

Dynamic Measures of Visual Function and Their Relationship to Self-Report of Visual Functioning

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PURPOSE. The purpose of this analysis was to determine whether dynamic measures of vision, such as dynamic acuity and motion threshold, are independently associated with self-reported difficulty in activities involving vision.

METHODS. Data were used from the third round of the Salisbury Eye Evaluation ($n = 1198$), a longitudinal, population-based study of older adults. Multiple measures of visual function were tested, including dynamic acuity, motion threshold, visual acuity, contrast sensitivity, visual fields, and stereoacuity. Difficulty was assessed using the Activities of Daily Vision Scale (ADVS). Polytomous logistic regression procedures were used to determine log odds ratios for the dynamic measures of vision while adjusting for demographic, health, and other measures of vision.

RESULTS. In fully adjusted models including other vision variables, worse dynamic acuity was associated with greater difficulty on the near-vision ADVS subscale ($\beta = 0.68$, $P < 0.01$), but not with the overall ADVS or the far-vision or night-driving subscales ($P > 0.05$). Motion threshold was not associated with the overall ADVS or any of the subscales after controlling for other vision variables, although it was associated when no other vision variables were in the models.

CONCLUSIONS. Motion threshold was not independently associated with any ADVS difficulty. Dynamic acuity was independently associated with self-reported difficulty with near-vision tasks only. Other studies should confirm this association. If confirmed, strategies to improve dynamic acuity could be developed to try to reduce difficulty with tasks involving near vision. (*Invest Ophthalmol Vis Sci.* 2006;47:4762–4766) DOI: 10.1167/iovs.06-0436

Older adults are more likely to have vision problems as they age, because of increased incidence of diseases such as cataract, age-related macular degeneration, glaucoma, and diabetic retinopathy.^{1,2} Even at relatively early stages of vision loss, some everyday tasks may become more difficult or even impossible. For example, in a population-based sample of older adults, approximately 25% aged 65 to 84 years reported moderate or severe difficulty with oncoming headlights while driving at night or with threading a needle, whereas 24% reported some difficulty with reading newspaper print.³

Understanding what components of visual function affect difficulty with visual tasks is important if we are to intervene successfully. Historically, researchers have tended to define

visual impairment narrowly, in terms of only acuity. However, now there is an appreciation that good function in multiple measures of vision may be needed to perform visual tasks with ease. Moreover, different tasks may emphasize different types of visual function. A study by Rubin et al.³ found multiple components of visual function to be independently associated with self-reported difficulty on tasks. Worse scores in acuity, contrast sensitivity, visual fields, stereoacuity, and glare sensitivity were all related to increased reported difficulty on the Activities of Daily Vision Scale (ADVS).^{3,4}

Worse scores on dynamic measures of visual function like dynamic acuity and motion threshold are found in individuals with certain eye diseases and vestibular problems.^{5–7} It is unknown whether dynamic measures of visual function are related to difficulty with visual tasks, particularly after adjustment for other static measures of vision. There is some preliminary evidence that dynamic acuity scores can be improved through training,^{8,9} which could provide a possible intervention to lessen visual difficulties. Therefore, the goals of this analysis were to determine whether dynamic measures of visual function were independently associated with reported difficulty on tasks on the ADVS.

METHODS

Study Population

The Salisbury Eye Evaluation (SEE) project is a longitudinal, population-based study of older people living in the community around Salisbury, Maryland, which was begun in 1993. Detailed descriptions of this population and its characteristics have been published.^{10–12} This study was performed according to the tenets of the Declaration of Helsinki and was approved by the Institutional Review Board of the Johns Hopkins School of Medicine. Informed consent was obtained from all participants.

Eligibility criteria at baseline were as follows: age between 65 and 84 years, living in greater Salisbury metropolitan area, not in a nursing home, ability to communicate, and a score greater than 17 on the Mini Mental State examination (the latter was to ensure that the participant could reliably follow instructions on vision tests). Of the 3906 eligible persons, 2520 completed both the home questionnaire and the clinical examination (65% response rate).

Because dynamic measures of visual function were first obtained at the third round of data collection in this longitudinal study, data for this analysis came from the third round, which was conducted between 1999 and 2001. There were 1504 individuals who were alive and returned to the third round (60% of the original cohort). Reasons for not returning were death (49%), refusal (32%), or relocation out of study area (18%). Of these individuals, 1198 completed all the relevant vision tests for this analysis.

Vision Tests

Dynamic acuity was measured by having the participant indicate the orientation of a Landolt C target that moved at a rate of 50° per second left or right across the screen. The participant had to indicate whether the C was pointing up, down, left, or right by moving a joystick in the appropriate direction. The target was presented at decreasing sizes. If the participant correctly identified two of the five trials at a particular size, the target size was decreased by a factor of 0.75. The outcome for

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TABLE 1. Characteristics of Participants at Round 3 Who Had Data on Dynamic Measures of Vision

Characteristic	Statistic
Number of Participants	1198
Age, mean \pm SD (y)	78 \pm 4.5
Gender (%)	
Male	43
Female	57
Race (%)	
White	79
African-American	21
Years of education, mean \pm SD	12 \pm 3.2
Mini-Mental State score (Mean \pm SD)	26 \pm 2.6
Depressive symptoms, %	5.9
Fair or poor self-report of general health (%)	24
Visual acuity, Median (IQR) (logMAR)	0.02 (0.14)
Ln(dynamic visual acuity), median (IQR), ln(min arc)	1.39 (0.98)
Ln(motion threshold+1), median (IQR), ln(min arc+1)	1.27 (0.45)
Overall ADVS score, median (IQR)	92 (15)
Far-vision ADVS score, median (IQR)	95 (12)
Near-vision ADVS score, median (IQR)	96 (12)
Night-driving ADVS score, median (IQR)	75 (31)

this test was the smallest gap size that the participant correctly identified in at least two of five trials. Viewing distance was initially set at 1 m and halved if the participant could not identify the orientation of a 2° gap in two trials. The test was stopped if participants could not identify the orientation of an 8.9° gap in two trials with a score of 130 min arc given. The scores were converted to ln(dynamic acuity) to achieve a greater spread.

Motion threshold was measured by having the participant move a joystick in the direction that a random dot pattern was moving across a computer screen. A similar test has been described in a paper by Turano et al.⁵ Briefly, the patterns were generated by a high-resolution graphics display (Imagraph; IMagraph Corp., Woburn, MA). Each display sequence contained three images, each of which in turn contained 50 dots. Displacement magnitude varied from trial to trial, according to a three-down, one-up staircase procedure. Testing was terminated after eight reversals, and threshold was defined as the mean of the displacements at the reversal points. The scores were converted to ln(motion threshold + 1) to achieve greater spread in the scores.

Static measures of visual function were measured as well. Presenting (habitual) visual acuity was measured binocularly under normal light using Early Treatment of Diabetic Retinopathy Study (ETDRS) charts and protocols.¹³ Visual acuity was scored as the number of letters read correctly and then converted to logMAR (log₁₀ minimum angle resolution) units.¹⁴ Contrast sensitivity, which is the inverse of the lowest contrast that an observer can detect, was measured by using a Pelli-Robson chart for each eye. Measures for the better eye were

used in subsequent analyses. Visual field, was measured with an 81-point, single-threshold full-field screen for each eye (Humphrey; Carl Zeiss Meditec, Inc.), and then an algorithm was used to combine the monocular scores into a binocular score.¹⁵ Finally, stereoacuity was tested using the Randot Circles test, which consists of a graded disparity series. The participant begins with the largest disparity and continues until an incorrect response is given. The score is the disparity of the panel of the last correct response (in log₁₀ seconds of arc visual angle).

Visual Disability Questionnaire

Trained interviewers evaluated visual disability with the ADVS.⁴ This 22-item questionnaire was designed to assess visual difficulty on a variety of tasks and was validated in a population of patients with cataract.⁴ For example, participants were asked about difficulty reading the newspaper, walking down steps, and driving at night. (One item on bus use was excluded because Salisbury did not have bus service at the time of the study.) Participants ranked each item according to its perceived difficulty as follows: 1, unable to perform because of vision; 2, extreme difficulty; 3, moderate difficulty; 4, a little difficulty; 5, no difficulty. If a person did not perform a task for reasons other than vision, the item was not scored.

Because this scale was created using clinic populations, its psychometric properties were evaluated in this population-based sample. For this analysis, only the subscales that had adequate content validity, internal consistency, and discriminability, as previously determined in

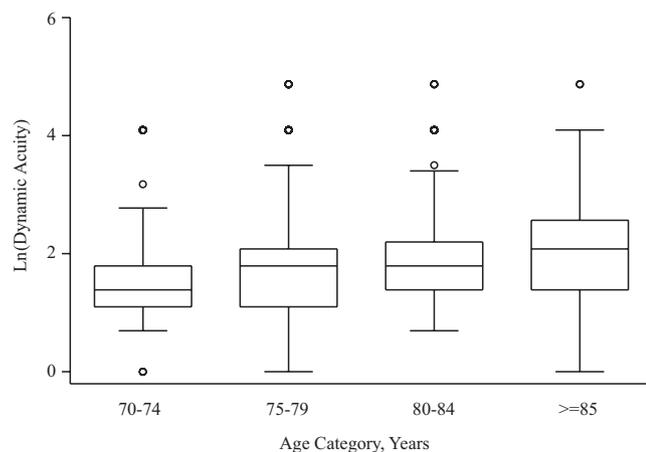


FIGURE 1. Distribution of dynamic acuity by age category.

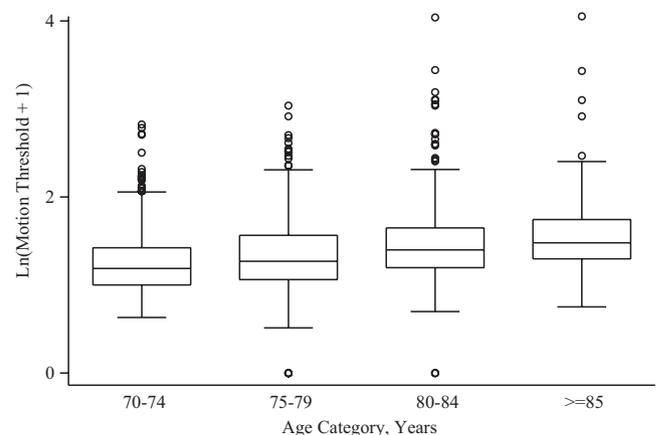


FIGURE 2. Distribution of motion threshold by age category.

TABLE 2. Correlation of Vision Variables

	Dynamic Acuity	Motion Threshold	Acuity	Contrast Sensitivity	Total Visual Fields	Stereoacuity
Dynamic acuity	1.00	0.39	0.41	-0.42	0.32	0.28
Motion threshold	—	1.00	0.43	-0.44	0.38	0.32
Acuity	—	—	1.00	-0.58	0.31	0.38
Contrast sensitivity	—	—	—	1.00	-0.47	-0.39
Total visual fields	—	—	—	—	1.00	0.34
Stereoacuity	—	—	—	—	—	1.00

Data are Pearson correlation coefficients.

this study population,^{3,16} were used. These were the overall ADVS score, the night-driving subscale, the far-vision subscale, and the near-vision subscale, after elimination of two items that were not performed by a large proportion of participants (playing cards and threading a needle). The overall and subscale scores were computed by averaging all relevant scored items and rescaling them to a 0 to 100 scale where 0 represents inability to perform all activities because of reduced vision and 100, difficulty with any activity.³

Demographic and Health Variables

Questions were also asked about demographics, health factors, and cognition. Information was collected on demographic information like age, gender, race, and formal education. Cognition was assessed with the Mini Mental State Examination¹⁷ and depressive symptoms with the General Health Questionnaire Part D.¹⁸

Statistical Analysis

To determine crude associations between the dynamic measures of vision and the ADVS outcomes, kernel smooth density plots with lowess running-line smoothers were created (Stata, ver. 7; StataCorp, College Station, TX). Lowess, or locally weighted scatterplot smoothing, is a robust nonparametric regression approach to fitting a line to a scatterplot.¹⁹ The lowess method acts to smooth out random noise, which more easily allows the examination of trends.

Next, because the ADVS scores were severely skewed, the scores were trichotomized into the 60% highest (the least difficulty), 25% middle (some difficulty), and 15% lowest (the most difficulty) scores, similar to Rubin et al.³

Then, polytomous logistic regression was used (the catmod procedure in SAS, ver. 6.12; SAS, Cary, NC) to determine the log odds of some difficulty or the most difficulty compared with little difficulty by measures of dynamic vision while adjusting for demographics, health factors, and other measures of visual function. The measures of vision were examined in a continuous fashion, although signs of nonlinearity were investigated by categorizing the vision measures, creating

dummy variables, and examining the estimates for signs of nonlinearity. Factors included as confounders included age, sex, race, education, cognitive status, depressive symptoms, and general health status. These variables were included because it was decided a priori that they might be associated with vision scores and report of visual difficulty on the ADVS.

RESULTS

The baseline characteristics of the surviving 1198 participants, who returned to the third round of the SEE study and had full vision data are shown in Table 1. The mean age of the sample was 78 years. The median scores for acuity, dynamic acuity, and motion threshold are given, as well as the median ADVS scores. Note that because this is a population-based sample, instead of a clinical sample, the median vision scores are generally quite good. Correspondingly, the median overall ADVS score was 92, indicating that most people had little difficulty with their vision. Those who reported more difficulty on the ADVS were more likely to be older and female, to report a fair or poor general health status, and to report symptoms of depression than were those who reported the least difficulty on the ADVS ($P < 0.05$ on Pearson's χ^2 test; data not shown).

The box plots of dynamic acuity and motion threshold by 5-year age category are shown in Figures 1 and 2. The median scores on both tests were worse as age increased.

The vision variables correlated moderately with one another (Table 2). The most correlated variables were between contrast sensitivity and acuity ($r = -0.58$), visual fields ($r = -0.47$), and motion threshold ($r = -0.44$).

Scatterplots showing associations between the dynamic measures of vision and the overall ADVS score are presented in Figures 3 and 4. As both dynamic visual acuity and motion threshold scores worsened, the overall ADVS scores wors-

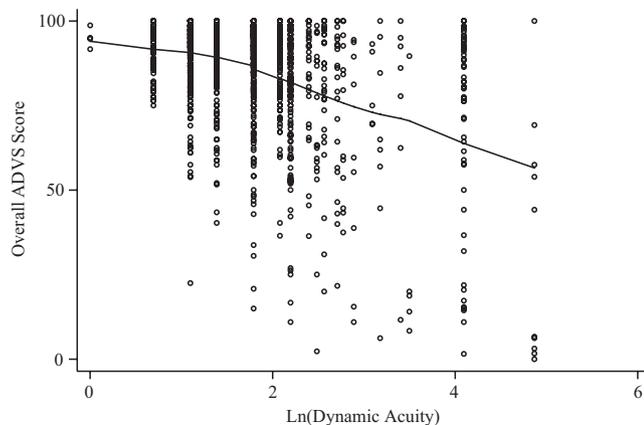


FIGURE 3. Lowess smoothed plot of dynamic acuity by overall ADVS score.

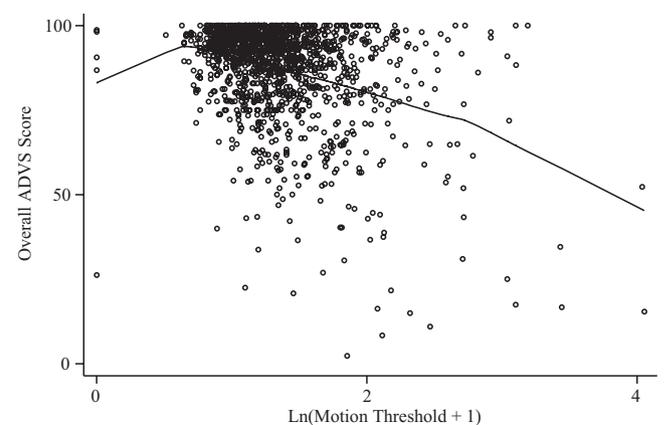


FIGURE 4. Lowess smoothed plot of motion threshold by overall ADVS score.

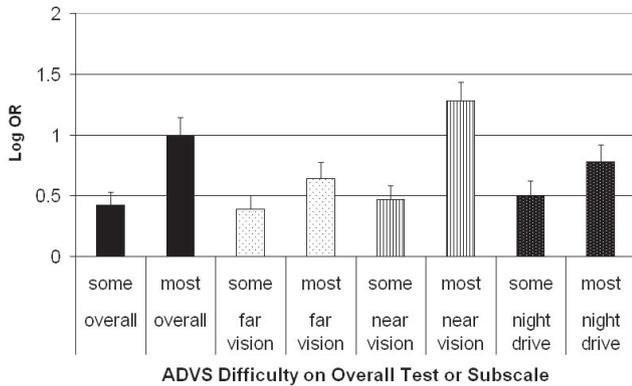


FIGURE 5. Log odds ratios and standard errors indicating the association between dynamic acuity and some or most difficulty on overall, far-vision, near-vision, and night-driving ADVS. *Estimates of log odds ratios and SE are from polytomous logistic regression models adjusting for age, sex, and race; all estimates were statistically significant ($P < 0.05$). †Compared with those with the least ADVS difficulty.

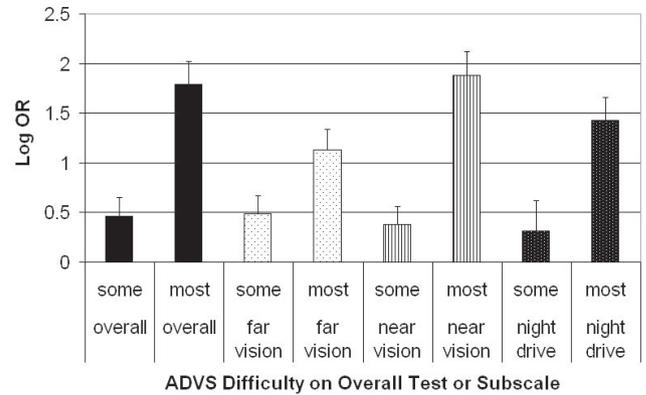


FIGURE 6. Log odds ratios and standard errors indicating the association between motion threshold and some or most difficulty on overall, far-vision, near-vision, and night-driving ADVS. *Estimates of log odds ratios and standard errors are from polytomous logistic regression models adjusting for age, sex, and race; all estimates were statistically significant ($P < 0.05$) except the estimate for some difficulty with night driving. †Compared to those with the least ADVS difficulty.

ened, as indicated by the downward slopes of the smoother lines. The plots revealed similar downward slopes for the near-vision, far-vision, and night-driving ADVS subscales (data not shown).

In polytomous regression models adjusting for age, race, and sex, worse dynamic acuity scores were associated with the log odds of both some difficulty and most difficulty on the overall ADVS and the far-vision, near-vision, and night-driving subscales ($P < 0.05$ for all estimates; Fig. 5). The results were similar for motion threshold (Fig. 6), except that motion threshold was not significantly associated with the log odds of some difficulty on the night-driving ADVS subscale ($P = 0.14$).

To determine whether dynamic acuity and motion threshold remained associated with having the most difficulty on the ADVS after adjustment was also made for static vision measures and other health and demographic factors, additional models were run. In Table 3 (model 1), dynamic acuity and motion threshold were associated with the most difficulty on the overall ADVS after adding acuity to the model, but these associations were greatly attenuated and not statistically significant after the addition of contrast sensitivity to the model (Table 3, model 2). The estimate for motion threshold decreased further after visual fields and stereoacuity were added to the model (Table 3, model 3). Data are not shown for some ADVS difficulty, since results of the dynamic measures of vision were not statistically significant once acuity was in the model.

Fully adjusted models were also run with the near-vision, far-vision, and night-driving ADVS subscales. In Table 4, dynamic acuity remained associated with the most difficulty on the near-vision ADVS, even after adjustment with the static measures of vision, demographic, and health variables ($\beta = 0.68$, $P < 0.01$; model 3). Motion threshold, however, was no longer statistically significantly associated with difficulty on the near vision ADVS once contrast sensitivity was added to the model (Table 4, model 2). Neither dynamic acuity nor motion threshold were associated with the most difficulty on the far-vision or night-driving subscales of the ADVS once visual acuity and contrast sensitivity were added to the model (data not shown).

DISCUSSION

It is important to understand the different components of vision that are related to self-reported difficulty with visual tasks to either improve that type of vision or else to teach patients how to cope better with loss of that type of vision. We found that dynamic acuity was associated with self-reported difficulty on the near-vision subscale of the ADVS, independent of other static measures of vision, whereas motion threshold was not related to the overall ADVS or any of its subscales in fully adjusted models.

TABLE 3. Polytomous Regression Models for the Relationship between Dynamic and Static Vision Measures and the Most Difficulty with Overall ADVS Tasks

Variables	Model 1		Model 2		Model 3	
	LogOR	P	LogOR	P	LogOR	P
Dynamic visual acuity, ln(min arc)	0.54	<0.01	0.29	0.12	0.26	0.18
Motion threshold, ln(min arc+1)	0.76	0.01	0.49	0.11	0.23	0.47
Visual acuity, 0.1 logMAR	0.58	<0.01	0.37	<0.01	0.34	<0.01
Contrast sensitivity, letters correct			-0.31	<0.01	-0.25	<0.01
Total visual fields, points missed					0.02	0.02
Stereoacuity, log sec arc					0.76	<0.01

The models present the relationship between dynamic and static vision measures and the adjusted log odds of the most difficulty with the overall ADVS tasks, adjusted for age, sex, race, education, general health status, depression, cognitive status, and other vision variables in the model and compared with those of the least difficulty. For all models, $n = 1185$.

TABLE 4. Polytomous Regression Models Presenting the Relationship between Dynamic and Static Vision Measures and the Most Difficulty with Near-Vision ADVS Tasks

Variables	Model 1		Model 2		Model 3	
	LogOR	P	LogOR	P	LogOR	P
Dynamic visual acuity, ln(min arc)	0.88	<0.01	0.70	<0.01	0.68	<0.01
Motion threshold, ln(min arc+1)	0.74	0.01	0.47	0.15	0.24	0.48
Visual acuity, 0.1 logMAR	0.51	<0.01	0.31	<0.01	0.27	<0.01
Contrast sensitivity, letters correct			-0.29	<0.01	-0.22	<0.01
Total visual fields, points missed					0.02	0.04
Stereoacuity, log sec arc					0.78	<0.01

Data represent the relationship between dynamic and static vision measures and the adjusted log odds of the most difficulty with near-vision ADVS tasks, adjusted for age, sex, race, education, general health status, depression, and cognitive status in the model and compared with those of the least difficulty. For all models, $n = 1185$.

Dynamic acuity has mainly been investigated for its clinical use in diagnosing vestibular dysfunction.⁷ Dynamic acuity tests measure not only the ability to resolve fine details using the fovea, but also the ability to maintain focus of the moving image on the fovea. This ability to maintain focus on a moving image is controlled by mechanisms such as the vestibulo-ocular reflex.²⁰ We found that dynamic acuity was associated with the near-vision subscale of the ADVS but not the far-vision subscale. This fits with experimental research which found a greater degradation in acuity between static and dynamic measures for near targets than for far targets.²⁰ The authors speculated that this may be due to inadequate vestibulo-ocular reflex control for near targets.²⁰

Just as low-vision specialists may train patients to learn how to cope better with impaired acuity or visual fields, additional strategies may be developed to help patients cope with poor dynamic acuity. Also, there is some evidence to indicate that scores on dynamic acuity can be improved after training.^{8,9} It is possible that this type of training could reduce difficulty with visual tasks like reading.

Motion threshold, another dynamic measure of vision, was not associated with difficulty on the ADVS or any of its subscales after accounting for static measures of vision. This measure of visual function was associated with difficulty on the ADVS when it was the only vision measure in the model, but it did not provide additional information beyond the static measures of visual function.

To conclude, we found that dynamic acuity was independently associated with self-reported difficulty on the near-vision ADVS subscale, but was not associated with difficulty on the far-vision, night-driving, or overall ADVS subscales. Motion threshold was not associated with overall ADVS difficulty or difficulty on any of the three subscales. Other studies should confirm our finding on the association between dynamic acuity and difficulty with near-vision tasks. If confirmed, strategies to improve dynamic acuity could be developed to try to reduce difficulty with tasks involving near vision.

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