

Cognitive and Vision Loss Affects the Topography of the Attentional Visual Field

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PURPOSE. The attentional visual field (AVF), which describes a person's ability to divide attention and extract visual information from the visual field (VF) within a glance, has been shown to be a good predictor of driving performance. Despite this, very little is known about the shape of the AVF and the factors that affect it. The purposes of this study were to describe the AVF in a large sample of older drivers and identify demographic, cognitive, and vision factors associated with AVF performance and shape.

METHODS. Registered drivers between 67 and 87 years of age, residing in Greater Salisbury, Maryland, were recruited to participate in the study. Participants underwent a battery of visual and cognitive assessments and completed various questionnaires for demographics, medical history, and history of depression. The AVF was assessed using a divided-attention protocol within the central 20° radius along the four principal meridians. The shape of the AVF was classified as either symmetric or one of two asymmetric shape profiles.

RESULTS. Symmetrically shaped AVFs were found in just 34% of participants. AVF performance was significantly better along the horizontal (15.3°) than the vertical (11.3°) meridian ($P < 0.05$). After adjusting for AVF area, we found that poorer cognitive and vision performance was associated with a symmetric AVF shape. Overall AVF extent was predicted by vision and cognitive measures as well as various demographic factors.

CONCLUSIONS. Good vision and cognitive ability appear to be associated with having an asymmetric as opposed to a symmetric AVF shape profile. (*Invest Ophthalmol Vis Sci.* 2008;49:4672-4678) DOI:10.1167/iovs.07-1112

The attentional visual field (AVF) refers to the size of the visual field (VF) over which a person can effectively divide attention and extract visual information within a glance. The AVF is typically estimated by measuring the most eccentric position or the processing speed at a set eccentric position, that a person can simultaneously process visual information from both central and peripheral VF locations. Previous studies have linked the AVF

with performance on a variety of everyday activities such as mobility,^{1,2} driving performance³⁻⁶ including crash rate,^{7,8} and other general activities of daily living, such as reading food cans and using a screwdriver and touch-tone telephone.⁹

The size or extent of the AVF, however, is dependent on the test parameters or display factors used to measure it. Specifically, the size of the AVF has been shown to decrease with an increase in the level of difficulty of the central task,¹⁰ with the presence of peripheral distractors,¹⁰⁻¹³ with the presence of backward masking,¹⁴ and when peripheral distractors are flashed briefly as opposed to a constant display.¹⁴ In addition, the size of the AVF decreases with age^{10,11,13-16} and eccentricity,^{10-14,16} but can be improved with training.^{10,11,16}

Although the measurement parameters affecting the size of the AVF have been well documented, characteristics about the shape of the AVF are less known. For example, is the AVF symmetrical about fixation or does the AVF's extent differ with meridian? How do losses in either vision and/or cognitive function affect the shape of the AVF? Knowing the shape of a person's AVF may provide useful information for predicting how well a person is able to perform a certain task. Given that losses in the inferior VF have been linked to deficits in mobility performance¹⁷ and driving cessation,¹⁸ one may expect that constriction of the AVF in the inferior hemifield will also have a significant impact on driving and mobility performance, since both these tasks also use the inferior AVF.

In most AVF studies, performance at each eccentricity has simply been averaged across the different meridians (typically the eight principal meridians). Sekuler and Ball¹¹ and Ball et al.¹⁰ reported that performance did not vary from one meridian to the next, although they did not provide any supporting data or statistical analyses. Seiple et al.¹⁴ did not find a significant interaction between meridian and eccentricity. The findings from these earlier studies differ, however, from those of more recent studies, which have reported differences in the extent of the AVF between the horizontal and vertical meridians.¹⁹⁻²¹

Given the inconsistent findings of previous research about the shape of the AVF, the goals of this study were to (1) describe the AVF along the four principal meridians in a large population of older drivers; (2) identify demographic, cognitive, and vision factors associated with AVF performance; and (3) explore factors associated with the anisotropy seen in the extent of the AVF.

METHODS

Population

The Salisbury Eye Evaluation Driving Study (SEEDS) is a longitudinal study of vision, cognition, and driving behavior of drivers aged between 67 and 87 years living in the Greater Salisbury Metropolitan Area. Using the Maryland Department of Motor Vehicles roster of registered drivers between 67 and 87 years of age as of June 1, 2005, postcards were mailed to all eligible drivers residing in Wicomico County, Maryland. From the 1425 participants enrolled in the study, reliable AVF test results were obtained in 1386 (97%) participants, and their results are included in this report (Table 1). AVF results deemed unreliable or inaccurate (i.e., incomplete AVF results from participants due to ill-

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TABLE 1. Characteristics of the Population Completing the Attentional VF Assessment

Characteristic	n	Statistic
Demographics		
Age, y (mean (SD), IQR)	1386	76.0 (5.2), 9.0
Race		
Black	173	12.5%
White	1206	87.0%
Other	7	0.5%
Sex		
Male	686	49.5%
Female	700	50.5%
Years of education (mean (SD), IQR)	1386	13.5 (2.6), 4.0
Cognitive function		
MMSE score (mean (SD), IQR)	1386	28.3 (1.8), 2.0
Brief test of attention score (mean (SD), IQR)	1381	6.5 (2.5), 4.0
Trials B, time to complete in seconds (mean (SD), IQR)	1366	127.6 (73.6), 64.0
Visual function		
Binocular presenting acuity (mean (SD), IQR)	1386	-0.01 (0.11), 0.16
Contrast sensitivity, better eye (mean (SD), IQR)	1386	35.2 (2.3), 2.0
Bilateral visual field, no. of either missed or initially undetected points within central 22° VF (mean (SD), IQR)	1376	0.33 (1.8), 0

ness, refusal to participate, or inability to follow instructions) were excluded from all data analyses.

Data for this report were collected in round 1 of the study (July 2005 to June 2006). Basic demographic data such as age, sex, race, level of education, and current medication use were obtained using structured questionnaires administered at the participant's home. Information about current and past history of specific comorbidities such as arthritis, stroke, heart disease, and depression were derived through structured medical history questionnaires and the Geriatric Depression Scale questionnaire.

The research adhered to the tenets of the Declaration of Helsinki, and informed consent was obtained from participants after explanation of the nature and possible consequences of the study. The Johns Hopkins Medical Institutions' review board approved the research.

Procedure

After the home interview, the participants underwent cognitive and visual assessments at a central examination site by trained technicians. The cognitive and visual assessments used in this study were selected because of their association to driving performance in other studies.²²⁻²⁵

Cognitive Measures

General cognitive status was assessed using the standardized Mini-Mental State Examination (MMSE)²⁶ which was administered in the usual manner. Research by Marottoli et al.²⁵ has shown that the MMSE is related to self-reported driving performance.

The Brief Test of Attention (BTA),²⁷ which has been shown to be linked to motor vehicle crashes among older individuals,²⁴ was used to assess the cognitive domain of auditory divided attention. In this task, participants were required to focus their attention on a specified stimulus set and use working memory to maintain it while withstanding distraction. Participants were instructed to listen to a tape-recorded list of 20 strings of intermixed numbers and letters, (e.g., "T-6-1-A-6-T"), that contained between 4 and 18 items. After listening to each string, participants reported the number of letters (part 1) and numbers (part 2) that they had heard and were scored based on the number of correct responses.

The Trail-Making Test, Part B (Trails B), which has been shown to predict both motor vehicle collisions and on-road driving performance,^{22,23} was used to assess executive cognitive function requiring psychomotor speed, visual search, and attention. In this paper-based task, participants were required to connect labeled circles consecutively that alternated between numbers (1-13) and letters (A-L), as

quickly as possible. The number of seconds participants took to complete this task was recorded, with a maximum timeout score of 480 seconds.

Vision Measures

All vision assessments were done with the participant's habitual correction if normally worn for driving, although for the VF and AVF assessments, participants were optically corrected for the shorter test distances.

Binocular visual acuity (VA) was measured by using a high-contrast ETDRS acuity chart²⁸ that was transilluminated with a light box (Light-house, New York, NY), to the recommended chart luminance of 85 to 120 $\text{cd} \cdot \text{m}^{-2}$. A strict forced-choice procedure was used by forcing participants to guess letters until they missed at least four of five letters in a row. Binocular threshold VA was determined by assigning each correctly identified letter with a value of $-0.02 \log \text{MAR}$.²⁹

Binocular and monocular contrast sensitivities (CSs) were assessed with the Pelli-Robson letter contrast-sensitivity chart,³⁰ which was illuminated to the recommended chart luminance of 85 $\text{cd} \cdot \text{m}^{-2}$.³¹ A forced-choice procedure was used to determine the threshold CS score by forcing participants to guess letters until two of three letters within a triplet were read incorrectly. Threshold CS was scored by assigning each correctly identified letter a value of 0.05 $\log \text{CS}$. A call of "O" for "C" was accepted as correct.^{32,33} Monocular CS measurement always preceded binocular CS assessment, and the order of the charts and eyes assessed were counterbalanced across subjects.

Monocular VFs in both eyes were measured in each participant by using the 81-point, quantify defect screening test strategy on a field perimeter (Humphrey Field Analyzer, HFA; Carl Zeiss Meditec, Inc., Dublin, CA). This automated VF test assesses the static VF over a 60° radius VF by using a Goldmann III white target against a background luminance of 31.5 apostilb or 10 $\text{cd} \cdot \text{m}^{-2}$. The quantify defect screening strategy initially presents light stimuli that are 6 dB brighter than the expected hill of vision based on the participant's age. If the participant does not detect this light, a 4-2 staircase procedure is used to determine a VF threshold. As is standard procedure, participants' vision was optically corrected during the central (30°) VF testing, but not for the peripheral (from 30°-60°) VF assessment.³⁴

For this report, the VF results of the two eyes were combined by using the algorithm of Nelson-Quigg et al.³⁵ to create a binocular VF plot consisting of 96 test points. The number of missed points (defects) in the binocular field within the central 20° VF was tallied for each participant and used for analyses.

The AVF was assessed binocularly by using a custom-written program that was modeled after the work of Sekuler and Bennett.¹⁵ The commercially available Vision Attention Analyzer (Vision Resources, Chicago, IL) was not used in this study because it assesses processing speed and only measures divided attention out to a maximum eccentricity of 15° radius. The custom program developed for this study assessed the AVF extent out to 20° radius in a divided-attention protocol.

For this test, participants were seated 35 cm in front of a touch-screen monitor and optically corrected for the test distance. Participants were instructed to fixate on a circular target positioned in the center of the monitor. Two numbers were simultaneously presented for a brief period (250 ms; Fig. 1). One number was located at the center of the screen and subtended a visual angle of 0.8°. The other (peripheral target) was located along one of four possible meridians (0°, 90°, 180°, and 270°) eccentric to the central target (Fig. 1). The visual angle subtended by the eccentric number was scaled in size using the equation of Antis³⁶ to ensure equal legibility of numbers with increasing eccentricity. At the same time that the targets were presented, seven filled circles (distractors) were presented at the same eccentricity and same size as the peripheral target (Fig. 1). The distractors and peripheral target were arranged into eight evenly spaced radial spokes. After the presentation of the targets and distractors, a masking pattern appeared. The numbers presented were chosen randomly between 0 and 9, and both the targets and the distractors were white presented against a black background. The short display duration of the test stimuli minimized the likelihood of the participants' making eye movements during the presentation. The participants were required to report orally the central and peripheral target numbers (which were entered into a computer by the experimenter) and to indicate the location of the peripheral target by touching the touch-screen monitor at its location.

We used a Parameter Estimation by Sequential Testing (PEST) procedure³⁷ to determine the eccentricity of the peripheral target on each trial for each meridian. Throughout the test session, four PEST algorithms, one for each meridian, were randomly interleaved. For a response to be correct, the numbers for both the central and peripheral targets and the location of the peripheral target had to be correctly identified. To reduce participant burden, the PEST was limited to a total of 24 trials: 6 trials in each of the four meridians. The last value calculated by the PEST procedure was used as the final estimate of the subject's AVF for that meridian. There is a tradeoff in using a fixed number of trials versus a fixed variance level. We chose to fix the number of trials to minimize the participant's testing time and level of fatigue. It is acknowledged that by fixing the number of trials, there may be increased uncertainty among the participants' AVF thresholds compared with allowing the PEST to run until a fixed estimate of the final AVF variance had been attained.

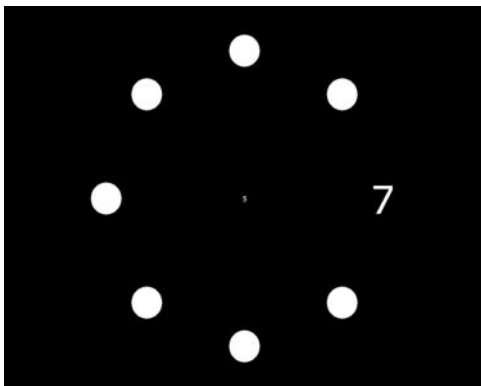


FIGURE 1. Sample screen display of a single trial on the AVF task.

Data Analysis

To identify demographic, cognitive, and vision factors associated with the AVF, a linear regression model was created. The model included preselected demographic (age, race, sex, education, depression), cognitive (MMSE, BTA, Trails B), and visual function (VA, CS in the better eye, and bilateral VF) measures. Variance Inflation Factors (VIF) for this model were also calculated to assess for collinearity between the vision and cognitive measures.

To assess the shape of each participant's AVF, the ratio between the horizontal and vertical AVF extent was computed for each participant. With this method of scoring, a ratio of 1.0 represented a symmetric AVF in which the extents of the AVF along the horizontal and vertical meridians were the same. Shape ratios between 0.8 and 1.2 were considered to represent a "symmetric" AVF, whereas shape ratios outside of this range were considered to be "asymmetric." The cutoff values used to classify the AVF shape profiles represented was set at 20% on either side of the symmetrical shape ratio of 1.0. This cutoff value was selected to ensure that each AVF shape category had sufficient participant numbers. Inferences, however, did not change when a 25% cutoff value was used.

To explore factors associated with anisotropy of the AVF, each participant's AVF was classified into one of three AVF shape categories: (1) symmetric AVF; (2) vertical AVF extent > horizontal AVF extent (i.e., shape ratio < 0.8); and (3) vertical AVF extent < horizontal AVF extent (i.e., shape ratio > 1.2). Univariate polytomous regressions were performed (the CATMOD procedure SAS, ver. 9.0; SAS, Cary, NC) to determine the log odds of asymmetry in either direction compared with the symmetric category for demographic, cognitive, and vision measures while adjusting for AVF area. Given that similar results were obtained when a multivariate analysis was performed, only the results of the univariate polytomous regressions for AVF asymmetry are reported in this article.

RESULTS

Of the 1425 participants in the study, the results of 39 (~3%) participants were not used for analyses due to unreliable AVF results because of illness, refusal to participate, or inability to follow instructions.

AVF Extent

The median (and interquartile range [IQR]) AVF extent across the four principal meridians in this cohort was 12.4° (7.8°), whereas the median (IQR) AVF extent in the horizontal and vertical meridians were 15.3° (9.3°) and 11.3° (8.3°), respectively. AVF extent along the horizontal meridian was significantly better than AVF extent along the vertical meridian (paired *t*-test, $P < 0.0001$). The AVF extent along the superior (90°) meridian (11.3°) was significantly better than the AVF extent along the inferior (270°) meridian (10.8°) (paired *t*-test, $P = 0.004$); no significant difference in AVF extents was found between the 0° (14.1°) and 180° (14.0°) meridians ($P > 0.05$).

The factors associated with overall AVF extent consisted of demographic, cognitive, and vision variables (Table 2), and these variables collectively accounted for approximately 32% of the total variance in overall AVF extent. The AVF extent of the male participants was significantly better than that of the female participants ($P = 0.0012$).

As illustrated in Figure 2, the AVF extent decreased with increasing age. This finding was true of both the horizontal and vertical meridians as well as of overall AVF extent.

Older participants tended to have a smaller AVF extent: For every year's increase in age, the overall AVF extent decreased on average by 0.15°. On average, the overall AVF extent was reduced by 1.66° in blacks and by 0.03° for every point increase in the depression score. On average, being male increased the overall AVF extent by 0.6° and there was a 0.14°

TABLE 2. Multivariate Model Describing Associations between Average AVF Extent and Demographic, Cognitive, and Visual Factors

Characteristic	Parameter Estimate	Standard Error	P
Demographics			
Age (per year increase)	-0.15	0.02	<0.0001
Male	0.60	0.25	0.013
Black/white	-1.66	0.37	<0.0001
Years of education (per year increase)	0.14	0.05	0.003
Depression score (per point)	-0.03	0.03	0.27
Cognitive function			
MMSE per 1-point increase	0.09	0.08	0.25
Brief test of attention per 1-point increase	0.34	0.06	<0.0001
Trials B per 5 seconds	-0.09	0.01	<0.0001
Visual function			
Visual acuity per loss of 1 line	-0.37	0.11	0.0012
Better eye contrast per increase of three letters	0.58	0.18	0.0009
Central visual fields per 5 points, either missed or initially undetected	-1.05	0.33	0.0017

increase in overall AVF extent for every year's increase in years of education.

Independent of these demographic factors, overall AVF extent also associated with various cognitive functions. As listed in Table 2, on average, for every point increase in the MMSE and the BTA, the overall AVF extent increased by 0.09° and 0.34° respectively. AVF extent decreased by 0.09° for every 5-second increase in performance time in Trials B.

Visual function also had an independent and significant contribution to overall AVF performance (Table 2). The overall extent of the AVF decreased on average by 0.37° for every line of VA lost and 1.05° per five points not detected in the central 20° radius VF. Overall AVF extent increased by 0.58° for every three letters correctly identified on the Pelli-Robson Contrast Sensitivity Letter Chart in the better seeing eye.

AVF Shape

Symmetrically shaped AVFs were found in 476 (34%) of the 1386 participants. The remaining 910 (66%) participants had an asymmetric AVF shape profile. Of the 910 participants who

had an asymmetric AVF shape profile, 751 participants (~83%) had a shape ratio greater than 1.2. Thus, their horizontal AVF extent was greater than their vertical AVF extent, or "H-AVF > V-AVF." The remaining 159 (17%) participants had a shape ratio less than 0.8, where the vertical AVF extent was greater than the horizontal AVF extent (V-AVF > H-AVF).

Table 3 lists the percentage of participants in each of the AVF shape profiles within each 5-year age group, sex, and race. Just over half of all participants, regardless of race, sex, and 5-year age group category had an asymmetric AVF shape of H-AVF > V-AVF. A third of all participants had a symmetrically shaped AVF, whereas the remaining ~10% to 15% of participants had an asymmetric AVF shape of V-AVF > H-AVF. With each 5-year increase in age, there was an increase in the percentage of participants who had an asymmetric AVF shape of H-AVF > V-AVF. A greater percentage of the women and blacks had an AVF shape of H-AVF > V-AVF compared with the men and whites. After adjustment for AVF area, the effects of age, sex, and race on the percentage of participants in each of the AVF shape profiles were less evident.

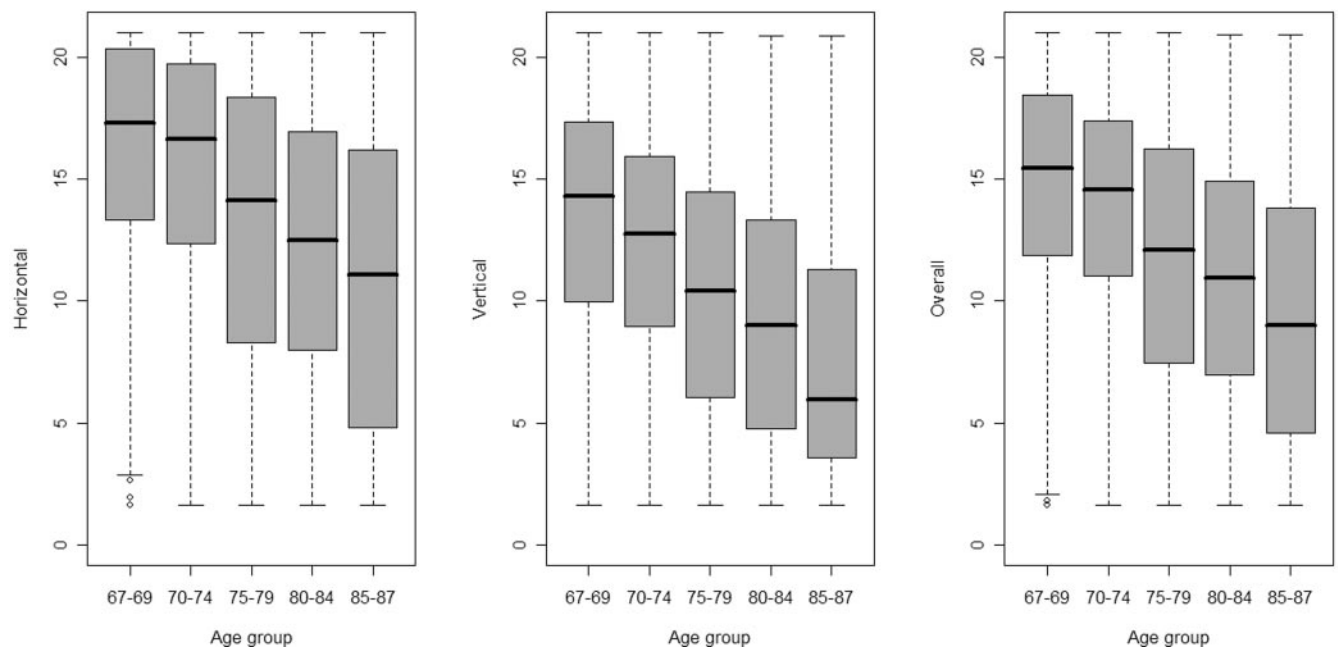


FIGURE 2. Average AVF extent along the horizontal meridian (left), vertical meridian (middle), and overall extent across all four principal meridians (right). The whiskers extend to the most extreme data point. Each box contains 50% of the observations, and the median value is indicated by the line within the box.

TABLE 3. Percentage of Participants in Each of the Different AVF Shape Profiles Broken Down by Age, Sex, and Race

Characteristic	<i>n</i>	Horizontal/Vertical Ratio < 0.8	Horizontal/Vertical Ratio between 0.8–1.2	Horizontal/Vertical Ratio > 1.2
Age (y)				
<75	631	9.7	38.7	51.7
75–79	388	12.1	32.5	55.4
80–84	307	15.3	27.4	57.3
85+	57	7.0	33.2	59.7
Sex				
Female	698	12.2	31.8	56.0
Male	685	10.8	36.6	52.6
Race				
Black	173	13.3	27.8	59.0
White	1210	11.2	35.1	53.6

The results of regressions examining the vision and cognitive factors associated with the two different AVF shape asymmetry groups are listed in Table 4. We adjusted for AVF area, and because of the association of area with demographic factors, we did not include the demographic factors in the models. When including the demographic factors, the inferences did not change (data not shown). Using the symmetric shape category as a reference, we found that participants with worse performance on Trials B were less likely to have an H-AVF > V-AVF asymmetric AVF shape profile than were participants with better Trial B scores. We also found that participants with better VA were more likely to have a V-AVF > H-AVF asymmetric AVF shape profile compared with participants with poorer VA. Participants with greater VF loss within the central 20° radius were less likely to have an H-AVF > V-AVF asymmetric AVF shape profile compared with participants with less VF loss in the central 20° radius.

DISCUSSION

One of the primary goals of this study was to describe the AVF in a large population of elderly drivers. Using our method of AVF assessment, we found that active, elderly drivers were able to divide their attention successfully, on average, out to an extent of 12.4°. Participants, however, did not divide their attention evenly across the different meridians. The average horizontal and vertical AVF extents were 15.3° and 11.3°, respectively. This difference was statistically significant and remained regardless of age and sex, thus revealing a larger AVF along the horizontal meridian.

Our finding of anisotropy of the AVF between the horizontal and vertical meridian is in agreement with previous research. Mackeben,¹⁹ Altpeter et al.,²⁰ and Carrasco et al.²¹ have all reported that the AVF is better along the horizontal meridian

than along the vertical meridian. In addition, He et al.,³⁸ Carrasco et al.,²¹ and Liu et al.³⁹ reported that performance in a discrimination task similar to a divided-attention task with low foveal load is better along the inferior than superior portion of the vertical meridian. We did not find such a trend along the vertical meridian. The AVF extent along the inferior (270°) meridian was significantly worse than that along the superior (90°) meridian. Our result of decreased performance along the inferior meridian is in agreement with the results of Wood et al.¹² who found, averaging results across intermediate meridians, that their subjects had made a significantly greater percentage of errors in peripheral localization in the inferior hemifield than in the superior hemifield.

A new finding of our study was the identification of different AVF shape profiles and the demographic, cognitive, and visual factors associated with the AVF shape. Our finding that most participants had an asymmetric AVF shape, especially one in which the horizontal meridian was greater than the vertical meridian, suggests that an asymmetrically shaped AVF may be the normal AVF shape, as opposed to a symmetric AVF shape for this age group. It may be that persons allocate their visual attention resources to areas of the visual field that maximize task performance.

The factors that were found to be significantly associated with AVF shape are listed in Table 4. For any two individuals with the same AVF area, the individual with the poorer Trials B score or worse vision, measured either as VA or VF, was more likely to have a symmetric AVF shape profile than an asymmetric AVF of either shape profile. This result suggests that across individuals with the same overall AVF area, persons with failing resources, either visual or cognitive, lose the ability to redistribute their visual attention resources to maximize task performance, thus resulting in a symmetric AVF shape.

TABLE 4. Regressions Examining the Factors Associated with AVF Shape Asymmetry*†

Characteristic	Horizontal/Vertical Ratio < 0.8 (<i>n</i> = 159)	Horizontal/Vertical Ratio > 1.2 (<i>n</i> = 751)
Age (per year increment)	1.00 (0.96–1.04)	1.00 (0.98–1.02)
Female/male	0.85 (0.58–1.25)	0.89 (0.70–1.13)
Black/white	0.80 (0.45–1.42)	0.96 (0.65–1.42)
Education (y)	1.02 (0.95–1.10)	1.03 (0.98–1.08)
BTA	1.02 (0.94–1.11)	1.04 (0.99–1.10)
Time Trials B (per additional 10 s)	0.98 (0.95–1.00)	0.98 (0.96–0.99)
Visual acuity (per line gain)	1.23 (1.03–1.47)	1.09 (0.97–1.22)
Binocular contrast (includes three letters)	1.12 (0.9–1.38)	1.06 (0.93–1.20)
VF points missing (includes five)	0.91 (0.63–1.32)	0.63 (0.43–0.93)

* Adjusted for AVF area.

† Results are expressed as the odds ratio (95% CI). Bold, statistically significant at $P \leq 0.05$

The demographic, cognitive, and visual factors measured in our study explained 32% of the variation in AVF extent. Specifically, we found that AVF performance decreases with increasing age, a finding that is consistent with those in several earlier studies.^{10,11,13-16,40}

We also found that being female, being black, and having fewer years of education were significantly associated with smaller AVF extent (Table 2). Another factor that was found to be predictive of overall AVF extent was depression. Participants with worse depression scores had worse AVF performance, perhaps because of the indirect effect that depression has on cognition. Previous research has shown that depressed patients exhibit lower cognitive abilities than do those who are not depressed.⁴¹⁻⁴³

Cognitive and visual factors were also found to be significantly associated with overall AVF extent (Table 2). In general, we found that decreased cognitive ability on the MMSE, BTA, and Trails B assessments were associated with smaller AVF extent. Similarly, vision loss, indexed in this study as decreased VA; CS in the better eye; and VF loss in the central 20° radius VF, all resulted in decreased AVF extent. Given that the AVF relies both on visual and cognitive skills, it is not surprising that these measures were found to play a significant role in predicting overall AVF extent.

Very few studies have assessed the association between measures of cognitive ability and AVF extent. As found in our study, Edwards et al.⁴⁴ reported that those participants with poor MMSE scores had a significant decrease in AVF extent compared with participants with better cognitive status.

Our finding that measures of VF and CS were predictive of AVF performance is in agreement with previous studies.^{8,13,44,45} The relationship between VA and AVF extent, however, is not as well understood. Like Edwards et al.,⁴⁴ we found that binocular VA loss was related to smaller AVF extent. Studies by Leat and Lovie-Kitchin¹³ and Owsley et al.,⁴⁵ however, have reported no associations between VA and AVF extent. A possible reason that some studies have found a significant association between VA and AVF extent and others have not, relates to the size of the stimulus and distractors used in the divided attention task. In our study, the angular subtense of the central number (stimulus) was 0.8°, and in the study by Edwards et al.⁴⁴ it was 1.4° × 1.88° (height × width). By comparison, the angular subtense of the central target used by Leat and Lovie-Kitchin¹³ was 3.38° and in the Owsley et al.⁴⁵ study, 3° × 5° (height × width). The smaller central target used in our study and that of Edwards et al.⁴⁴ most likely made these AVF assessments more sensitive to the effects of VA loss, since the smaller central target sizes would not be as robust against the detrimental effects of optical blur or distortion (i.e., decreases in VA) compared with the larger central target sizes used in the other studies.

In conclusion, the AVF extent was larger along the horizontal meridian compared with the vertical meridian, and overall AVF extent was associated with various demographic, cognitive, and vision measures. We also found that most of the participants had an asymmetric AVF shape profile in which the horizontal AVF extent was greater than the vertical AVF extent. Finally, declines in cognitive and visual performance were associated with having a symmetric AVF shape profile.

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