



# Real-world Evaluation of Drivers with Glaucoma

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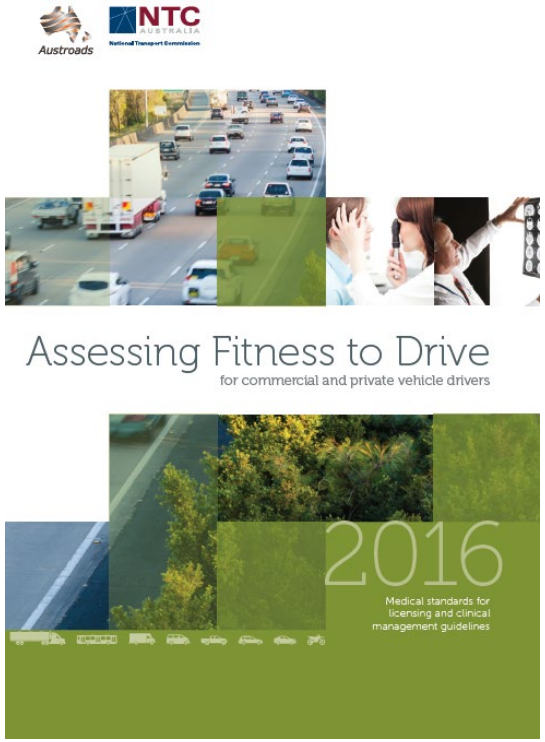
# Conflict of Interest Disclosure

- ❑ XI have no potential conflict of interest to disclose

- ❑ I have the following potential conflict(s) of interest to report :
  - ❑ Receipt of grants/research supports:
  - ❑ Receipt of honoraria or consultation fees:
  - ❑ Participation in a company sponsored speaker’s bureau:
  - ❑ Stock shareholder:
  - ❑ Spouse/partner:
  - ❑ Other support (please specify):

# Glaucoma and Driving

- Glaucoma is characterised by visual field defects and contrast sensitivity loss
  - Functional impact on activities of daily living such as driving
  - Driving is important for maintaining independence[1,2]
    - Cessation linked to isolation and depression
- Drivers with glaucoma regularly assessed to ensure that they meet the visual standards for driving
  - Conflicting evidence regarding the impact of glaucoma on driving ability and safety
  - Unclear whether visual licensing requirements predict the capacity for safe/unsafe driving in those with glaucoma




1. Marottoli et al (1997); 2. Windsor et al (2007)

# Glaucoma: Crash Risk

- Previous research: self-reported crashes
  - Drivers with severe glaucomatous field loss reported more crashes in the previous 10 yrs than controls (n=144 G; 157 C)[1]
    - 25% of those with severe field loss (MD -10 dB or worse in the worse eye) reported MVC in past 10 years

Have you been involved in one or more traffic accident in the past ten years? yes/no

  - No association between integrated binocular visual field (IVF) loss and crashes reported in the previous 5 yrs (n=247)[2]

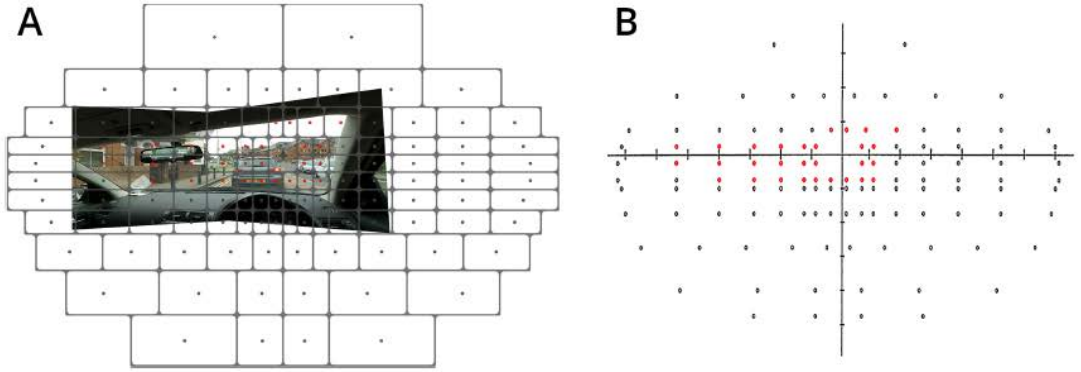
1. Tanabe et al (2011); 2. Yuki et al (2014)

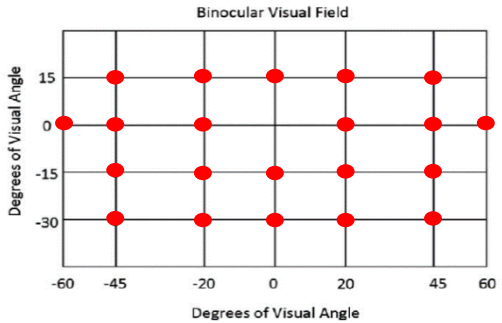
# Glaucoma: Crash Risk

FIGURE 1. Driver's view through the windshield and side windows of a vehicle; this view is the widest possible panoramic view from the driver's vantage point as the driver's head turns from one side of the roadway to the other.

- Previous research: state-recorded crashes
  - Case-control study, drivers with glaucoma (n=48) were >6x more likely to crash than controls, strongest association with impaired selective attention (Useful Field of View)[1]
  - At-fault crash rates
    - 6x higher with moderate/severe loss (AGIS scores) in worse eye (n=240)[2]
    - 2x higher with severe binocular PD impairment (n=438)[3]
    - 1.65x higher with severe loss in novel 'driving visual field' (n=206)[4]

**Figure 1** The Esterman Visual Field Test (EVFT) grid superimposed over a road scene as seen from the driver's perspective (A), and an example of a clinical EVFT output (B). Test locations within the region covered by the car windscreen are coloured red: it can be seen that many points on the EVFT, especially in the inferior visual field, are irrelevant to the driving scene.

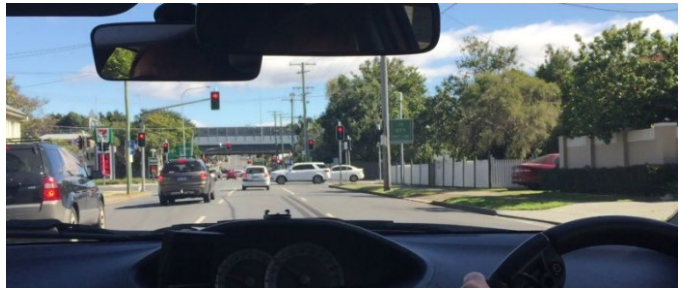


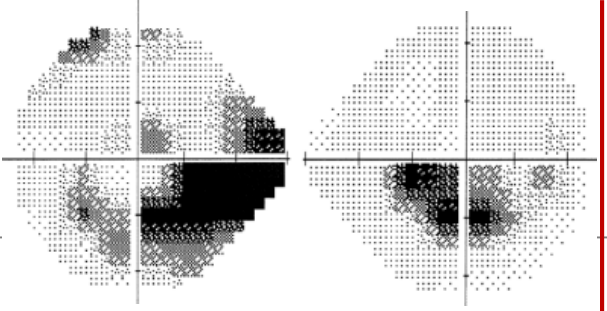

1.Haymes et al (2007); 2.McGwin et al (2005); 3. McGwin et al (2015); 4. Kwon et al (2016)

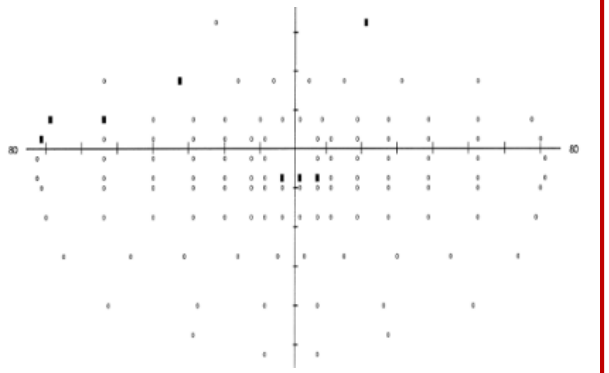
# Glaucoma: Real-World Driving Performance

- On-road driving assessment
  - Useful to evaluate real-world driving performance, using standardised protocols and can explore which aspects of performance are impaired
- Previous on-road driving research: drivers with glaucoma demonstrate poorer performance:
  - Lane-keeping, scanning ability, anticipatory skills (n=10-27)[1,2]
  - More driving instructor interventions (n=20)[3,4]
- Underlying differences in performance poorly explained by standard clinical vision tests[2,4]
  - These standard tests unlikely to capture the relevant visual requirements of driving
  - Potential compensation by increased visual scanning

1. Bowers et al (2005); 2. Kasneci et al (2015); 3. Haymes et al (2008); 4. Bhorade et al (2016)





Binocular Esterman
Score 93/100

# Glaucoma and Open-Road Driving

- 75 older adults aged 65+ with a diagnosis of glaucoma and mild to moderate field loss (M=73.2 ± 6.0 yrs)
  - HFA 24-2 Mean Defect:
    - Better eye: -1.21 dB ± 4.90 (-23.24 - 3.99 dB)
    - Worse eye: -7.75 dB ± 8.47 (-31.00 - 2.10 dB)
- 70 age-matched drivers without glaucoma (M=72.6 ± 5.0 yrs)
- All participants licensed to drive and drove regularly
  - Mean days/week: 4.9 (glaucoma)  vs 5.3 (controls)
- Vision testing battery:
  - Visual acuity, visual fields (binocular Esterman, monocular 24-2), contrast sensitivity (Pelli-Robson), motion sensitivity (moving dot RDK)

Wood JM, Black AA, Mallon K, Thomas R, Owsley C (2016) Glaucoma and driving: On-Road driving characteristics. PLoS ONE 11: e0158318.


# Driving Performance: Open-Road

- Driving Instructor and Occupational Therapist (masked)
- Dual brake vehicle
- Standard route (19 km)
  - Car park to more complex traffic situations
  - City and suburban streets
  - 148 locations at which driving ability rated
- Quantitative driving scores
  - Types of driving errors (eg. lane-keeping, observation, merging) and driving situations (eg. give-way, roundabouts) where errors made
  - Number of critical errors (CE) requiring driving instructor interventions
  - Global driver safety rating (1-10)

# Results: Visual Function

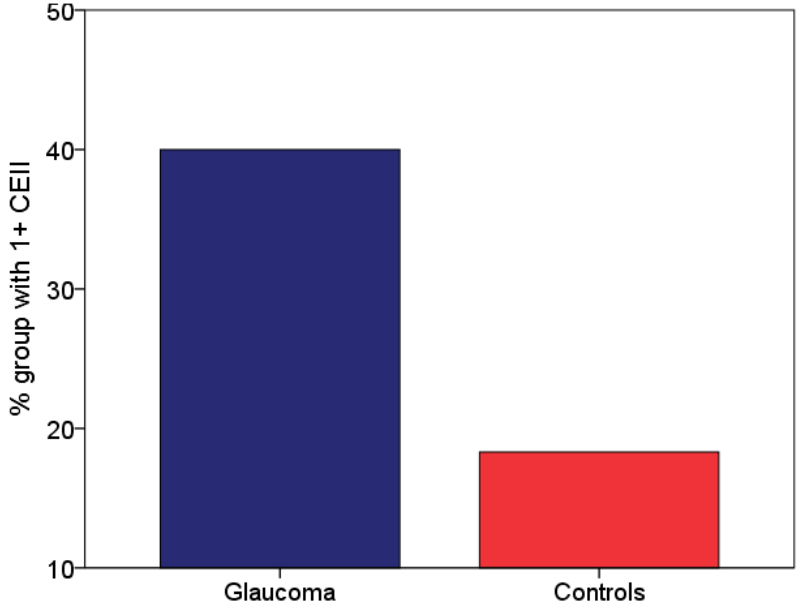
- Visual acuity, contrast sensitivity and central visual fields of the glaucoma patients were significantly worse than that of the age-matched controls ($p<0.05$)
- Esterman fields were not significantly different

| | Group Mean (SD) | |
|---|---|---|
| | Glaucoma | Controls |
| Visual Function | | |
| Binocular Visual Acuity (logMAR) | 0.01 (0.11) | -0.05 (0.09) |
| Binocular Contrast Sensitivity (LogCS) | 1.87 (0.14) | 1.95 (0.03) |
| HFA MD 24-2 Best Eye | -1.21 (4.90) | 1.86 (1.15) |
| HFA MD 24-2 Worst Eye | -7.75 (8.47) | 1.01 (1.38) |
| Esterman Efficiency Score (max 100) | 95.9 (5.9) | 96.4 (4.2) |

# Results: Overall Driving Scores

- Drivers with glaucoma were rated as significantly less safe than controls (5.2 vs 5.8)
- Drivers with glaucoma were 2x more likely to have a critical error (CE) requiring instructor intervention than controls
  - RR = 2.06 (95% CI 1.17 - 3.62)

| Driving Outcomes | Group Mean (SD) | |
|---|---|---|
| | Glaucoma | Controls |
| **CE total#** | **0.83 (1.16)** | **0.43 (0.73)*** |
| | | |
| CE observation# | **0.48 (0.76)** | **0.24 (0.52)*** |
| CE vehicle control# | 0.11 (0.35) | 0.14 (0.39) |
| CE lane keeping# | 0.19 (0.39) | 0.16 (0.40) |
| CE speed# | 0.15 (0.56) | 0.06 (0.29) |

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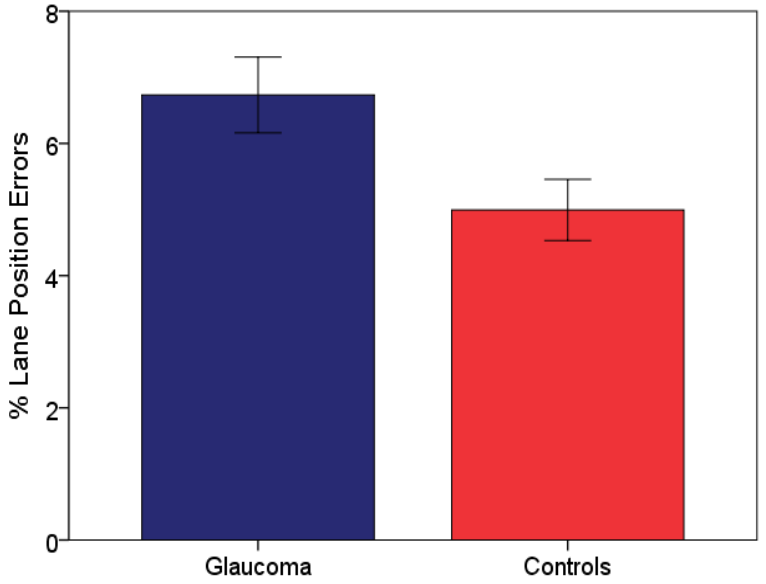
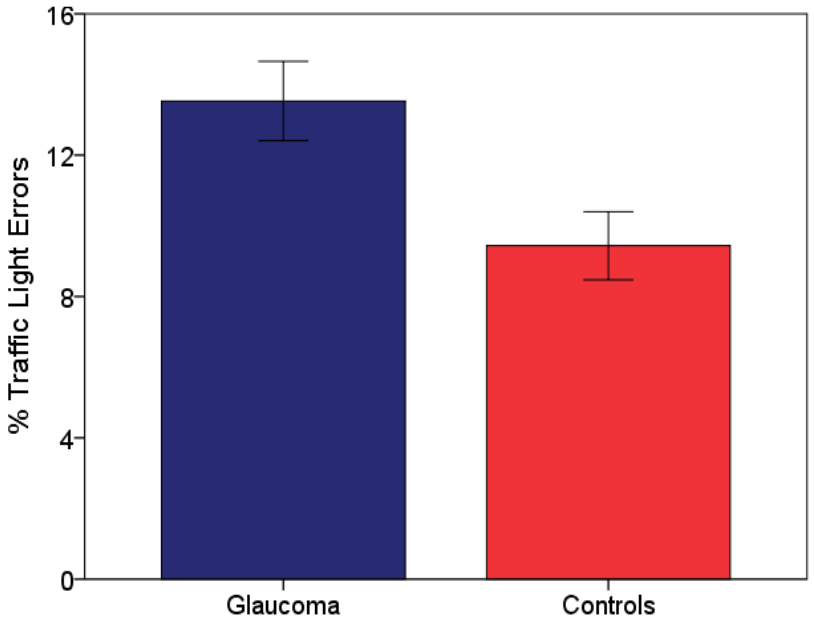
# Results: Driving Errors and Driving Locations

- Types of errors
  - Significant differences: lane keeping, observation and approach




- Location of errors
  - Significant differences: traffic-light controlled intersections, give-way

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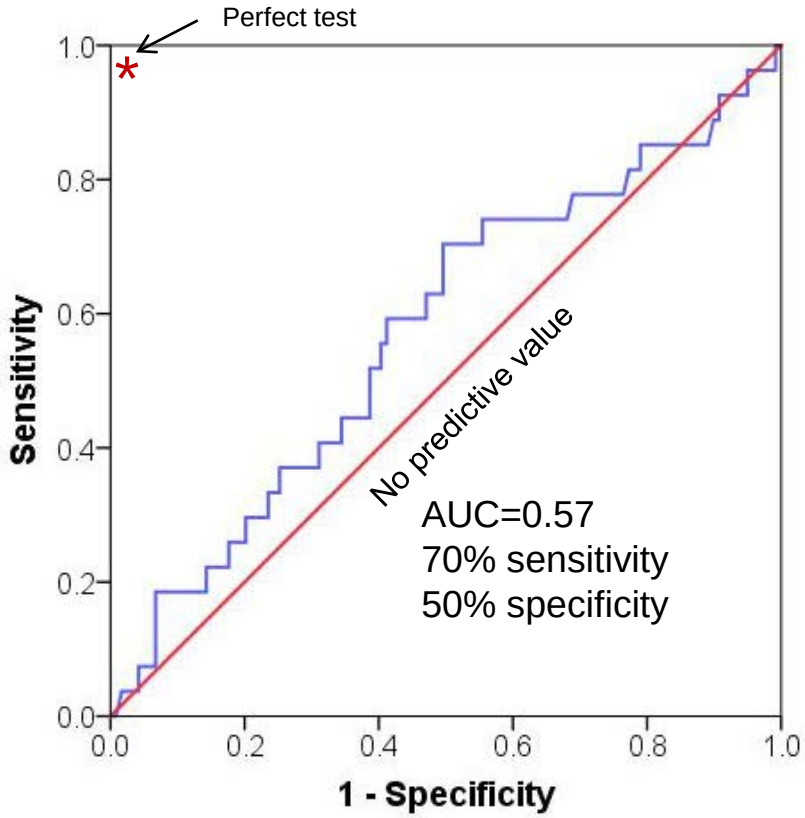
# Results: Visual Predictors of Driving

- None of the standard visual field measures were significantly associated with driving performance or safety ratings
  - Worse eye MD best of the vision measures

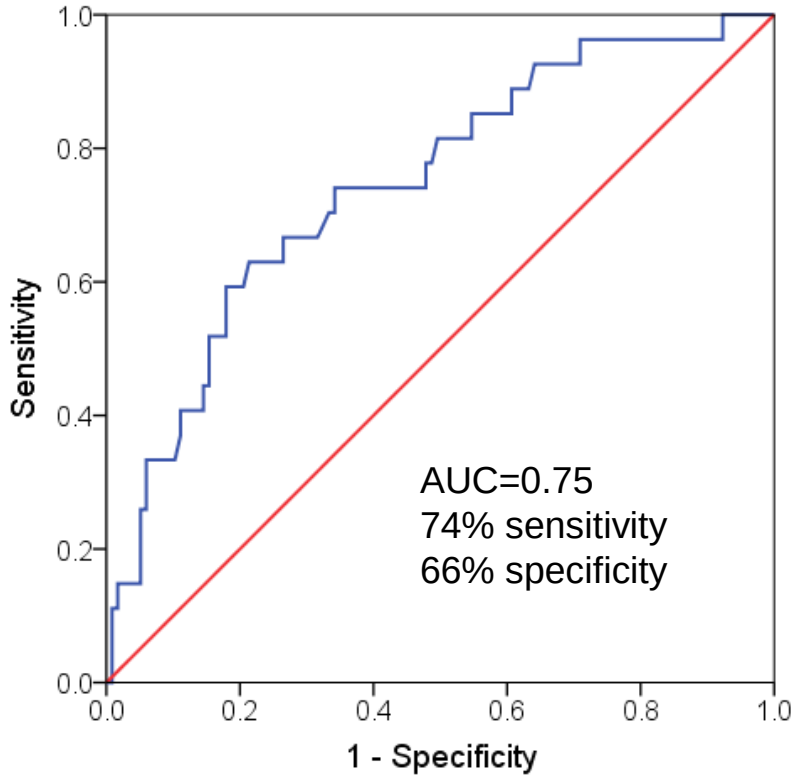
ROC curve:worse eye MD



# Results: Visual Predictors of Driving

- None of the standard visual field measures were strongly associated with driving performance or safety ratings
  - Worse eye MD best of the vision measures
- BUT motion sensitivity was significantly associated with a range of driving performance measures

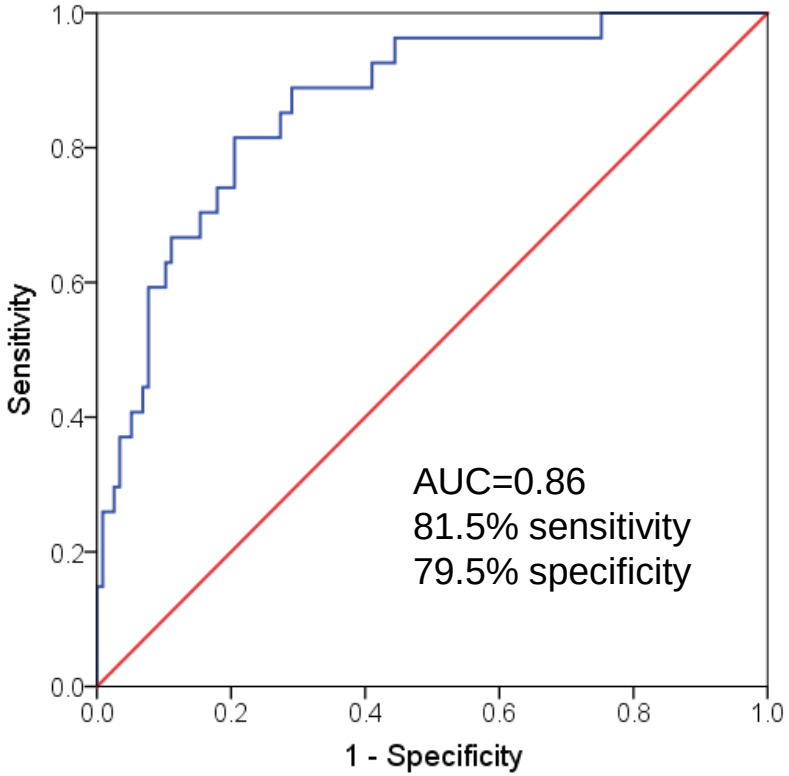
ROC curve: motion test



# Results: Visual Predictors of Driving

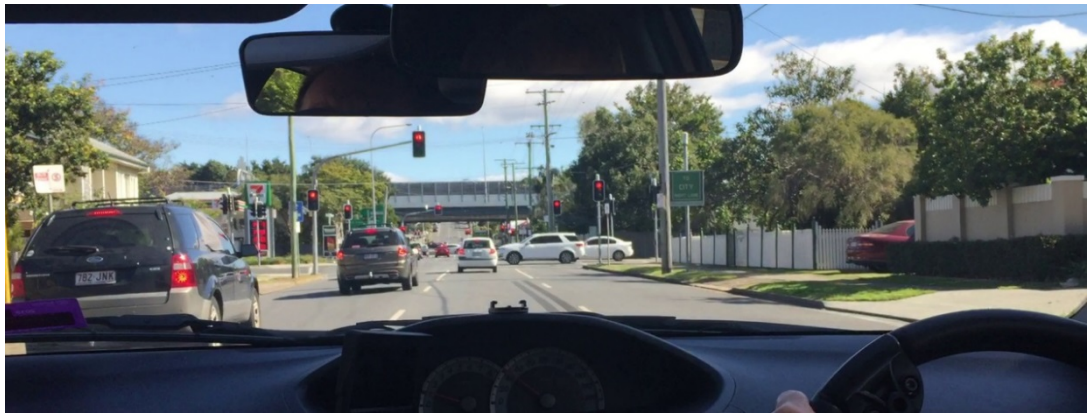
- None of the standard visual field measures were strongly associated with driving performance or safety ratings
  - Worse eye MD best of the vision measures
- BUT motion sensitivity was significantly associated with a range of driving performance measures
  - High sensitivity and specificity when combined with measures of cognitive and motor performance and driving exposure

ROC curve: motion test combined with cognitive and motor measures



# Discussion

- Small but significant differences in driving safety between groups
  - Drivers with mild to moderate glaucoma were rated as less safe than controls
  - Errors included lane-positioning, approach and observation and were more common at give-way and traffic-light controlled intersections



  - Critical errors that involved an instructor intervention were higher - observation errors were the main problem

# Discussion

- Of the visual function tests assessed, motion sensitivity was most strongly associated with driving performance
  - Standard vision tests (including visual fields) were poorly associated with driving ability and safety in drivers with mild to moderate glaucoma
- Some drivers may compensate for their field loss through eye movements, which may explain the lack of predictive ability of visual fields for driving[1-3]
  - Potential for training interventions to enhance scanning and search strategies while driving
- Fitness to drive should be based on performance rather than age or disease status
  - Consider the use of on-road assessments to assist in licensing decisions
  - Decisions must ensure fair outcomes for all drivers including those with glaucoma

1. Wood et al (2010); 2. Kasneci et al (2015); 3. Lee et al (2018)

# Acknowledgments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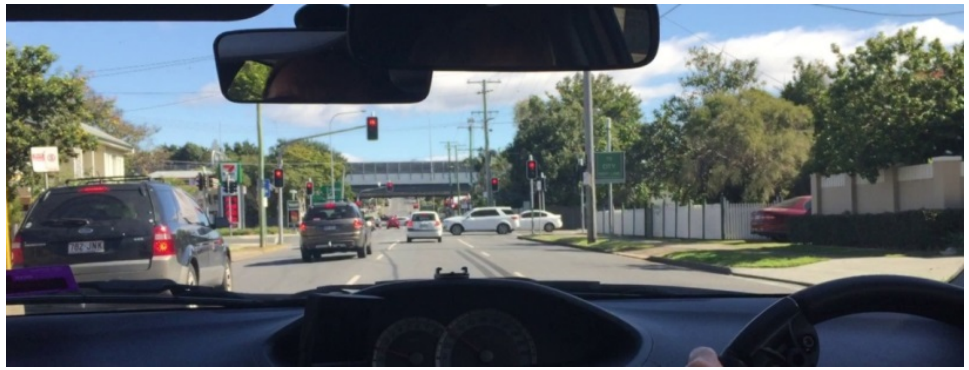
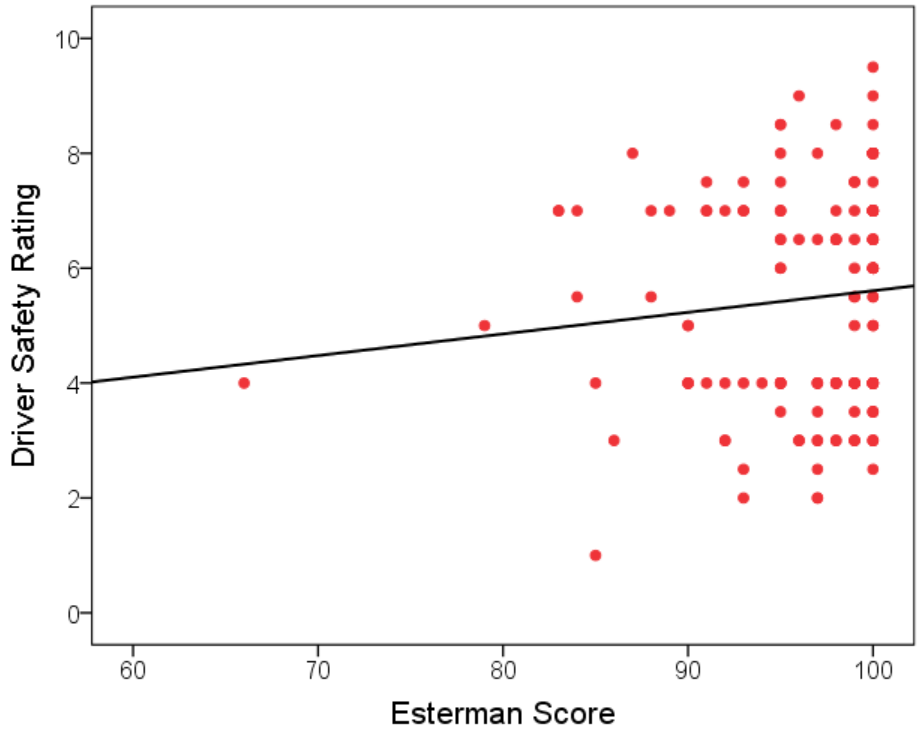
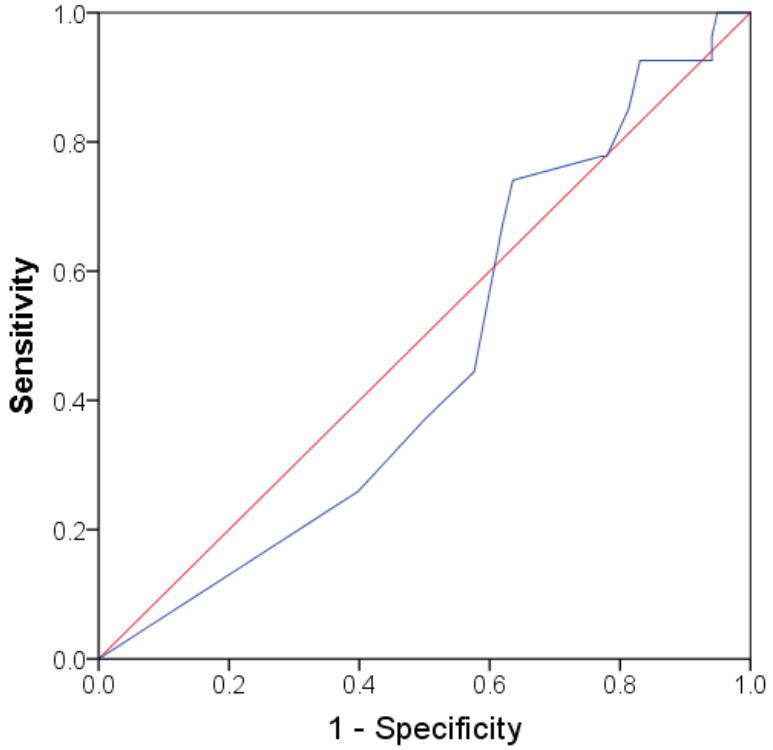
- Vision and driving research team and Ivor Booker
- All drivers who participated in this study

# Supplementary Data




ROC curve: Esterman Score



# Supplementary Data

**RE**

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | -21 | -28 | -12 | -13 | | |
| | | -30 | -23 | -28 | -23 | -13 | -4 | |
| | -28 | -29 | -11 | -32 | -29 | -12 | -15 | -3 |
| -28 | -29 | -25 | -33 | -32 | -33 | -33 | | -1 |
| 2 | 0 | 0 | -1 | -1 | -2 | -1 | | 2 |
| | 0 | 1 | 1 | 1 | 0 | -2 | 1 | -2 |
| | | 1 | 4 | 1 | 1 | -1 | -1 | |
| | | | -1 | -1 | 1 | -1 | | |

**LE**

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | -15 | -23 | -25 | -25 | | |
| | | -9 | -15 | -16 | -21 | -20 | -13 | |
| | -5 | -18 | -12 | -21 | -29 | -18 | -14 | -26 |
| 0 | | | -5 | -2 | -14 | -26 | -21 | -29 | -23 |
| | 0 | | -2 | -1 | -2 | -1 | 0 | -3 | -3 |
| | -1 | 1 | 0 | -2 | -2 | -1 | 0 | -2 | |
| | | 2 | 3 | -3 | -2 | -2 | -1 | | |
| | | | 1 | -2 | 0 | -3 | | | |

**Integrated Visual Field (IVF)**

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | -15 | -23 | -12 | -13 | | |
| | | -9 | -15 | -16 | -21 | -13 | -4 | |
| | -5 | -18 | -11 | -21 | -29 | -12 | -14 | -3 |
| 0 | -25 | -5 | -2 | | -14 | -26 | -21 | -1 |
| 0 | 0 | -1 | -1 | | -2 | -1 | 0 | 2 |
| 0 | 1 | 1 | 1 | | 0 | -1 | 1 | -2 |
| | 2 | 4 | 1 | | 1 | -1 | -1 | |
| | | 1 | -1 | | 1 | -1 | | |

**Binocular Mean Deviation = -7.07**

ROC curve: central 20 degrees IVF