Assessing visual fields for driving in patients with paracentral scotomata

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ABSTRACT

Background: The binocular Esterman visual field test (EVFT) is the current visual field test for driving in the UK. Merging of monocular field tests (Integrated Visual Field, IVF) has been proposed as an alternative for glaucoma patients.

Aims: To examine the level of agreement between the EVFT and IVF for patients with binocular paracentral scotomata, caused by either ophthalmological or neurological conditions, and to compare outcomes with useful field of view (UFOV) performance, a test of visual attention thought to be important in driving.

Methods: 60 patients with binocular paracentral scotomata but normal visual acuity (VA) were recruited prospectively. Subjects completed and were classified as "pass" or "fail" for the EVFT, IVF and UFOV.

Results: Good agreement occurred between the EVFT and IVF in classifying subjects as "pass" or "fail" (kappa = 0.84). Classifications disagreed for four subjects with paracentral scotomata of neurological origin (three "passed" IVF yet "failed" EVFT). Mean UFOV scores did not differ between those who "passed" and those who "failed" both visual field tests ($p = 0.11$). Agreement between the visual field tests and UFOV was limited (EVFT kappa = 0.22, IVF kappa 0.32).

Conclusions: Although the IVF and EVFT agree well in classifying visual fields with regard to legal fitness to drive in the UK, the IVF "passes" some individuals currently classed as unfit to drive due to paracentral scotomata of non-glaucomatous origin. The suitability of the UFOV for assessing crash risk in those with visual field loss is questionable.

Links between driving performance and visual field loss have been demonstrated,[1–3] but determining the limits of paracentral visual field loss for safe driving is problematic. In relation to driving, the binocular Esterman visual field test (EVFT)[4] is the current gold-standard for testing binocular visual fields in the UK. At the time of writing, the visual field requirements specified by the Driver Vehicle Licensing Authority (DVLA) in the UK for a Group 1 (ordinary car) licence are as follows: "A minimum horizontal field of vision of 120° and no significant defect within 20° of fixation".[5]

Scattered single missed points and a single cluster of up to three contiguous points (Esterman protocol) are acceptable. The following are unacceptable: a cluster of four or more adjoining points that is either wholly or partly within the central 20° area; loss consisting of both a single cluster of three adjoining missed points up to and including 20° of fixation, and any additional separate missed point(s) within the central 20° area; any central loss that is an extension of a hemianopia or quadrantanopia of size greater than three missed points.

Design limitations, in particular the poor sampling density of the EVFT within the functionally relevant visual field of a car driver[6] and difficulties with binocular fusion and fixation monitoring, have led both the International Council of Ophthalmology[7] and the Eyesight Working Group of the European Union[8] to advise against the use of binocular visual field assessment and to recommend the merging of monocular measurements to estimate the binocular visual field. Merged fields relate more closely than EVFT results to visual and mobility problems reported by patients.[9 10]

Crabb and colleagues proposed the Integrated Visual Field (IVF) as an alternative method of assessing individuals suffering from primary open angle glaucoma.[11 12] It is derived from merging monocular full threshold visual field data from the Humphrey Visual Field Analyser (HFA), routinely collected as part of the disease monitoring process. They found good agreement between the IVF and EVFT in classifying a group of glaucoma patients in relation to the UK visual field requirements for a Group I driving licence.[11 12] They also compared visual field outcomes with performance on the useful field of view (UFOV) test, a measure of visual processing speed that has been associated with relative crash risk in older drivers.[13–15]

The purpose of this study is to determine if the substantial level of agreement shown by Crabb and colleagues[12] between the IVF and EVFT in classifying glaucoma patients is present for a more representative sample of the target population, that is those with binocular paracentral visual field loss but preserved VA resulting from a wide range of both ocular and visual pathway disease in addition to glaucoma, who are required to undergo binocular visual field assessment by the DVLA. In attempting to replicate the study performed by Crabb and colleagues,[12] we also compare visual field outcomes with UFOV performance and consider whether this test, a psychophysical test specifically designed to examine visual attention in drivers, can be employed as an arbiter between visual field tests for driving.

METHODS

Subjects

Patients with normal VA but paracentral visual field loss in both eyes that was either homonymous or overlapping to produce binocular paracentral scotoma(ta) were identified from their full threshold central visual field plots. Participants with a single, consistent diagnosis for their visual field loss and a binocular VA of at least 6/9 (20/30) were recruited prospectively from several participating hospital eye clinics. The DVLA have recently stated that a monocular acuity of 6/12 or better in the better eye indicates an almost certain pass in the number plate test, except in unusual cases such as patients with nystagmus. A VA of 6/9 is the approximate Snellen equivalent of the number plate test,[16] and therefore provides a suitable VA cut-off for the selection of participants. We aimed to achieve a representative cross-section of typical binocular paracentral visual field loss attributable to a range of ophthalmological and neurological conditions that require the patient to notify the DVLA of their need for visual field assessment. The study was approved by the ethics committees of each of the participating institutions and followed the tenets of the Declaration of Helsinki. Written informed consent was obtained from each participant after the nature and possible consequences of the study had been explained.

Experimental procedure

The following tests were undertaken as part of a larger battery of psychophysical tests, the results of which are reported elsewhere.[6] Each subject attended on two occasions separated by no more than 2 weeks.

Visual fields

The HFA Model II (Humphrey Instruments, Dublin, CA) was used to perform an EVFT and bilateral monocular full-threshold central visual field testing using the 24-2 SITA Standard program. Potential participants were excluded if they produced unreliable fields at the first screening visit (false negative, false positive or fixation losses ⩾20%). Monocular data were merged using the PROGRESSOR software (Institute of Ophthalmology, University College, London) to derive the Integrated Visual Field (IVF).[11 17] This software takes the maximum sensitivity from 32 corresponding points in the right and left monocular central $\pm 20^\circ$ visual fields, to give an estimate of the binocular sensitivity at that point. Locations with a sensitivity of 10 dB or less (equating to the intensity of the EVFT stimulus) were identified. The DVLA group I (ordinary car) licence requirements[5] and the modified criteria proposed by Crabb *et al*[12] were used to classify subjects as "pass" or "fail" for the EVFT and IVF respectively. The modified criteria are adjusted to account for the greater sampling density within the central $\pm 20^\circ$ of the IVF compared with the EVFT, and require a cluster of six or more missed points, compared with four or more for the EVFT, to constitute a "fail".

UFOV test

The UFOV (Visual Attention Analyzer Model 2000, Visual Resources, Chicago) is a computer-administered test examining the central ± 30 that has been specifically designed to examine visual attention in drivers.[18] The UFOV test score is expressed as a function of three tasks: the minimum target duration required to perform a central discrimination task (speed of processing task: identification of a central target of varying duration presented in a fixation box), the ability to divide attention between central and peripheral tasks successfully (divided attention task: identification of the central target at the same time as localising a peripheral target of varying duration presented simultaneously at eccentricities up to 30°) and the ability to filter out distracting stimuli (selective attention task: same as second task but peripheral target is embedded in distractors). For the speed of processing task, the minimum duration that subjects can perform the task with 75% correct is noted. For the divided and selective attention tasks, the best-fitting line reflecting the relationship between eccentricity and localisation errors is computed for each stimulus duration from which the UFOV size is defined as the eccentricity at which peripheral targets can be correctly localised 50% of the time. Performance on each task is combined to arrive at three scores, representing the extent of difficulty (0% = no problem, 30% = great difficulty) with regard to speed of processing, divided attention and selective attention.[19] To summarise UFOV performance, the three scores are added together to yield a score of between 0 and 90%, which represents the percentage reduction of a maximum 30° radius field. We classified subjects as a "fail" if they exhibited ⩾40% loss of UFOV, since studies employing the same UFOV model have identified a greater crash history, an increased risk of future crash involvement and poorer driving performance in such individuals.[13–15]

Following classification of each subject as "pass" or "fail" for each test, data were transferred to Minitab Version 14 for the production of frequency tables and statistical analysis.

RESULTS

Sixty patients satisfying the methodological criteria were recruited for this study. They represented a wide range of conditions resulting in paracentral scotomata, including glaucoma, bilateral retinal disease and lesions to the visual pathway. They ranged in age from 23 to 86 years (mean 52 years). Their mean Esterman efficiency score was 86 (range 15 to 100), and they all achieved a binocular VA of 6/6 (20/20) or better.

Table 1 indicates that there is excellent agreement between the binocular EVFT and IVF tests in classifying subjects as "pass/fail" with respect to the UK fitness-to-drive visual field criteria (93% exact agreements). This is equivalent to a kappa value of 0.84, indicating that the agreement is well beyond what would be expected by chance alone. Fifty-nine per cent of subjects "passed" the criteria in both tests, and the sensitivity and specificity of the IVF in predicting EVFT outcome for this group of subjects are high (86% and 97%, respectively). Full agreement between the two tests occurred for the subgroup of 20 glaucoma patients. Table 1 also highlights four subjects who were classified differently by the EVFT and IVF. One individual presented with a discrete scotoma close to fixation that allowed him to "pass" the EVFT yet "fail" the IVF (fig 1). The other three "passed" the IVF but "failed" the EVFT, since the missed points were an extension of mid-peripheral visual field loss (eg, fig 2). All four exhibited binocular scotomata of neurological origin.

When UFOV performance was considered, both the individual who met the UK visual field requirements for driving ("passed" the EVFT) yet "failed" the IVF, and the three subjects who "failed" the EVFT visual field requirements yet "passed" the IVF, showed a reduction in UFOV of 25% or less ("pass"). This suggests that these individuals are most likely to belong to the group whose vision does not put them at greater risk when driving according to the UFOV. In this study, however, there is no statistically significant difference in the total UFOV scores of subjects who either "passed" or "failed" both visual field tests (parametric unpaired t test). There is a similar statistical outcome for the glaucoma subgroup (table 2).

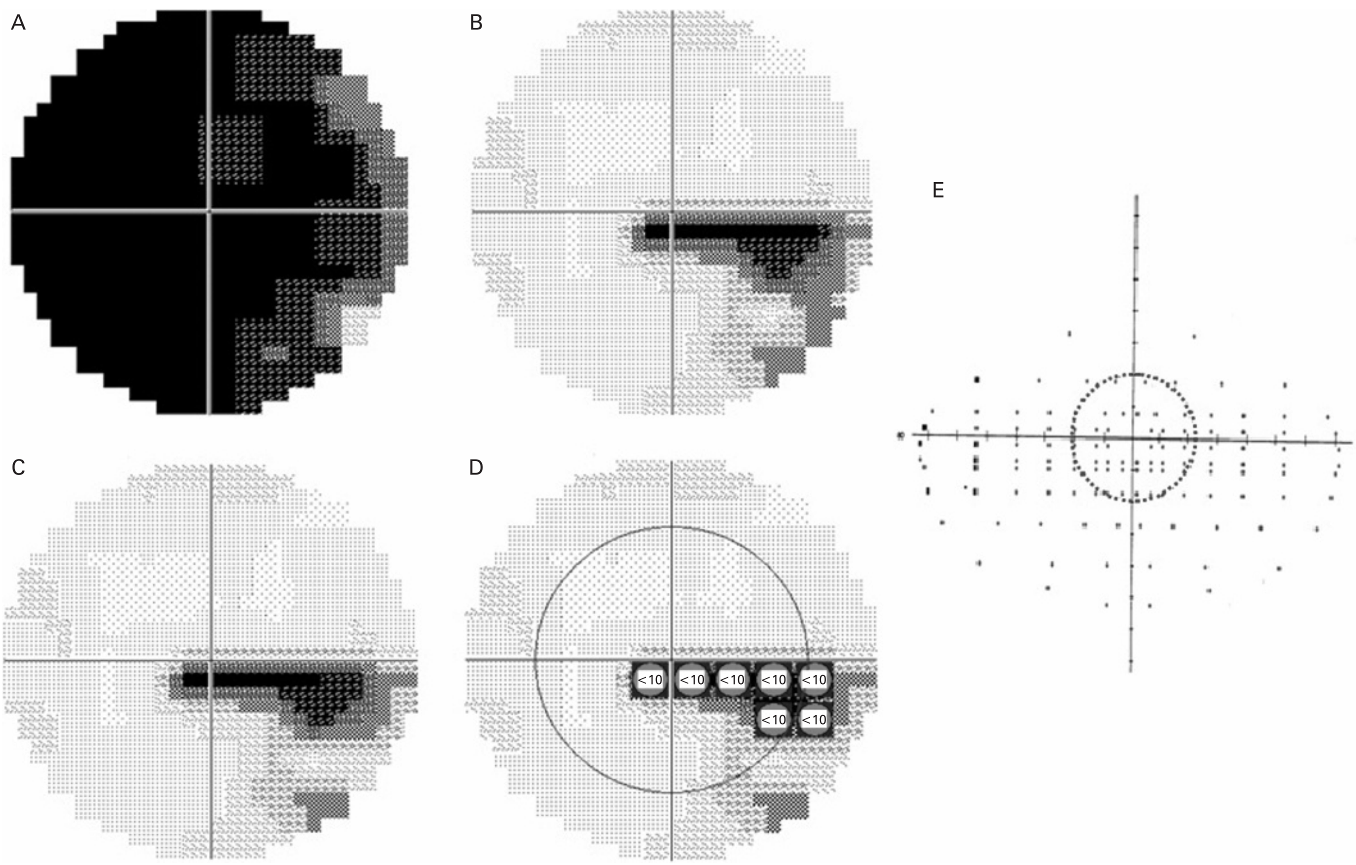

Figure 1 Visual field results from patient 31, a 36-year-old individual with bilateral optic nerve compression resulting from a tumour. Plots A and B show the monocular HFA grey-scale for the left and right eyes, respectively. Plot C shows the integrated visual field achieved by merging plots A and B. Plot D shows the IVF with symbols superimposed to indicate the points where the sensitivity falls below 10 dB. Six contiguous points <10 dB that are wholly or partly within the central 20° means that this patient fails the modified pass/fail criteria for the IVF proposed by Crabb and colleagues.[12] Binocular visual acuity was normal despite the closeness of the scotoma to fixation. Plot E shows the EVFT with no points missed within the central 20° area (indicated by the dotted circle). The patient passes the DVLA criteria for the Esterman (additionally achieving a horizontal field greater than 120°). This patient exhibited UFOV performance within the normal range (5% loss), which may suggest a useful field of view compatible with driving.

Although agreement between the EVFT and the UFOV test was 65% with a large proportion of subjects "failing" the EVFT yet "passing" the UFOV (table 1), a kappa value of 0.22 indicates that chance plays a significant role, and agreement can only be classed as fair. Agreement between the UFOV and the IVF was similarly limited (69.2%, kappa = 0.32; table 3).

DISCUSSION

Given that the EVFT and IVF are both based on conventional visual field tests, it is not surprising that there is very good agreement between them (kappa = 0.84). In addition, the IVF "pass/fail" criteria proposed by Crabb and colleagues[12] are derived from the EVFT criteria[5] adjusted for the greater sampling density of the IVF within the central $\pm 20°$.The specificity of the IVF in predicting the EVFT outcome was 97%, relating to a single subject exhibiting a binocular scotoma within the central $\pm 7.5°$ (fig 1), an area neglected by the EVFT. Such a pattern of visual field loss without an associated reduction in VA is not uncommon and was reported in 12% of the glaucoma cases examined by Crabb and colleagues.[12] It is concerning that such binocular visual field loss currently goes largely undetected, and yet its proximity to fixation is likely to have implications for the timely detection of discrete hazards, such as cyclists.

In our opinion, the sparse stimulus array of the EVFT makes it inappropriate for examining the visual field of a car driver, since only 25% of measured points fall within the most functionally relevant area.[6]

The IVF has been proposed as a more practical test for assessing central visual fields in the context of driving for glaucoma patients, supported by the 100% sensitivity achieved in predicting the outcome of the EVFT.[11 12] A sensitivity value of 100% is found for the glaucoma sub-sample in this study, but this falls to 86% when the total sample is considered due to the test outcomes from three subjects with mid-peripheral visual field loss of neurological origin affecting the EVFT but not the IVF. Monocular full threshold visual fields are routinely assessed in glaucoma patients, and peripheral visual field loss tends to occur in conjunction with reduced sensitivity within the central $\pm 30°$.[20] This does not necessarily apply to other retinal and optic nerve conditions, and is certainly not the case for most neurological conditions. If our study sample had been fully representative of the population of patients who are required to inform the DVLA of their need for visual field assessment (ie, included those with peripheral binocular visual field loss but no or minimal paracentral visual field loss), we would expect an even lower sensitivity value with a greater proportion of subjects failing the EVFT yet passing the IVF. The IVF, being a test of the central visual field, cannot take into consideration the extension of paracentral missed points into the mid-peripheral visual field.

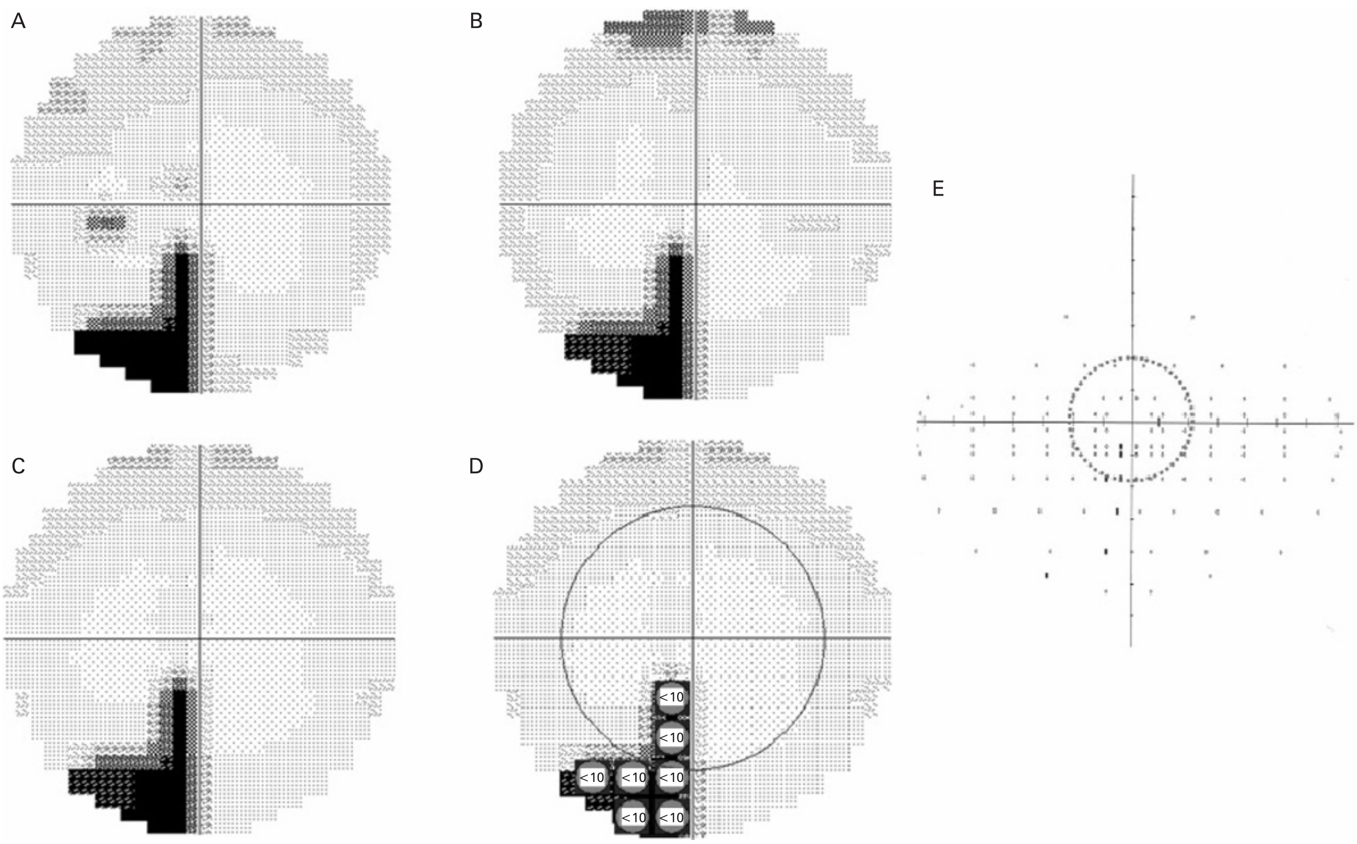

Figure 2 Visual field results from patient 15, a 48-year-old individual with a longstanding right optic radiation lesion of unknown origin. This composite figure is made up in the same way as fig 1. The patient fails the DVLA criteria for the Esterman, since the cluster of three missed points within the central 20° is an extension of a larger defect outside the central 20°. The patient passes the modified pass/fail criteria for the IVF proposed by Crabb *et al*,[12] since only three contiguous points <10 dB are partly within the central 20°. This patient exhibited UFOV performance within the normal range (17.5% loss), which may suggest a useful field of view compatible with driving.

Crabb and colleagues[12] employed the UFOV as a surrogate measure of the visual attention capacity needed for safe driving because of its high sensitivity (89%) and specificity (81%) in predicting which older drivers have a driving crash history.[13] They compared visual field outcomes with UFOV performance and concluded that the IVF had a better sensitivity than the EVFT in predicting glaucomatous patients at risk when driving. In this study, however, mean UFOV scores for our subject sample did not differ significantly between those who "passed" and those who "failed" both visual field tests. This also applies to our glaucoma sub-group, although this may be influenced by the small sample size (n = 20) relative to the sample of glaucomatous patients examined by Crabb and colleagues.[12]

Table 1 Frequency table showing agreement between "pass/fail" decisions based on the binocular EVFT compared with the IVF and UFOV

Total no. of EVFT subjects (n = 56*)	EVFT "fail" (+ve) 24	EVFT "pass" (–ve) 32	Agreement
IVF (n = 54*)			
Fail (+ve)	18	1	93% (kappa = 0.84)
Pass (–ve)	3	32	
UFOV (n = 52*)			
Fail (+ve)	7	4	65% (kappa = 0.22)
Pass (–ve)	14	27	

*Subject numbers vary slightly, as a minority were unable to complete all tests. EVFT, Esterman visual field test; IVF, integrated visual field; UFOV, useful field of view test.

As a result, the UFOV cannot be used as an arbiter between visual field tests in this study.

The kappa values indicate that much of the apparent agreement between the UFOV and visual field tests can be attributed to chance. The UFOV test only identified 33% of subjects considered unfit to drive based on current UK visual field requirements, although it correctly identified 87% of subjects considered fit to drive. These findings suggest that either the current visual field criteria are too strict or the UFOV is relatively insensitive to visual field loss. Given that some subjects showed extensive paracentral visual field loss yet "passed" the UFOV (fig 3), it seems implausible that these individuals would have a crash risk within the normal range.

The UFOV employs large, high-contrast targets to measure deficits in visual attention and was never designed to be sensitive to visual field loss. As part of a parallel study, we found UFOV errors coincided with the area of lowest visual field sensitivity in only around one-third of cases.[6] Similarly, Owsley

Table 2 Comparison of total UFOV scores for subjects who "passed" both the binocular EVFT and the IVF, with those who "failed" both visual field tests

	Total UFOV scores (%) (SD)		
	Pass both field tests	Fail both field tests	t test p value
Whole subject group	27.0 (15.3) (n = 30)	33.3 (10.8) (n = 16)	0.11
Glaucoma subgroup	26.8 (11.0) (n = 15)	36.5 (10.5) (n = 5)	0.10

An identical comparison is shown for the glaucoma subgroup.

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Table 3 Frequency table showing agreement between "pass/fail" decisions based on the proposed IVF "pass/fail" standard compared with the UFOV

Total no. of IVF subjects (n = 57*)	IVF "fail" (+ve) 19	IVF "pass" (–ve) 38	Agreement
UFOV (n = 52*)			
Fail (+ve)	6	5	69% (kappa = 0.32)
Pass (–ve)	11	30	

*Subject numbers vary slightly, as a minority were unable to complete all tests.
IVF, integrated visual field; UFOV, useful field of view test.

and colleagues[21] found that visual field sensitivity only accounted for 36% of the variance in UFOV target localisation and that some subjects exhibited good UFOV performance in areas of significant visual field loss. The uneven distribution of peripheral test targets between radial locations within a single UFOV run reduces the chances of agreement, and the total UFOV score is therefore unlikely to reflect the visual field loss until it reaches a critical level in terms of both extent and depth. Learning effects are well documented,[6 22] adding further complexity to the relationship between UFOV score and visual field loss.

Examination of the characteristics of those who "failed" the UFOV test suggests that age rather than the extent of visual field loss plays a more important role in determining UFOV performance. An increase in UFOV score with age has been reported[23 24] and confirmed by a study of 100 normal subjects we ran parallel to this study.[6] The youngest of the 11 subjects who "failed" the UFOV test was aged 57 years, the next 60 years and all others were over the age of 70. Six out of 11 of these subjects showed UFOV scores within the age-matched normal range. The 3% of normal participants who "failed" the UFOV (>40% loss) were all over the age of 70. If the UFOV test were used to determine fitness to drive, a significant proportion of older drivers exhibiting visual function within the age-matched normal range would lose their licence, with profound social consequences.

In conclusion, these data support the use of the IVF for classifying patients with regard to legal fitness to drive in the UK, with visual field loss associated with glaucoma. Its use for patients with neurological disorders, and retinal and optic nerve conditions other than glaucoma is however questionable. This study adds to previous suggestions that the use of the UFOV test as a surrogate measure of the visual attention capacity needed for safe driving in individuals with visual field loss may not be appropriate. Despite the limitations of the EVFT for assessing fitness to drive with respect to visual fields, for the foreseeable future it remains the most appropriate single test across the range of conditions leading to central scotomata, since an aetiology-dependent dual standard would not be practical.

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Competing interests: None.

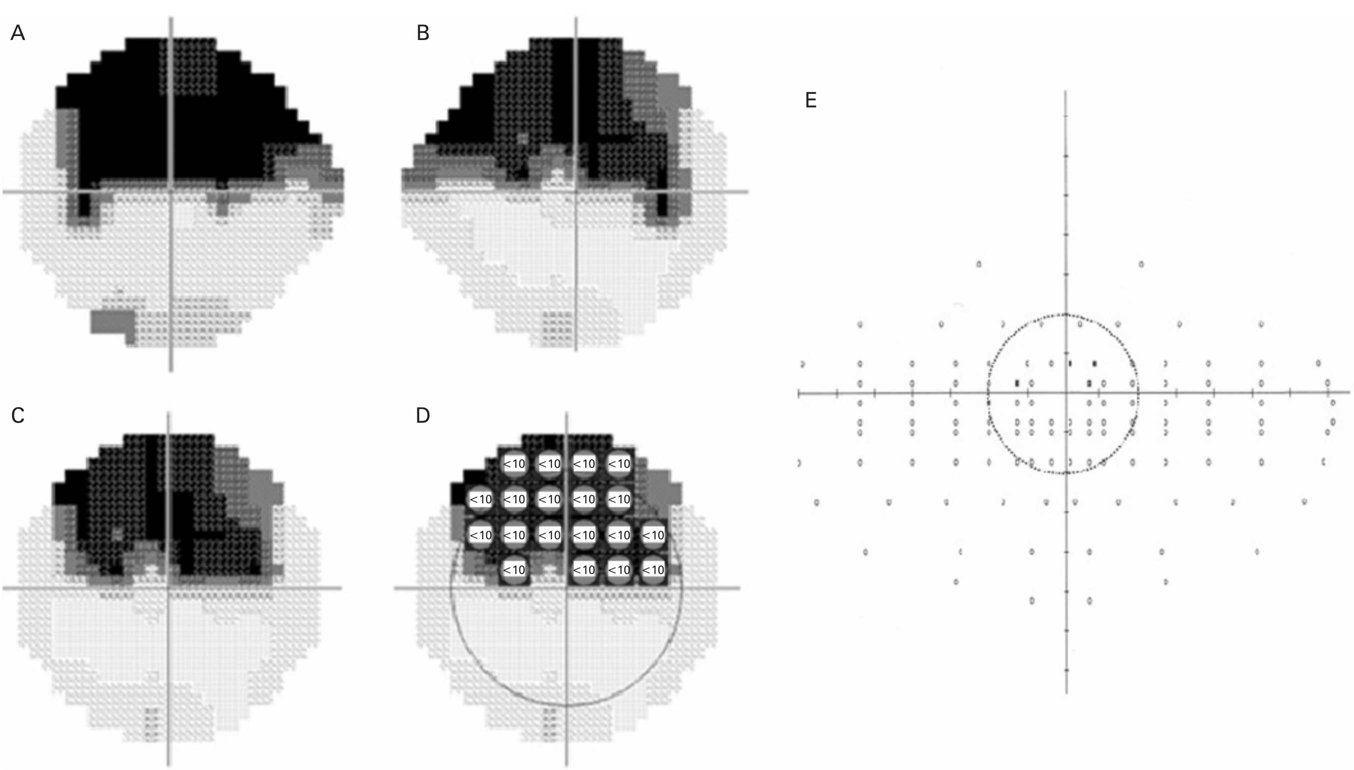

Figure 3 Visual field results from patient 55, a 57-year-old individual with bilateral primary open angle glaucoma, diagnosed 16 years previously. Plots A and B show the monocular HFA grey-scale for the left and right eyes respectively. Plot C shows the integrated visual field achieved by merging plots A and B. Plot D shows the IVF with symbols superimposed to indicate the points where the sensitivity falls below 10 dB. More than six contiguous points <10 dB within the central 20° means that this patient fails the modified pass/fail criteria for the IVF proposed by Crabb and colleagues.[12] Plot E shows the EVFT plot with three contiguous missed points and one additional scattered point within the central ±20°, equating to a fail of the DVLA criteria based on the Esterman. This patient exhibited UFOV performance within the normal range (30% loss) despite the extensive superior visual field loss.

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