The effects of visual field loss from glaucoma on performance in a driving simulator

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ABSTRACT.

Background: To examine the effects of different stages of visual field loss (VFL) from advanced glaucoma on performance in a driving simulator.

Methods: Data on performance and safety from a traffic simulator test for 104 participants with withdrawn driver’s licences due to visual field loss from advanced glaucoma were compared with data from 83 individuals without visual deficits in a cross-sectional study. Individuals with glaucoma that regained their driving licences after a successful simulator test were then followed in a national accident database.

Results: Glaucoma participants passed the test in 71% (95% confidence interval 61–79%) of the cases. Younger participants were more successful than older. No significant differences on safety or performance measures were detected between glaucoma- and normally sighted participants. Compared with passed glaucoma participants, failed glaucoma participants had more collisions, more critical failed to give way events, longer time headways, and longer reaction times. This group had also a higher extent of central visual field loss. None of the participants with a regained licence were involved in a motor vehicle accident during the 2 to 4 year follow-up after the simulator test.

Conclusion: Severity of glaucoma predicts driver safety on a group level. However, even individuals with severe visual field loss from glaucoma might drive safely, which highlights the need for individual assessments for licencing purposes.

Key words: driving licence – glaucoma – legislation – traffic medicine – visual field defects – visual field loss

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Introduction

Driving a car is inarguably a highly visual task. Countries all over the world have therefore set visual requirements for holding a driver’s licence, and those requirements usually include a minimum visual acuity and visual field. However, the relationship between visual field loss (VFL) and ability is far from clear. Some studies have shown that drivers with VFL are more unsafe, while others have failed to show any correlation (Owsley 2010). Comparing results is also complicated because definitions of both VFL and safe driving vary across studies. Two major outcomes are used in research on driving: safety and performance. Safety is defined by adverse events, typically collisions that might be studied in accident statistics, surveys or simulators. Performance refers to driver behaviour when manoeuvring the vehicle that may be tested either on-road or in a driving simulator. On-road driving is obviously more authentic but might have difficulties to test hazardous situations in a systematic way. Simulator tests, on the other hand, make it possible to test attention and reactions under standardized conditions. However, it is not yet possible to create a perfect imitation of reality and simulators might cause simulator-induced motion sickness. In the absence of a strong correlation between visual functions and driving, the ultimate method and cut-off values for vision testing in licensing issues are yet to be defined. As a consequence, the visual requirements for driving differ both between and within nations. Even if the Nordic countries use the same European juridical framework, Sweden and Norway, for example, have relatively stricter regulations than Denmark, Iceland and Finland (Bro & Lindblom 2018).

Glaucoma and visual field loss

Glaucoma is the leading cause of irreversible blindness globally. The estimated global prevalence of the most common form, primary open-angle glaucoma (POAG), was over 3% of the population aged 40–80 years in 2013. The disease is estimated to affect 76 million people of the world
population in 2020 (Tham et al. 2014). Lowering of intraocular pressure (IOP) is the only treatment proven to slow down glaucoma deterioration (Heijl et al. 2002). The vast majority of glaucoma is medically managed with topical hypotensive medications. As early treatment reduces visual field loss, the prevalence of advanced glaucoma depends on the group studied. In a study of more than 400 individuals with previously undetected glaucoma, about two thirds had early or moderate visual field defects. One third had advanced visual field loss in at least one eye (Heijl et al. 2013). As individuals with glaucoma often are unaware of their vision loss (Crabb et al. 2013), they are also unlikely to cease driving on their own volition.

Previous studies of visual field loss from glaucoma using on-road and simulated driving tests

Smaller on-road studies of drivers with glaucoma have highlighted problems with lane position, anticipatory skills (Bowers et al. 2005) and an increased number of events requiring driving instructor interventions (Haymes et al. 2008; Bhorade et al. 2016). These findings have been verified in a larger study of 75 drivers who had self-reported their driving to be relatively good, which reinforces the need for evidence-based assessments for evaluating driving ability (Wood et al. 2016).

Driving performance of individuals with glaucoma has also been analysed in driving simulators. A study from USA showed that 25 patients with mild to moderate glaucoma had no significant difference in general driving measures compared to 29 age-matched controls (Szyłk et al. 2002). In a later work by the same first author, 40 drivers with glaucoma had more collisions than 17 controls. The visual field defects correlated significantly with increased risk of collisions, specifically when the visual field was reduced to <100° in the horizontal plane (Szyłk et al. 2005).

A German study with 6 glaucoma patients showed that patients with glaucoma might compensate visual field loss by increased visual exploration (Kubler et al. 2015). However, a contemporary Dutch study did not find any difference in eye-scanning behaviour in 23 patients with glaucoma compared with 12 normal-sighted controls. Steering activity, number of missed letters and reaction times were nevertheless significantly higher for glaucoma patients (Prado Vega et al. 2013). In a recent study from Japan, 100 patients with advanced glaucoma had significantly more collisions than 43 controls. Glaucoma patients involved in collisions had lower mean sensitivity in the inferior hemifield than glaucoma patients who had not been involved in collisions (Kunimatsusanuki et al. 2017).

The purpose of this study was to compare driving simulator performance of glaucoma participants with a normally sighted control group and to analyse driving performance among glaucoma participants with varying degrees of VFL.

Materials and methods

Participants

In the end of 2014 and beginning of 2015, normally sighted individuals were recruited to perform a driving simulator test at the Swedish Road and Traffic Research Institute (VTI) in Linköping. They should state themselves as healthy, drive approximately 15,000 km/year and be between 55 and 75 years of age. All of them were screened for visual field defects with Humphrey perimetry 24-2. These 83 individuals were paid 100 Euro for participation. The driving behaviour for the normally sighted was used to create reference values for critical behaviour that was used to define a passed test.

Thereafter, between June 2016 and August 2018, individuals who had had their driver’s licences withdrawn due to VFL could apply for the test. It was initially performed only for research purposes, but a successful test was later accepted by the Swedish Transport Agency as a cause for dispensation (i.e. return of the driver’s licence) if no other medical complications were present. The cost for the individual was about 2000 Euro. Despite the price, the interest was very high. More than 300 individuals with VFL for different reasons completed the test until August 2018 when the activity was paused for evaluation. Besides glaucoma, stroke and laser treatment for diabetic retinopathy were other common reasons for VFL. This study only analyses the results from the driving simulator test for 104 participants with VFL due to glaucoma compared with the control group. Nearly all (95%) of the participants knew that they could have their driver’s licence renewed following a successful test. The remaining individuals were informed of the possibility to use the test result as a case for dispensation, which made all participants highly motivated. Ethical approval was given by Linköping University Committee (Dnr 2014/124-31).

Background information

The participants attached medical journals and visual field charts when applying for the simulator test. Diagnosis and visual field examinations were therefore always done in advance in a clinical setting. If medical information was missing, this was asked for from the Swedish Transport Agency, which archives all decisions for individuals with withdrawn driver’s licences.

Field of vision

All glaucoma participants had severe visual field loss according to the Swedish legislation. To hold a driver’s licence in Sweden, all corresponding test points within 10° radius must be at least 20 dB measured with Humphrey perimetry with object size III or equivalent static threshold perimetry. Only one corresponding test point between 10 and 20° is allowed to be less than 10 dB (TSFS 2010:125). To be included in the analysis of visual field, an examination with Humphrey perimetry 24-2 or 30-2, Henson Zata 24-2 or Octopus G standard was needed. The examinations had to be performed within 4 years from the test and have no more than 30% false-positive errors. Examinations performed with Octopus were converted to Humphrey Field Analyser (HFA) according to previously described algorithms (Zeyen et al. 1995). The binocular integrated visual field (IVF) was calculated by merging the points from monocular HFA, using the point with higher sensitivity from each test (Crabb et al. 2004). The number of corresponding test points below 20 dB within 10° in the IVF and the mean dB for different visual field clusters were thereafter...
extracted for each participant for comparison (Figure 1).

The simulator

The driving simulator Sim III consisted of a real truncated car body (Nordmark et al. 2004). Moving road patterns and landscape were showed on a large screen in front of the car. Six projectors created one seamless image on the screen. The field of view was therefore approximately 140°. By linking the cradle’s motion to the vehicle, the simulator’s motion algorithm creates realistic lateral motions. Three high-frequency reproduction of road unevenness and moved the compartment/cab relative to the projected image. Even if the simulator resembled an authentic vehicle in almost all respects, it was still a simulated reality, which all participants knew and understood (Figure 2).

Procedure

The procedure was the same for the control group and the glaucoma participants in a number of respects. However, the normally sighted also completed a screening Humphrey perimetry 24-2 that showed no visual field loss. This group also completed some cognitive tests such as reading span (Andersson & Peters 2019). The pretesting took approximately one hour. Glaucoma participants, on the other hand, completed the background questionnaire at home before the driving test session. All participants signed an informed consent before the test drive. The testing in the simulator started with a practice session for approximately 8 min giving the participant a possibility to get acquainted with the car (especially braking and steering behaviour). All participants could abort at any time, without giving an explanation. However, all participants completed the test.

The simulator scenario

The driving scenario contained three types of roads: city driving (speed limit 30–50 km/h), rural road (speed limit 70 km/h) and motorway (speed limit 110 km/h). The drive took approximately 30 min to complete, depending on the participant’s chosen speed. Thirty-seven events that required a response by the driver were of particular interest for sufficient safety margins. However, the drive also included situations that were not critical, but added to provide a feeling of ordinary driving and thus create a more relaxed driving behaviour. Pedestrians, buses, cars coming from left or right and sometimes from two directions at the same time were presented. These objects imitated driving situations from real life; for example, pedestrians could emerge behind a bus to ‘take a look’ if it was possible to pass. The actions made by buses, cars and pedestrians were initiated by the speed and distance from the car driven by the participant. Each action’s centre of interest (buses, cars, pedestrians, etc.) was the same for all participants. In such a scripted event, several aspects were measured: speed when a parked bus was seen, speed while passing the bus, position in the lane, braking pressure when the face/body of the pedestrian became visible, brake reaction time, possible collision, distance to bus and speed passing the pedestrian. The events used in the scenario were designed to vary in criticality and difficulty. This was to reduce floor or ceiling effects, that is to be able to discriminate between drivers with good safety margins versus those with insufficient safety margins. During the development of the scenario, turning 90° to left or right were included. However, the pilot testing with individuals at this age range (55–75 years) revealed that over 50 per cent strongly experienced simulator sickness. Therefore, the final version, and the version used in this study, did not include any sharp turns. It should also be noted that collisions were not followed by a ‘crash experience’ (sound or vibration, etc.). In this way, all participants could complete the scenario and we could continue to gather data on performance and safety during the rest of the simulator test without negative psychological effects from the ‘collision’ or other critical driving.

Assessment of passed versus failed glaucoma participants

All test results were digitally stored in the protocol divided into 37 events together with a video recording of the full driving scenario. This was retrospectively analysed by 2 independent traffic safety experts, one traffic inspector and one traffic safety researcher. These experts did a subjective assessment of the scenario to analyse risk management, scanning, speed adjustment and manoeuvring. The assessments were completed with the help of test protocols and video recordings from the simulator. The experts could replay the complete drive on their own computer screen and move forward or back in time at different speeds if necessary. The assessments were also performed by comparison to the reference values from the control group. The instruction to the traffic inspector (who assess road driving on a daily basis) was to use his/her understanding of a normal on-road driving licence test session. The traffic safety researchers used the values in the protocol (THW, speed and break power, etc.) from normally sighted individuals to a further extent, in combination with the video recordings. Hence, the classification into pass or failed was still based on subjective assessments. However, if the experts disagreed in their opinion, a third assessment was performed by an additional traffic safety researcher. Disagreements were rare, and less than 7% needed a third assessment.

Design

The design was a between-participant design with glaucoma versus normally
sighted as one variable. The independent variable was also between different stages of central VFL from glaucoma measured in corresponding test points with HFA below 20 dB within 10° radius. The dependent measures used in this study were passed test, but also several safety and performance parameters. The most important safety parameters were actual collisions and failure to give way, and the most important performance parameters were reaction time and time headway (THW).

Collisions: The test included 33 possible collisions, including both with other vehicles and pedestrians. Among these, 7 collisions were to objects in front of the car, 6 in the back, 14 to the right, 2 to the left, and 4 both to the right and to the left.

Failure to give way: Failure to give way (FGW) was measured 11 times and included only pedestrians. Of these events, 7 were to the right and 4 to the left. We used the minimal distance to the pedestrian, and when passing we considered distances between 0 and 1 m as hazardous and distances between 1 and 2 m as risky.

Time headway: Time headway (THW) is the distance to different moving objects divided by the experimental vehicle speed (Mamdoohi et al. 2014). THW was measured 29 times during the test. A number of THW values below 1 second were considered as critical (Ostlund et al. 2005).

Reaction time: Reaction time was measured 17 times during the test with objects (vehicle or pedestrian) that suddenly appeared and required braking.

Velocity: Speed on different stretches was recorded from the simulator. Participants drove in three different environments: city, rural and motorway.

### Statistical considerations

The comparisons of interest were initially between normally sighted and glaucoma participants. The second step was to compare passed glaucoma participants with failed. The final step was to compare different stages of VFL among glaucoma participants. The dependent measures used in the study created different statistical analyses. The alpha level of $p < 0.05$ was always used.

### Car accidents among dispensation cases

One part of the evaluation of the simulator-based driving test was to conduct a follow-up of each individual who had regained his/her driving licence after a successful performance in the simulator. The Swedish Traffic Accident Data Acquisition (STRADA) database was used that includes all road accidents with personal injuries in Sweden reported by the police or emergency hospitals.

### Results

#### Descriptives

The glaucoma participants matched the control group by age but consisted mainly of men. Seventy-one per cent of the glaucoma participants passed the simulator test (95% confidence interval 61–79% with Wilson procedure for correction for continuity) (Table 1). Younger participants were more successful than older (Figure 3). Fifty-eight per cent of individuals 70 years or older passed the test whereas 86% below 70 years age passed ($p < 0.05$ with Fisher’s exact test).

#### Glaucoma participants versus normal sighted

Statistical analysis of reaction time, THW (with independent t-tests), collisions and FGW (with Fischer exact test) did not show any significant differences between glaucoma participants and controls. Glaucoma participants also drove as fast as the control group overall. A mixed 2 by 3 ANOVA (glaucoma participants versus normal sighted and speed on 3 types of roads) did not show any significant interaction effects ($F(2, 258) = 1.01, p > 0.05$, $MSe = 24.29$). However, pairwise comparisons revealed that glaucoma patients drove more carefully, hence, on a group level the glaucoma participants drove as safely as the normally sighted.

#### Passed glaucoma participants compared with failed glaucoma participants

Fisher’s exact test revealed that the failed glaucoma participants had significantly more collisions, more hazardous FGW under 1 meters, and more risky FGW between 1 and 2 meters than the passed glaucoma participants. An independent two-tailed t-test on THW and mean reaction time values revealed significant differences,

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Figure 2. Picture of Sim III at VTI with the motion platform and the interior used in the test.
showing that the glaucoma individuals who passed had better safety margins and reacted faster than the individuals who failed. The 2 × 3 ANOVA (passed versus failed glaucoma participants and 3 types of roads) showed that passed and failed glaucoma patients drove equally fast in the scenario. Pairwise comparisons are presented in Table 2. Taken together, the failed group was less safe and performed less well on all measures studied, but they did not drive faster on any of the types of roads. This finding showed that both safety measures and performance measures explained the success rate for the passed group, even if both groups used the same speed on all stretches.

Central test points and superior versus inferior visual field loss

Visual field data that met the inclusion criteria were found in 80 cases (77%).

Central visual field loss had a negative correlation with a passed test (Figure 4). Participants with 0–2 test points corresponding to test points below 20 dB in cluster A + B passed in 87% versus 63% for participants with 3 or more test points below 20 dB (p < 0.05 with Fisher’s exact test). Failed glaucoma participants also had lower mean sensitivity than passed participants in the same cluster (p < 0.05 with two-tailed t-test). No significant differences between the passed versus failed glaucoma patients were found for mean sensitivity for the inferior versus superior visual fields, nor for the central versus peripheral fields (Table 2).

Table 1. Driving simulator data for controls and patients with glaucoma

<table>
<thead>
<tr>
<th></th>
<th>Control</th>
<th>Glaucoma total</th>
<th>p-value</th>
<th>Glaucoma passed</th>
<th>Glaucoma failed</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>n</td>
<td>83</td>
<td>104</td>
<td>74</td>
<td>30</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average age (years)</td>
<td>65</td>
<td>69</td>
<td>66</td>
<td>74</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female sex</td>
<td>61%</td>
<td>11%</td>
<td>11%</td>
<td>10%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average speed city driving (km/h)</td>
<td>41</td>
<td>38</td>
<td>&lt;0.05</td>
<td>37</td>
<td>39</td>
<td>0.13</td>
</tr>
<tr>
<td>Average speed rural road (km/h)</td>
<td>80</td>
<td>75</td>
<td>&lt;0.05</td>
<td>75</td>
<td>74</td>
<td>0.13</td>
</tr>
<tr>
<td>Average speed motorway (km/h)</td>
<td>106</td>
<td>103</td>
<td>0.10</td>
<td>103</td>
<td>103</td>
<td>0.76</td>
</tr>
<tr>
<td>Drivers with collisions</td>
<td>18%</td>
<td>13%</td>
<td>0.35</td>
<td>5%</td>
<td>33%</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>Drivers with hazardous (0–1 m) FGW</td>
<td>2%</td>
<td>7%</td>
<td>0.12</td>
<td>0%</td>
<td>23%</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>Drivers with risky (1–2 m) FGW</td>
<td>18%</td>
<td>9%</td>
<td>0.07</td>
<td>3%</td>
<td>23%</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>Average critical (&lt;1 s) THW events</td>
<td>3.9</td>
<td>3.9</td>
<td>0.91</td>
<td>3.3</td>
<td>5.2</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>Average RT in seconds</td>
<td>0.66</td>
<td>0.69</td>
<td>0.18</td>
<td>0.66</td>
<td>0.74</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>Average LP city driving (m)</td>
<td>0.0</td>
<td>−0.1</td>
<td>&lt;0.05</td>
<td>−0.1</td>
<td>−0.07</td>
<td>0.58</td>
</tr>
<tr>
<td>Average LP rural road (m)</td>
<td>0.0</td>
<td>−0.1</td>
<td>0.09</td>
<td>−0.1</td>
<td>−0.06</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>Average LP motorway (m)</td>
<td>0.0</td>
<td>0.1</td>
<td>&lt;0.05</td>
<td>0.1</td>
<td>−0.17</td>
<td>0.76</td>
</tr>
</tbody>
</table>

FGW, failed to give way; LP, lateral position (- to the right + to the left); RT, reaction time; THW, time headway.

Table 2. Comparison of mean sensitivity in different clusters of the integrated visual field (IVF)

| A–D = visual field clusters according to Figure 1. |
|---------|---------|---------|
| Passed | Failed | p-value |
| n = 58 | n = 22  |         |
| IVF mean sensitivity (dB) |         |         |
| Central (A + B) | 23.1 | 17.5 | <0.05 |
| Peripheral (C + D) | 20.7 | 19.3 | 0.23  |
| Central superior (A) | 21.5 | 17.5 | 0.11  |
| Central inferior (B) | 24.7 | 21.9 | 0.10  |
| Peripheral superior (C) | 19.7 | 18.4 | 0.52  |
| Peripheral inferior (D) | 21.6 | 20.2 | 0.40  |

Figure 3. Percentage of passed patients with glaucoma in different age groups with total number of patients in each age group.
Car accidents among dispensation cases

The majority of all glaucoma individuals (92%) with a passed test applied for a renewed driver's licence. Among these, 21% were rejected because of other medical circumstances. None of the 54 glaucoma participants with a regained licence were found involved in a motor vehicle accident according to The Swedish Traffic Accident Data Acquisition (STRADA) in October 2020, 2.3-4.1 years (median 3.4) after the simulator test.

Discussion

This study of simulator driving performance of individuals with different types of homonymous visual field loss showed that younger patients were considerably more successful than older. The extent of central visual VFL from glaucoma may predict driver safety on a group level.

To the best of our knowledge, this is the largest study so far of driving behaviour in a simulator test for individuals with glaucoma and one of very few that measured mean dB for different visual field clusters. Other strengths of the study are the detailed simulator scenario and that the patients performed the test with the aim to regain their licences, which guarantees very good participation. However, the study also had important weaknesses. The control group was not sex matched with the study group. Sharp turns could not be used because of simulator-induced ‘motion sickness’, which made the simulator scenario less like reality. As head and ocular movements were not recorded, its meaning for compensation could not be evaluated. As glaucoma is a progressive disease, many participants could probably have developed more VFL at the time for the simulator test than the visual field examination which could have been up to 4 years previously. The most important weakness, however, was that the normally sighted were not assessed in terms of passed or failed due to resources (i.e. the availability of traffic inspectors), whereupon we do not know if all controls passed the test. At the same time, the reference values for safe driving were created based on the results of this normally sighted control group. It should also be noted that the high cost for the testing (2000 Euro) might have affected the selection of participants. Among all Swedish glaucoma patients with withdrawn driver’s licences, individuals with less affected driving and better economy were probably more disposed to apply for the test. It is therefore not surprising that the success rate was as high as 71%.

Driving simulators could be used to evaluate a range of driving skills in a controlled manner. It is also possible to probe specific aspects that are likely to be affected by glaucoma. Still, a simulator does not fully replace a car and a simulated collision has no effect on personal safety, which may influence the driving behaviour (Owsley et al. 2015). Nevertheless, an earlier study showed a high overlap (77%) between pass versus fail for on-road testing and simulator testing (Ungewiss et al. 2018). The present study also included an accident involvement follow-up that compared the participants with the accident database that exists on a national level. This showed that the participants that passed the simulator test and received a new driving licence did not have a higher risk for accidents than the normal-sighted population. Hence, even if participants understood that they were in a simulated environment, the two findings above support that simulator examinations could be used to discriminate between safe versus unsafe drivers.

Individuals with advanced glaucoma as a group might be safe drivers from the general driving measures, which conforms to previous research (Szlyk et al. 2002).

In some respects, for example collisions, the glaucoma participants performed on the level of normally sighted on a group level, which contradicts previous research (Szlyk et al. 2005; Kunimatsu-Sanuki et al. 2017). This might be explained by both optimized performance as a passed test could lead to return of the driver’s licence and differences in the severity of glaucoma in the study group.

The major differences (on all measures studied) were obtained between passed and failed glaucoma participants. Compared with passed glaucoma participants, failed glaucoma participants had more collisions, more critical failed to give way events, and longer time headway and reaction time. The glaucoma participants with a passed test had significantly higher sensitivity in the central visual field. We

![Figure 4](image-url)  
**Figure 4.** Percentage of passed patients with glaucoma in different groups based on number of corresponding test points below 20 dB within the central 10°. Total number of patients is shown in each group with mean age in parenthesis.
could not find similar differences between the superior and the inferior visual field, which has been shown in previous studies (Kumimatsu-Sanuki et al. 2017). Failed participants did not even drive slower to adjust for a driving inability which indicates a metacognitive inability as well (Andersson & Peters, 2019). This needs, however, to be studied further. Previous research have shown that individuals with glaucoma have higher variability in lane position (Bowers et al. 2005). Our study did not analyse this aspect but found smaller differences in average lane position both in the control versus glaucoma groups and in the passed versus failed glaucoma participants. This result will also be followed in future research but did not affect our main results.

The individuals with renewed licences had no higher risk for on-road collisions in reality at follow-up. The significance of this result, however, is unsure due to the low number of licence renewals (54) and the short time period of follow-up (2.3–4.1 years). Hence, it is not possible to conclude that our simulator assessment can discriminate between safe and unsafe drivers yet. However, the data support that the method is valid even if further evaluation is needed. Previous studies have shown that driving simulator testing seems to be a well-standardized method with good conformity to on-road driving, and it is appropriate for assessment of driving performance in individuals with binocular visual field loss (Ungewiss et al. 2018). Multivariate analysis of visual, attentional, perceptive, cognitive and psychomotor abilities combined with structured road testing might also distinguish safe from unsafe drivers (McKnight & McKnight 1999) among persons with other medical or psychological conditions.

In summary, central visual field loss in glaucoma seems to be more crucial than peripheral. Even if the extent of central visual field loss from glaucoma may predict driver safety on a group level, drivers with severe visual field loss from glaucoma might also be safe drivers. It seems therefore reasonable to provide an opportunity for individualized assessments of practical fitness to drive in licencing issues. On-road testing by a certified driving examiner is currently considered the clinical golden standard. However, driving simulators may provide a useful adjunct to a road test for evaluation of responses to potential hazards under safe, controlled and repeatable conditions.

References