

Car Driving Performance in Hemianopia: An On-Road Driving Study

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Submitted: January 27, 2014

Accepted: August 26, 2014

Citation: de Haan GA, Melis-Dankers BJM, Brouwer WH, Bredewoud RA, Tucha O, Heutink J. Car driving performance in hemianopia: an on-road driving study. *Invest Ophthalmol Vis Sci.* 2014;55:6482–6489. DOI: 10.1167/ iovs.14-14042

PURPOSE. To study driving performance in people with homonymous hemianopia (HH) assessed in the official on-road test of practical fitness to drive by the Dutch driver's licensing authority (CBR).

METHODS. Data were collected from a cohort (January 2010–July 2012) of all people with HH following the official relicensure trajectory at Royal Dutch Visio and the CBR in the Netherlands. Driving performance during the official on-road tests of practical fitness to drive was scored by professional experts on practical fitness to drive, using the visual impairments protocol and a standardized scoring of visual, tactical and operational aspects. Age ranged from 27 to 72 years (mean = 52, SD = 11.7) and time since onset of the visual field defect ranged from 6 to 41 months (mean = 15, SD = 7.5).

RESULTS. Fourteen (54%) participants were judged as fit to drive. Besides poor visual scanning during driving, specific tactical, and operational weaknesses were observed in people with HH that were evaluated as unfit to drive. Results suggest that judgement on practical fitness to drive cannot be based on solely the visual field size. Visual scanning and operational handling of the car were found to be more impaired with longer time not driven, while such an effect was not found for tactical choices during driving.

CONCLUSIONS. Training programs aimed at improving practical fitness to drive in people with HH should focus on improving both visual scanning, as well as driving aspects such as steering stability, speed adaptation, and anticipating environmental changes.

Keywords: hemianopia, visual field defects, driving, patient safety

Driving a car is an essential way of transportation for the majority of people in industrialized countries and forms an important prerequisite for independent daily life, but opportunities for driving may be limited in the presence of visual field disorders. Although in most countries the minimum horizontal visual field size required for driving a car is set to 120°, in some countries, like the Netherlands, smaller field sizes are not an absolute contra-indication. Aiming at an inclusive society with equal opportunities for disabled people, the Dutch government allows people under strict conditions to prove practical fitness to drive despite an impairment. In these cases licensing is strictly regulated, including specialist medical assessment and a requirement to be judged fit to drive in an official on-road test of practical fitness to drive where the driver must demonstrate that (s)he adequately compensates the field defect.^{1,2} This procedure is allowed under the European Union (EU) driving license directive³ where it states in Annex III, paragraph 6.1: “Driving licenses shall not be issued or renewed if during the medical examination, it is shown that the horizontal field of vision is less than 120°, apart from exceptional cases justified by a favourable medical opinion and a positive practical test.”

Practical fitness to drive is defined as being able to drive safely and smoothly (i.e., driving without abrupt changes in speed and course), taking impairments into account (i.e.,

compensating for the impairment). Where medical fitness to drive refers to impairments on the body level (i.e., visual field size), practical fitness to drive refers to driving performance on the activity level. A person with a visual impairment is considered “fit to drive” if driving performance in a range of road and traffic situations falls within the normal range of sighted drivers, and if no impairment-related driving errors are made. Where a regular driving exam focuses on driving skills, the test of practical fitness to drive evaluates the ability to adapt driving skills and driving behavior in case of impairments.^{1,2}

The system as applied in the Netherlands is followed with high interest by other European countries. In some countries skepticism is widely prevalent about driving abilities in people with visual field defects and some countries are considering to copy the Dutch system. Publication of the results from the Dutch system is therefore required and now provided. Not only is it relevant to present how many people with visual field defects are judged as fit to drive; it is also highly important to know about the errors these people tend to make so that training methods and technical aids can be developed.

A frequently occurring visual field defect for which the Dutch government issued official regulations is homonymous hemianopia (HH). Homonymous hemianopia is the most common form of homonymous visual field defects (HVFD)

TABLE 1. Participant Characteristics

	Fit to Drive, n = 14	Unfit to Drive, n = 12	Total, n = 26
Sex			
Men	10	8	18
Women	4	4	8
Sid of HH			
Left-sided HH	9	12	21
Right-sided HH	5	0	5
Size of field defect (FFS)	66 (10.7)	57 (6.2)	62 (10.0)
Quadrantanopia	4	1	5
Hemianopia	10	11	21
Visual acuity	1.17 (0.18)	1.04 (0.29)	1.11 (0.24)
Contrast sensitivity	1.93 (0.16)	1.99 (0.04)	1.96 (0.13)
Age			
Mean (SD)	52 (10.4)	52 (13.5)	52 (11.7)
Range	29–65	27–72	27–72
Time since onset of HH, mo			
Mean (SD)	14 (9.3)	15 (5.0)	15 (7.5)
Range	6–41	8–23	6–41
Driving experience, y	31 (10.2)	32 (15.0)	32 (12.4)
Mean (SD)	10–47	6–53	6–53
Range			
Time not driven, mo			
Mean (SD)	11 (10.8)	19 (17.5)	15 (14.6)
Range	0–41	8–73	0–73
Driving at time of assessment	3	0	3

Data for continuous variables are presented as mean (SD). FFS, Functional Field Score.¹⁶

and refers to a loss of perception for either the left or the right half the visual field, affecting both eyes, resulting from post chiasmatic brain injury. Homonymous hemianopia is one of the most frequent visual disorders following acquired post chiasmatic brain damage, such as stroke (estimations of HH among stroke 8%–31%).^{4,5}

A number of studies performed in the Netherlands,^{6,7} Canada,⁸ and the United States^{9–12} have examined on-road driving performance in people with HH. These studies suggest that people with HH use several viewing strategies when driving, but do not always apply these in a consequent or effective way. Other frequently observed problems are difficulties with gap judgement, driving too slow or fast, frequent sudden braking, poor reaction to unexpected events, and problems regarding steering stability and adequate positioning on the road. Nevertheless, some people with HH were found to drive safely despite their visual impairment.

Traffic infrastructure and mix of transport modalities in the European Union differs significantly from those in North America.¹³ For example, the road systems in European towns and cities tend to have more narrow roads and irregular intersections than the typical American checkerboard layout. In addition, speed differences between road users tend to be larger in Europe, where there are often more bicycles, trams, and other slow vehicles on the road and where speed limits for cars may be higher. European countries are therefore reluctant to simply apply the results from American studies to the European situation.

Knowledge about driving performance of people with HH in European countries is therefore highly relevant for clinical and legal decision-making concerning driving in Europe. Over a decade ago, Tant and colleagues,⁶ delivered significant groundwork by showing that in a selected group of people with HH, some (4 of 28) appeared fit to drive. This has lead to an expanding number of people with HH applying for the relicensure procedure at the Dutch driver's license authority (CBR). Royal Dutch Visio, Centre of Expertise for blind and partially sighted people, cooperates with the CBR in guiding and assessing these people. The current study examines the outcomes from a cohort (January 2010–July 2012) of all people with HH following the official route as now established by the CBR and Royal Dutch Visio.

METHODS

Participants

Between January 2010 and July 2012, 86 people with HH applied for help at Royal Dutch Visio, Centre of Expertise for blind and partially sighted people, in preparing for the assessments of fitness to drive.

To determine whether these people met the legal requirements for driving (Box 1 in the Supplementary Material), extensive and standardized ophthalmologic and neuropsychological testing was performed. The following visual functions were assessed: visual acuity (Early Treatment Diabetic Retinopathy Study 2000 letter chart), refraction, reading acuity (LEO-charts), monocular and binocular Goldmann, as well as monocular Humphrey 10-2 perimetry, eye and head motility, Vistech contrast sensitivity and image distortion (Amsler grid). Visual perception and (neuro)psychological functioning were assessed with the Mini Mental State Examination, Visual Object and Space Perception, Balloons, Trail Making Test, Eight word test, Drawings, Line Bisection, Rey Complex Figure Test, Hospital Anxiety and Depression Scale, and behavioral tests for optic ataxia and sticky fixation. Assessments were performed at regional departments of Visio and outcomes were evaluated by an independent national team (GAdH, BJMM-D, JH) in consultation with the Dutch driver's license authority (RB).

Sixty people did not meet the legal requirements. The most frequent reasons for not meeting the requirements were a horizontal visual field larger than 120° or comorbidity (visual perception disorders, cognitive disorders, unstable tumor growth, recent additional stroke, Alzheimer's disease, and/or unstable cardiac situation). The characteristics of the remaining 26 participants are presented in Table 1. The visual field defect resulted from post chiasmatic brain damage caused by infarction ($n = 18$), hemorrhage ($n = 2$), traumatic brain injury ($n = 1$), tumor resection ($n = 1$), extirpation of arteriovenous malformation with postoperative hemorrhage ($n = 1$), and combined etiology ($n = 3$). Although people with HH are not allowed to drive by law unless they have been judged fit to drive by the CBR, three participants were current drivers at time of the assessment.

All patients provided written informed consent. The study design was approved by the Medical Research Ethics Committee of the University Medical Center Groningen and performed in accordance with the 2008 Declaration of Helsinki.

Procedure

The 26 participants were assessed during a test of practical fitness to drive. Although all participants had a driver's license before the onset of the HH, proving that they had learned the

TABLE 2. Average (SD) Subscores From the On-Road Driving Assessments, N = 26 Participants

	VIS	OPER	TACT	GLOB
Total, N = 26	2.59 (0.52)	2.71 (0.48)	2.66 (0.42)	2.50 (0.65)
Fit to drive, N = 14	2.92 (0.10)	2.97 (0.07)	2.92 (0.10)	3.00 (0.00)
Unfit to drive, N = 12	2.20 (0.53)	2.40 (0.58)	2.36 (0.44)	1.92 (0.52)
P value‡	<0.001†	<0.001†	<0.001†	<0.001†
LHH, N = 21	2.50 (0.54)	2.64 (0.52)	2.61 (0.45)	2.38 (0.67)
RHH, N = 5	2.95 (0.12)	2.98 (0.05)	2.88 (0.11)	3.00 (0.00)
P value§	0.034*	0.105	0.374	0.049*
Hemianopia, N = 21	2.52 (0.55)	2.63 (0.52)	2.59 (0.43)	2.45 (0.66)
Quadrantanopia, N = 5	2.86 (0.23)	3.00 (0.00)	2.95 (0.12)	2.73 (0.60)
P value	0.121	0.034*	0.019*	0.374

Scales range from 1 to 3, higher scores indicate better performance. P values for the differences between the groups are based on Mann-Whitney U tests.

* P < 0.05.

† P < 0.001.

‡ Comparison between fit and unfit drivers.

§ Comparison between LHH and RHH.

|| Comparison between hemianopia and quadrantanopia.

driving skills previously, most participants were not current drivers. Participants were allowed to practice vehicle control in the unfamiliar test vehicle for one lesson at maximum. The driving instructor was explicitly told not to give any instructions on visual scanning during this driving lesson, since the interest of the study was to examine driving performance without visual training or instructions on viewing strategies. During the test of practical fitness to drive, an expert on practical fitness to drive (DPR; Box 1 in the Supplementary Material) evaluated driving performance. Fifteen DPRs were involved in the current study. The on-road assessment took place in a car with dual control, allowing the DPR to apply the brakes and clutch from the passenger side in order to avert immediate danger, if required. The ride consisted of trajectories in urban areas, as well as more rural, suburban and highway routes and took approximately 45 minutes. For each participant, the DPR scored a standardized checklist (TRIP). Furthermore, a short additional report was written and a final decision was made about practical fitness to drive ("fit" or "unfit to drive").

Test Ride for Investigating Practical Fitness to Drive (TRIP)

The TRIP checklist is a list of 57 items reflecting different aspects of driving (Appendix A).^{6,14} For each item, the DPR indicated whether the behavior was sufficient (3 points), doubtful (2 points), or insufficient (1 point). Because of their content, three items had different answer alternatives. "Lateral position on the driving lane" was rated as approximately in the middle (3 points), fluctuating (1 point), too much to the left (1 point), or too much to the right (1 point). The possible ratings for the item "following distance" were sufficient (3 point), long (2 points), or short (1 point). The item "choice of speed" was rated as average (3 points), slow (2 points), or fast (1 point).

Based on subsets of items, four subscores were calculated, in a similar way as performed by Tant and colleagues.⁶ The visual subscale (VIS) was calculated by averaging 23 items related to visual scanning behavior. The operational subscale (OPER) was created by averaging nine items on operational actions, such as steadiness of steering and operating the brakes. The tactical subscale (TACT) was composed by averaging 15 items on tactical driving behavior, such as adapting speed and anticipating environmental changes. The

average of three items regarding general impressions of "practical fitness to drive," "mechanical operation," and "traffic perception and traffic insight" brought forth the global subscale (GLOB).

Statistics

Data analysis was performed with SPSS (version 20; IBM Corp., Armonk, NY, USA). All tests were conducted two-sided. P values less than 0.05 were considered significant and P values between 0.05 and 0.1 suggestive for trends.

First, driving performance was analyzed for the total group of HH participants. The number of participants rated as fit to drive, as well as the average subscores and Spearman's correlations between subscores were calculated. The distributions of insufficient, doubtful, and sufficient ratings on the TRIP questionnaire were examined and a χ^2 test was conducted for the differences in distributions between the subscales.

Second, it was examined which aspects of driving behavior made that people were judged as unfit to drive. The differences in the average subscores (VIS, OPER, and TACT) between the fit and unfit drivers were analyzed with Mann-Whitney U tests and effect sizes (Cohen's d^{15}). The percentages of sufficient ratings on the individual TRIP items were compared between the fit and unfit drivers. The additional reports were checked for interventions by the DPR.

Third, the influences of several participant characteristics on driving behavior were examined. Differences between fit and unfit drivers regarding continuous variables (age, visual field size, time since onset, years of driving experience, and/or time not driven) were analyzed with t-tests or, in case of nonnormality of data, Mann-Whitney U tests. Relations between participant characteristics and TRIP subscores were analyzed by conducting Mann-Whitney U tests for the dichotomous variables (sex, side of HH, hemianopia versus quadrantanopia) and Spearman's correlations (ρ) for the continuous variables (see above).

RESULTS

Driving Performance

Fourteen (54%) participants were evaluated as fit to drive and regained a valid driver's license for a maximum of 5 years and

TABLE 3. Distributions of Ratings ("Insufficient," "Doubtful," and "Sufficient") Expressed in Percentages and Arranged by Subscale and Fitness to Drive, $N = 26$ Participants

	Insufficient	Doubtful	Sufficient
VIS			
Total, $N = 26$	14.9	12.8	72.3
Fit to drive, $N = 14$	0.9	6.2	92.9
Unfit to drive, $N = 12$	31.3	20.3	48.5
OPER			
Total, $N = 26$	10.3	10.7	79.0
Fit to drive, $N = 14$	0.0	3.2	96.8
Unfit to drive, $N = 12$	22.2	19.4	58.3
TACT			
Total, $N = 26$	11.1	13.1	75.8
Fit to drive, $N = 14$	1.9	4.8	93.3
Unfit to drive, $N = 12$	21.7	22.8	55.6
GLOB			
Total, $N = 26$	20.5	11.5	67.9
Fit to drive, $N = 14$	0.0	0.0	100.0
Unfit to drive, $N = 12$	44.4	25.0	30.6

for private use only. The average subscores are included in Table 2. High positive correlations were found between the TRIP subscales (all combinations: $\rho > 0.687$, $P < 0.001$, data not shown).

The TRIP ratings for the individual items are presented in Figure A1 and summarized on subscale level in Table 3. The items of the VIS subscale were not significantly more often rated as insufficient or doubtful than the items of the OPER and TACT subscales (χ^2 two-tailed: $P = 0.789$). For all three subscales, several items were rated as insufficient or doubtful for a considerable number of participants, mainly related to viewing behavior in several situations, steering stability, speed adaptation, and anticipating changes in road and traffic situations (Fig. A1).

Driving Aspects Related to a Negative Evaluation of Fitness to Drive

All TRIP subscores were significantly lower for the unfit drivers than for the fit drivers (Table 2) with large effect sizes¹⁵ (VIS: 1.96, OPER: 1.44, TACT: 1.82). The differences in the number of 'sufficient' ratings between the fit and unfit drivers were largest for item 31 (perception and judgement during overtaking and passing by), 28 (anticipatory viewing behavior with regard to changing traffic situations), and 34 (tactical anticipation with regard to changing traffic situations). These items were rated as sufficient for 100% of the fit drivers versus 25% of the unfit drivers.

All the fit drivers had average subscores of at least 2.7 on all subscales (VIS, OPER, and TACT), while the unfit drivers received lower scores on at least one subscale (VIS < 2.7 in 10 cases; OPER < 2.7 in 7 cases, and TACT < 2.7 in 9 cases). However, one participant rated as unfit to drive scored higher than 2.8 on all three subscales. This participant received lower scores than any of the fit drivers on the items 13, 19, 31, 55, and 57 (items explained in Appendix A). The additional reports showed that interventions in braking or steering by the DPR were necessary for 5 of 12 unfit drivers and for none of the fourteen fit drivers. For three unfit drivers it was explicitly reported that looking toward the blind side resulted in maladjusted driving behavior and an inappropriate position

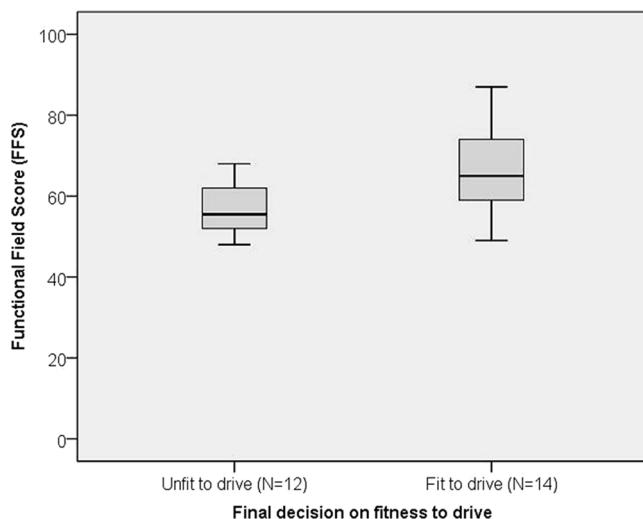


FIGURE 1. Boxplots of FFS categorized by fitness to drive. Interquartile ranges depicted.

on the road. Scanning behavior of all 14 fit drivers was reported to be sufficient and not interfering with operational or tactical driving.

Participant Characteristics

Table 1 shows the differences in participant characteristics between fit and unfit drivers and Table 2 presents the correlations between participant characteristics and TRIP subscores. No evidence was found for effects of age, sex, and years of driving experience on the end-verdict (fit or unfit to drive) or the TRIP subscores. The only noteworthy finding for time since onset was a near-significant correlation with VIS ($\rho = -0.359$, $P = 0.072$); the longer time since onset, the lower the evaluations of viewing behavior. A trend for a difference between the fit and unfit drivers was found in the number of months participants had abstained from driving (fit: mean = 11.2, unfit: mean = 19.3; $P = 0.060$). The three current drivers were all judged as fit to drive. The longer participants had not driven, the lower their scores on the VIS ($\rho = -0.474$, $P = 0.014$), OPER ($\rho = -0.498$, $P = 0.010$), and GLOB ($\rho = -0.490$, $P = 0.011$) subscales (correlation with TACT failed significance, $\rho = -0.285$, $P = 0.159$).

The visual field size was quantified in terms of Functional Field Score (FFS),¹⁶ a higher FFS meaning a larger remaining visual field. The fit drivers on average had a larger visual field (mean = 66.1) than the unfit drivers (mean = 56.6; $P = 0.012$). However, Figure 1 shows that there is no cut-off point below which all participants are unfit to drive. The larger the visual field, the higher the VIS, OPER, and GLOB scores (VIS $\rho = 0.521$, $P = 0.006$; OPER $\rho = 0.458$, $P = 0.019$; GLOB $\rho = 0.472$, $P = 0.015$). Correlation with TACT failed significance ($\rho = 0.340$, $P = 0.090$).

All five right-sided hemianopia (RHH) participants were rated as fit to drive, while this was the case for only 9 of the 21 left-sided hemianopia (LHH) participants. The participants with RHH performed better than the LHH participants (Fig. 2), as confirmed by significant differences in VIS and GLOB (Table 2). The relations between side of field defect and the other subscales (OPER and TACT) failed significance. These results have to be interpreted cautiously because of the different sample sizes. Furthermore, time not driven was shorter and visual field size larger for the participants with RHH, two

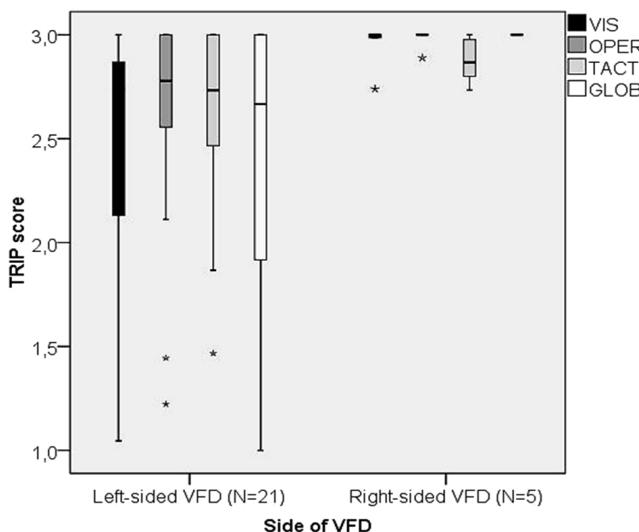


FIGURE 2. Boxplots of TRIP subscale scores split by side of field defect. Interquartile ranges depicted. *Outliers: cases with values more than 1.5 box lengths (interquartile range) from the lower edge of the box.

variables found to be significantly associated with the subscores.

Problems maintaining an appropriate position on the road were only found for LHH participants. Positioning on the road (TRIP item 1) was evaluated as not sufficient in 7 of the 21 LHH participants (33%). Three of them drove too much to the right, one drove too much to the left, and the remaining three showed too much fluctuation in lateral position. Steadiness of steering (TRIP items 2–7) was evaluated as not sufficient in 11 LHH participants (52%). With regard to lane choice (TRIP items 8–11), eight LHH participants (38%) scored not sufficient, most often regarding lane choice when turning left.

DISCUSSION

Data were collected from a cohort (January 2010–July 2012) of all people with HH performing the official on-road test of practical fitness to drive as part of the official trajectory at Royal Dutch Visio and the CBR in the Netherlands. Fourteen (54%) people with HH were evaluated as fit to drive, against 14% to 77% in previous studies.^{6,9–11} The different outcomes might be caused by differences in participant characteristics, selection, assessment procedures, as well as traffic conditions and regulations. As expected in a group of people with visual impairments, items regarding viewing behavior were often rated as insufficient. More interestingly, handling of the car and the choices made during driving were often rated insufficient as well. Items most often rated as insufficient or doubtful were mainly related to viewing behavior, steering stability, speed adaptation, and anticipation to changes in the environment. These difficulties are in close agreement with the driving skills found to be affected in an earlier study using the TRIP questionnaire on people with HH.⁶

In contrast to the previous European study by Tant and colleagues,⁶ the number of fit drivers ($N = 14$) was roughly equal to the number of unfit drivers ($N = 12$), allowing for additional analyses of the differences between these groups that could not be performed by Tant. These analyses showed that observed difficulties with visual scanning during driving,

as well as impaired tactical and operational driving performance were associated with the decision that someone is unfit to drive. Insufficient performance in each of these three driving aspects could be a reason for being judged as unfit to drive. Since vision is the main source of information input during driving,¹⁷ driving with a visual field defect asks for extra efforts to perceive all necessary information. This may create time pressure and may constrain available attention capacities, resulting in difficulties with tactical and operational aspects of driving. This hypothesis is supported by the TRIP scores as well as the additional reports in the current study.

Although substantial parts of the results are in agreement with the results from previous studies, some differences are worth mentioning. A particular driving skill found to be impaired in people with HH is maintaining an adequate position on the road. While in the study of Tant and colleagues⁶ a problematic lateral deviation toward the right side was only found for some people with RHH and no deviation for people with LHH, Wood and colleagues¹¹ found a tendency for LHH as well as RHH people driving too much to the unaffected, seeing side. In the present study, this was only found for LHH participants.

To our knowledge, this is the first study to include analyses of the time interval the participants have stopped driving. Earlier studies have found that current drivers were evaluated more often as safe to drive^{7,10} and received higher scores on visual behavior during driving⁶ than people who had stopped driving. In the present study, evidence was found for lower scores on the VIS, OPER, and GLOB subscales, but not the TACT subscale, with an increasing period of time not driven.

Some comments should be made with regard to the assessment procedure applied in the present study. The official on-road driving test is by definition a valid test to evaluate whether persons with impairments are fit to drive, since the evaluation takes place in the exact same situation that is being evaluated (driving on the road). Furthermore, the tests of practical fitness to drive were conducted by government-trained professional evaluators (DPRs) with a legal say on fitness to drive, in contrast to the previous American studies. However, high validity does not necessarily imply that measurements are reliable. Although all assessments were conducted according to a standardized protocol guaranteeing sufficient diversity in traffic conditions, reliability of assessments may have been negatively affected by the fact that the driving route could not be standardized across different regions. While interrater reliability of all DPRs is maximized by the education system including regular evaluations (Box 1 in the Supplementary Material) and the standardized assessment procedure including the TRIP questionnaire, exact data of the interrater reliability of the 15 DPRs participating in this study were not available. This forms a limitation to this study. In general, masked evaluators are preferred in observational studies. In case of our study the evaluators (DPRs) had to be informed about the nature of the visual impairment (HH and affected side of visual field). One could argue that this may have lead to a bias in their evaluations toward vision-related problems. However, the purpose of the on-road test of practical fitness to drive is to specifically evaluate whether the impairments lead to impairment-related driving errors. The risk that evaluations were based only on viewing behavior was minimized by the extensive training and reliability-checks of the DPRs and by using the TRIP that predefined specific operational and tactical aspects to be evaluated besides the visual aspects. Still, chances are that

the results would have been different in case of completely masked evaluators.

Mobility plays a major role in independent living and participation in industrialized society and ceasing car driving has been associated with social isolation, depression, and decreased quality of life, among other negative consequences.¹⁸ Therefore, it is highly relevant that people with visual field defects are allowed to demonstrate their driving skills in a valid driving assessment, on the condition of positive evaluations of visual and (neuro)psychological functioning. For people judged as unfit to drive, applying such a careful test protocol is likely to increase their acceptance of and compliance with the final decision. The current legislation in the Netherlands states that for consideration for a test of practical fitness to drive, the horizontal visual field has to be at least 90°.¹⁹ Different boundaries for a minimal required visual field size are applied in other countries. None of these values, including the values applied in the Netherlands, are based on scientific evidence or clear rationales.¹⁸ Although several studies have found evidence for people with HH being more impaired in car driving than people with quadrantanopia, no relation has been demonstrated between the extent of the horizontal visual field defect and driving performance.^{8–10,12} In the current study, visual field size correlated positively with viewing behavior and operational handling during driving, but there was no indication for a cut-off below, which all participants were unfit to drive. Until future research has found support for a certain threshold in terms of visual field size, policy makers could reconsider the criterion for a minimal horizontal visual field as a requirement for participation in a test of practical fitness to drive.

None of the participants had received training preceding the test of practical fitness to drive. The results provide suggestions for rehabilitation programs. Not only visual behavior was found to be affected in a substantial part of people with HH, but tactical and operational aspects as well. Training programs aiming at improving practical fitness to drive in people with HH should therefore not only focus on improving compensatory visual scanning,²⁰ but also on driving aspects such as steering stability, speed adaptation, and anticipating environmental changes. In other words, people with HH need to learn compensatory scanning mechanisms without operational and tactical driving to be affected. The current results provide a wealth of information on the specific driving aspects that deserve attention during training (e.g., perception and judgement during overtaking and passing by appears to be a common and decisive difficulty). Both the visual scanning behavior and the operational handling of the car are found to be poorer, the longer the person has not driven. This emphasizes the need for driving lessons (on-road or in a simulator) to be included in the training program preceding the test of practical fitness to drive.

Acknowledgments

The authors thank all study participants, all colleagues from the Dutch driver's licensing authority involved in the data collection, and all colleagues from Royal Dutch Visio involved in recruitment of participants.

Supported by grants from ZonMw-InZicht (94307005; Den Haag, The Netherlands), Royal Dutch Visio (OI0204; Haren, The Netherlands), and The University of Groningen (Groningen, The Netherlands).

Disclosure: **G.A. de Haan**, None; **B.J.M. Melis-Dankers**, None; **W.H. Brouwer**, None; **R.A. Bredewoud**, None; **O. Tucha**, None; **J. Heutink**, None

References

1. Brouwer WH, Ponds RWHM. Driving competence in older persons. *Disability and rehabilitation*. 1994;16:149–161.
2. Paparella G, Piccoli S, Brouwer WH, Hunter J. Cognitive impairment and dementia. In: Hunter J, Vries J de, Brown Y, Hekstra A, eds. *Handbook of Disabled Driver Assessment*. Ljubljana, Slovenia: Institute for Rehabilitation; 2009:381–390.
3. European Parliament, Council of the European Union. Directive 2006/126/EC of the European Parliament and of the Council of 20 December 2006 on driving licences (Recast). *Official Journal of the European Union*, L403. 2006;49:18–60.
4. Feigenson JS, McCarthy ML, Greenberg SD, Feigenson WD. Factors influencing outcome and length of stay in a stroke rehabilitation unit .2. Comparison of 318 screened and 248 unscreened patients. *Stroke*. 1977;8:657–662.
5. Gilhotra JS, Mitchell P, Healey PR, et al. Homonymous visual field defects and stroke in an older population. *Stroke*. 2002; 33:2417–2420.
6. Tant MLM, Brouwer WH, Cornelissen FW, Kooijman AC. Driving and visuospatial performance in people with hemianopia. *Neuropsychol Rehab*. 2002;12:419–437.
7. Brouwer WH, Busscher RB, Tant ML. On-road driving in homonymous hemianopia after stroke: the importance of attention and perceptual speed. In: Final Program The 2013 International Neuropsychological Society Mid-Year Meeting; July 10–13, 2013; Amsterdam, The Netherlands. Abstract 100.
8. Racette L, Casson EJ. The impact of visual field loss on driving performance: evidence from on-road driving assessments. *Optometry Vision Sci*. 2005;82:668–674.
9. Elgin J, McGwin G, Wood JM, et al. Evaluation of on-road driving in people with hemianopia and quadrantanopia. *Am J Occup Ther*. 2010;64:268–278.
10. Wood JM, McGwin G Jr, Elgin J, et al. On-road driving performance by persons with hemianopia and quadrantanopia. *Invest Ophtalmol Vis Sci*. 2009;50:577–585.
11. Wood JM, McGwin G Jr, Elgin J, et al. Hemianopic and quadrantanopic field loss, eye and head movements, and driving. *Invest Ophtalmol Vis Sci*. 2011;52:1220–1225.
12. Parker WT, McGwin G Jr, Wood JM, et al. Self-reported driving difficulty by persons with hemianopia and quadrantanopia. *Curr Eye Res*. 2011;36:270–277.
13. Kooijman AC, Melis-Dankers BJM, Peli E, et al. The introduction of bioptic driving in the Netherlands. *Visual Impair Res*. 2008;10:1–6.
14. Withaar FK. *Divided Attention and Driving: The Effects of Aging and Brain Injury*. Groningen: University of Groningen; 2000.
15. Cohen J. *Statistical Power Analysis for the Behavioral Sciences*. 2nd ed. Hillsdale: Lawrence Erlbaum Associates; 1988.
16. Rondinelli RD, Genovese E, Katz RT, et al. The visual system. In: Rondinelli RD, Genovese E, Katz RT, et al., eds. *Guides to the Evaluation of Permanent Impairment*. 6th ed. Chicago: American Medical Association; 2008:281–319.
17. Rockwell TH. Skills, judgement and information acquisition in driving. In: Forbes TW, ed. *Human Factors in Highway Traffic Safety Research*. New York: Wiley-Interscience; 1972:133–164.
18. Owsley C, McGwin G Jr. Vision and driving. *Vision Res*. 2010; 50:2348–2361.
19. Regeling Eisen Geschiktheid 2000. Available at: http://wetten.overheid.nl/BWBR0011362/geldigheidsdatum_08-04-2013. Accessed June 14th, 2013.
20. Bouwmeester L, Heutink J, Lucas C. The effect of visual training for patients with visual field defects due to brain damage: a systematic review. *J Neurol Neurosurg Psychiatry*. 2007;78:555–564.

APPENDIX A: TRIP

Position on the Road

1. What is the average lateral positioning on the driving lane (on a regular two-lane road)? (*Too much to the left, approximately in the middle, too much to the right, fluctuating*)

How is the steadiness of steering (swaying and drifting away)?

On Straight Roads

2. speed < 50 km/h
3. speed > 50 km/h

In Curves

4. speed < 50 km/h
5. speed > 50 km/h

When Making Head/Eye Movements

6. speed < 50 km/h
7. speed > 50 km/h

How good is the choice of position for the following specific situations?

8. Lane choice for straight ahead
9. Lane choice for turning right
10. Lane choice for turning left
11. Lane choice for/at roundabouts

Car Following Distance

12. How would you classify the style of car following of the driver?
(short, sufficient, long)

How well is the following distance adapted to variations of speed of the cars ahead?

13. In town areas
14. Outside town areas

Choice of Speed

15. How would you classify the driver in terms of his choice of speed?
(average, slow, fast)

How good is the driver's adaptation of speed to the circumstances?

16. In town areas
17. Outside town areas

Observation Behavior (Head and Eye Movements)

General

18. When moving straight ahead
19. Crossing junctions without designated priorities
20. Crossing priority junctions
21. When turning right at junctions or forks
22. When turning left at junctions or forks
23. In curves
24. When using inside mirror
25. When using outside mirror
26. Observation in the blind angle

Anticipatory viewing behavior

27. With regard to changing road situations
28. With regard to changing traffic situations

Traffic Signals (Lights and Signs)

29. Perception
30. Reaction

Overtaking and Passing By

31. Perception and judgement
32. Performing the maneuvers

Anticipation

(At a tactical level, e.g., slowing down when a pedestrian approaches the driving lane)

33. With regard to changing road situations
34. With regard to changing traffic situations

Communication With and Adaptation to Other Traffic Participants

35. With other car drivers
36. With cyclists and pedestrians

Assessment of Specific Situations

- A. Turning left on a priority road or no traffic lights.

When Approaching the Junction

37. Adaptation of speed
38. Use of mirrors and looking sideways
39. Operating the direction indicator
40. Position on the driving lane
41. Viewing behavior (head movements)
42. Effectiveness of viewing behavior (seeing other traffic)

At the Junction

43. Choice of position
44. Viewing behavior (head movements)
45. Effectiveness of viewing behavior (seeing other traffic)
46. Application of the priority rules
47. Tempo of perception and action

- B. Merging with a fast moving stream of traffic (merging lane trunk road or motorway).

48. Acceleration on the merging lane
49. Looking sideways
50. Adaptation of speed to other traffic
51. Operating the direction indicator
52. Driving on to the main lane

Mechanical Operation

53. Operating the accelerator
54. Operating the brakes

General Impressions

55. Practical fitness to drive (general)
56. Mechanical operation
57. Traffic perception and traffic insight

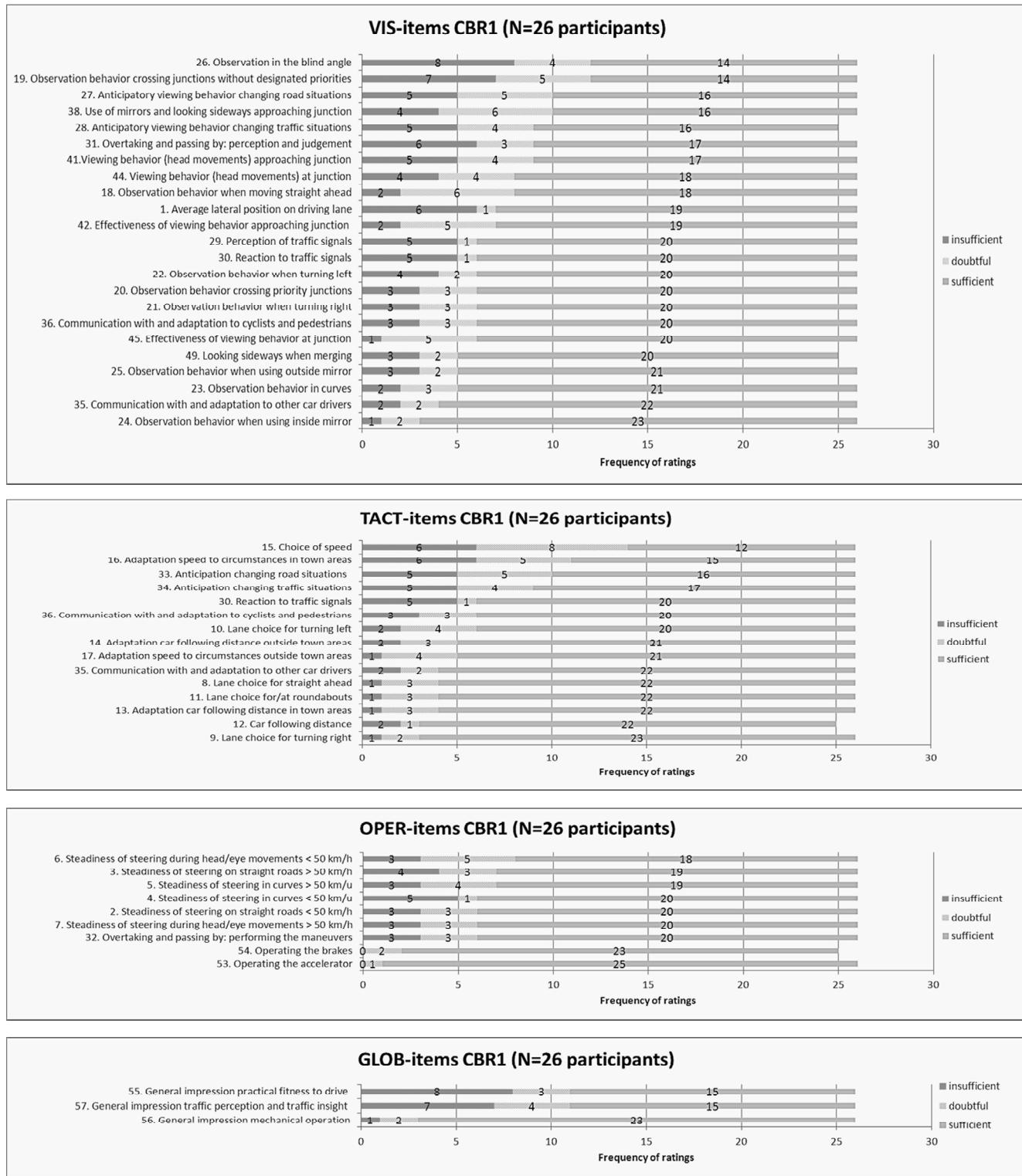


FIGURE A1. Frequency of ratings ("sufficient," "doubtful," and "insufficient") for every individual TRIP item, organized by subscale for the total group of participants ($N = 26$). For some items the DPR failed to report a rating, resulting in 25 observations instead of 26.