the comparisons between DEM first and ADEM first are statistically significant.*

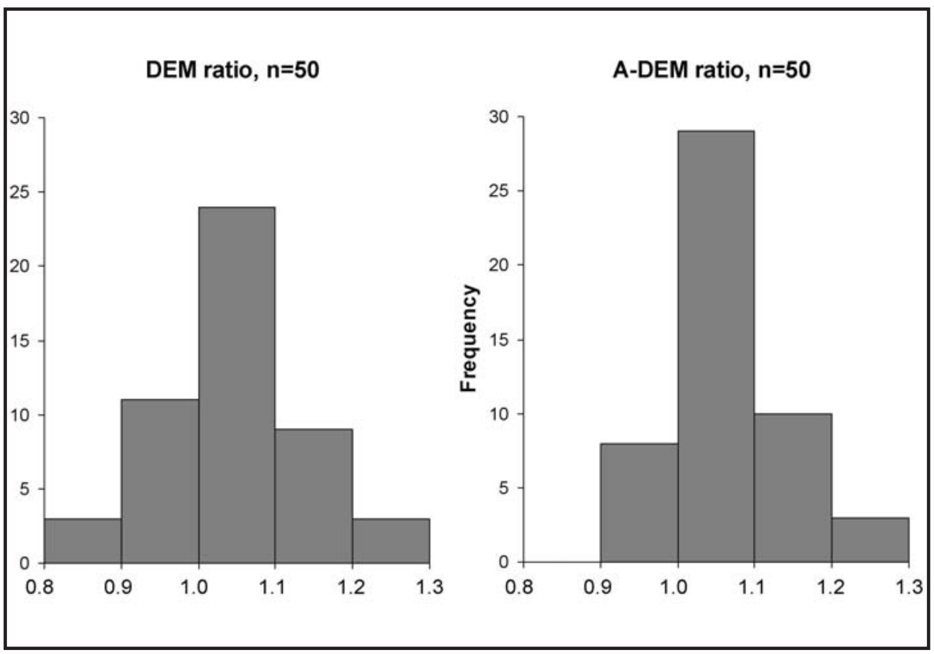

Figure 1. Distribution of DEM and modified A-DEM ratios

As can be seen in Figure 1, the distribution of the DEM ratios was approximately normal. The distribution of the modified A-DEM ratios was skewed to the right towards higher ratio scores and worse performance. While the overall mean modified A-DEM ratio was slightly higher (i.e., worse) than the overall mean DEM ratio (1.06 versus 1.05), this difference was not statistically significant (t=-1.34, df=49, p=0.19). The relationship between each participant's ratio scores on the two tests is presented graphically in Figure 2. As indicated by the pat-

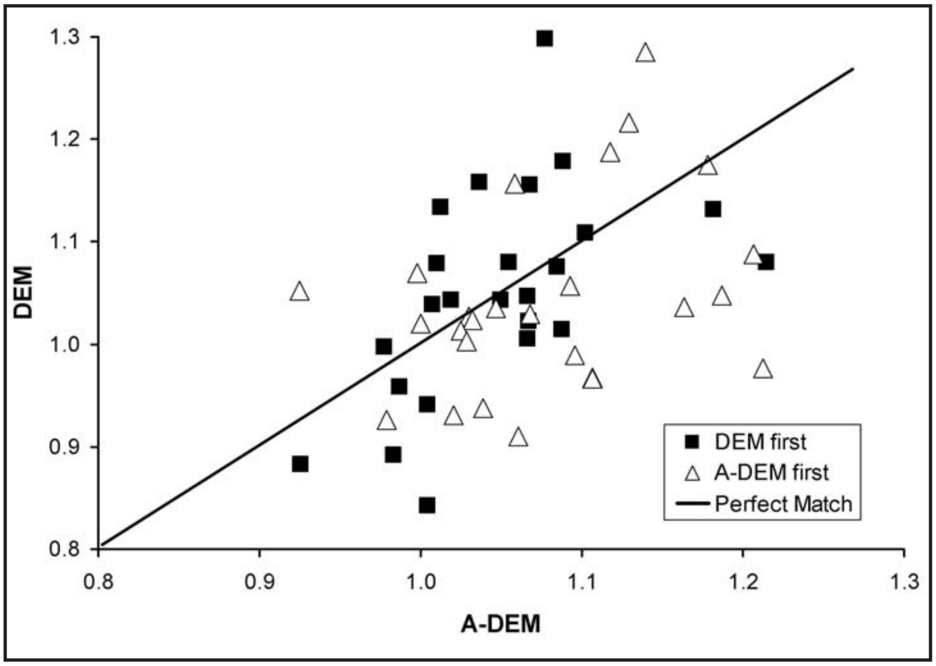

Figure 2. Relationship of DEM and modified A-DEM ratios scores

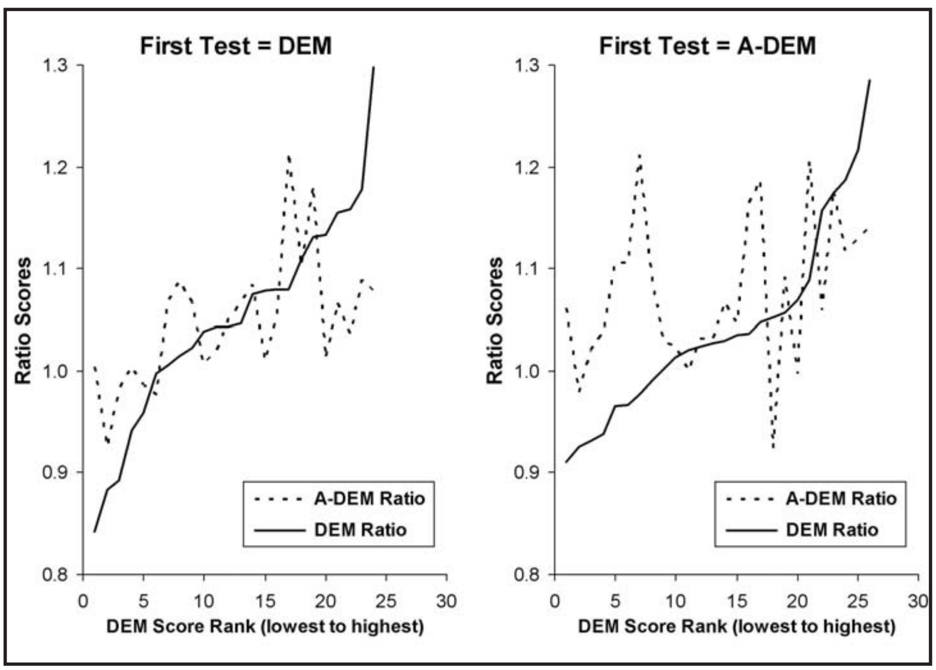

Figure 3. Relationship of DEM and modified A-DEM ratio scores by test order.

Table 2. Number of Participants (percentages by row) by DEM and Modified A-DEM Ratio Score Quartiles.

DEM quartile		A-DEM quartile			
	1	2	3	4	
1	6 (50%)	2 (17%)	1 (8%)	3 (25%)	100%
2	2 (15%)	5 (38%)	5 (38%)	1 (8%)	100%
3	4 (31%)	3 (23%)	3 (23%)	3 (23%)	100%
4	0 (0%)	3 (25%)	4 (33%)	5 (42%)	100%

tern in this scatter plot, the two variables are only moderately correlated (r=.42, Fisher's z=0.444, p=.002). Differences between the test scores by test order are highlighted in Figure 3. In both instances, some participants performed better and some worse on the second test. There appear to be greater differences between the scores on the two tests when the modified A-DEM was given first.

By using quartiles, a type of ranking system that allows comparison of scores, we could compare results in a different manner. Quartiles are established by dividing the group into four equal parts so that each part represents 25% or one quarter of the sample. In this instance, participants were placed into the first, second, third, or fourth quartile based on the ratio scores for each test (from lowest to highest). The quartile placements on the two tests were then compared for each participant. As can be seen in Table 2, 62% (N=31) of participants had ratio scores that were not in the same quartile on the two tests.

DISCUSSION

The DEM was developed to measure saccadic eye movement performance in English-speaking school-age children, while the A-DEM was developed to measure saccadic eye movement performance in Spanish-speaking adults into the seventh decade of life. While studies to develop norms on such tests for English-speaking adults are needed, it has not been clear if the single-digit format of the DEM or the double-digit format of the A-DEM should be used for that purpose. This study was conducted to investigate the relationship between the number formats of the DEM and a modified version of the A-DEM as a first step towards making that decision.

The results of this study indicate that, for this sample of older adults, the DEM and the modified A-DEM did not demonstrate the degree of statistical similarity needed for test forms that can be used interchangeably. While the ratio scores were not significantly different on average, the two tests were only moderately correlated (r=0.42). This relationship is much weaker than the .8 to .9 correlation level that would be considered indicative of parallel test forms where either version of the test could be given.[36] One possibility is that the two tests are, in fact, measuring the same construct with the lower correlation resulting solely or primarily from a difference in the normal ranges for the two tests. However, this explanation appears unlikely. As seen in the quartile comparison, less than half (only 38%) of individuals had ratio scores that fell in the same quartile on the two tests. In addition, the participants scoring above or below two standard deviations from the mean on the two tests were not the same. It appears that the single-digit and double-digit tests are measuring somewhat overlapping, but not identical, constructs, at least for the older adults in this sample.

The DEM and A-DEM were both developed for ease and simplicity in clinical testing of saccadic eye movements using number-naming tasks. Both tests do not directly measure basic components of eye movements, e.g., velocity, accuracy, or latency. Rather, they indirectly assess overall saccadic tracking function in integrated tracking and cognitive visual-verbal identification tasks and are, perhaps, best described as measures of saccadic efficiency. The primary difference between the two tests appears to be the use of double-digit numbers in the A-DEM rather than the single-digit numbers of the DEM. It appears that this seemingly small difference in test format resulted in a variation in test performance.

While it appears likely that the source of the weaker than expected correlation between ratio scores on the two test formats is the difference in number format, the underlying reason for the difference is not as clear. There was a tendency for the test scores in this sample to be worse on the modified A-DEM. One possibility is that the modified A-DEM reflects a more accurate measurement of saccadic eye movement than the DEM. According to Sampredo and colleagues,[27] the double-digit numbers in the A-DEM were used to "increase the cognitive visual-verbal retrieval demand on rapid number calling." The more complicated visual stimuli of the double digits may result in an increase in what Larter et al.[37] termed the spatial-load factor. These authors found that timed tests of tasks with high spatial load indicated that spatial factors may be of further predictive value in identifying reduced saccadic function and, potentially, reading ability.

On the other hand, perhaps the use of double-digit numbers introduced one or more confounding factors leading to a less accurate measurement of saccadic eye movement. One possible complicating factor is cognitive fatigue occurring with the reading of double-digit numbers as the test progressed. As the vertical baseline was always given first as per standardized instructions, cognitive fatigue could have differentially slowed performance on the horizontal sections leading to worse ratio scores. Another possible complicating factor is proactive interference, i.e., difficulty letting go of information in working memory that is no longer relevant. This factor, which has been seen in other studies of older adults,[38-40] could have impacted scores in a similar fashion to cognitive fatigue. Attentional effects have been reported as a possible factor in the DEM with children as well.[41,42]

Based on visual inspection, it appeared that the DEM and modified A-DEM test results were closer for those who received the DEM test first than for participants who received the modified A-DEM test first. It appears that the experience of taking the modified A-DEM may have impacted the experience of taking the DEM to a greater degree than vice versa, at least when there is no rest break between the two tests as in this study. The reasons for these possible differences cannot be determined from this study. However, these test order effects may have been related to variations in allocation of attentional processes affecting cognitive processing and warrant additional investigation.

This study had several limitations. First, it only investigated the performance of older adults. In addition, the sample size was relatively small. Different results may have been obtained with a larger sample, especially given the well-established variability of older adults across a wide variety of measures. While these findings add to previous evidence[20,27] that the average ratio score for adults may be relatively stable in the 1.04-1.08 range, it is important to note that it would be premature to draw conclusions about the normative performance of older adults on these tests given the small sample size along with the variability in the performance of older adults. Indeed, any conclusions from this study must be taken as somewhat preliminary in nature and their generalizations to other populations is uncertain.

Further research is needed to better understand the underlying constructs and differences between the number formats of the DEM and A-DEM. A study comparing performance on the DEM and the modified A-DEM with adults in younger age groups would help determine if the findings from the current study are reflective of factors unique to older adults or are similar for other ages. Our recommendation for those interested in proceeding with normative studies for English-speaking adults is that studies be conducted on both test versions. In addition, follow-up studies of the relationship of the findings of these eye movement tests to everyday function could assist with sorting out the clinical implications and usefulness of the two tests. The DEM has been reasonably helpful in relating clinical symptoms in vision problems to eye movements,[16] predicting reading and school performance,[43,44] and planning treatment in reading disorders.[45] Similar studies with the A-DEM and additional studies looking at the relationship of these two tests with other everyday activities (e.g., home management tasks, driving) in typical and atypical populations may be beneficial.

In moving forward with future studies, it should be noted that the examiners in this study reported that errors on the modified A-DEM were challenging to record correctly. Part of this was simply due to the increased amount of time required to record errors of addition (i.e., saying non-test numbers) with the double-digit numbers. However, it also took greater attention with the double-digit format to discern if the participants were saying the numbers correctly, to identify an incorrect number, and to keep track when participants corrected errors. It could be useful to use a tape recorder to assist with identifying and recording errors for the A-DEM test version, especially for populations where increased numbers of errors in number naming are likely, such as older adults or individuals with speech and/or language difficulties following brain injury.

Valid and reliable measurements of saccadic eye movement are important in identifying and treating impairments in oculomotor function related to activities of everyday life. This is a particular concern in older adults given the evidence for changes in eye movements with normal aging and the higher risk of acquired brain injury in this population. The results of this study indicate that further research is needed to investigate the use of the ratio measurement of saccadic eye movements with the DEM and the A-DEM. It appears that it would be worthwhile to investigate the relationship between the different number formats with other age groups, establish norms for adults on each of the two tests, further investigate the relationship of the tests to everyday function, and explore the clinical value of giving one or both tests. It is our hope that the subsequent benefits of a greater understanding of saccadic eye movements in the adult population will offset the time and effort involved in moving forward with these studies.

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