Distracted driving and Effective Field of View in drivers with glaucoma on a novel panoramic Driving Simulator Visual Field task

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Introduction

- Glaucoma affects 2% of the U.S. population over 40 and significantly increases the risk of Motor vehicle crashes (1-3)
- A key question is whether Humphrey visual fields (HVF), administered with careful control over eye fixation, accurately reflect patients' visual performance and safety behavior in context, on the road.
- We define "effective field of view" (EFOV) as the dynamic field of view in naturalistic conditions of eye and head movements.

Objective

Our goal is to understand the critical relationship between standard HVF (static visual fields) and EFOV (dynamic visual fields) during driving under varying cognitive loads.

We hypothesize that EFOV will decrease with tasks that increase cognitive load.
To achieve this goal, we have developed an innovative driving simulator visual field : **the DSVF task that allow us to map EFOV** in realistic driving conditions

Aim 1: To assess the validity and reproducibility of the DSVF task
Aim2: To map EFOV using the DSVF in the simulator with head and eye movements allowed, under differing task loads created during driving.

Our main outcome measure is the driving simulator visual field index **(DSVF-VFI),** a global score calculated by weighting the number of responses based on their location similar to VFI calculations in HVF.

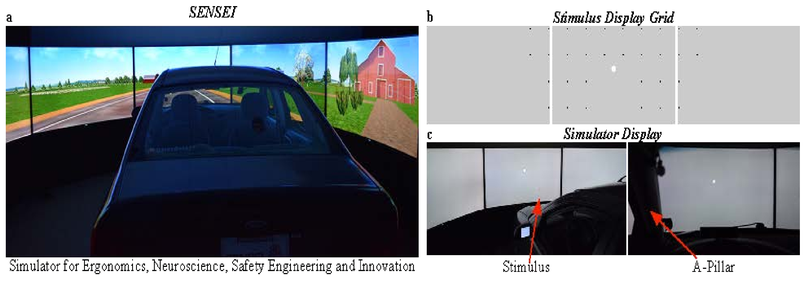
Methods

Driving Simulator Visual Field (DSVF)

- Implemented in SENSEI (Simulator for Ergonomics, Neuroscience, Safety Engineering and Innovation), a DriveSafety RS-600 high fidelity driving simulation system with a 290 degrees display environment, retinal level display and a full-size automobile cab.
- DSVF tests total 60˚horizontal and 20˚ vertical visual field at 2.5 m. Forty grid test locations are placed 6˚apart, straddling the horizontal and vertical meridian similar to HVF 30-2 strategy.
- Red supra-threshold stimulus images (0.5˚visual angle, similar to HFA stimulus size III) are presented randomly 4 times at each locus with stimulus duration 200 milliseconds, and a varying inter-stimulus interval from 1.2 to 1.7 seconds for a total test duration of 4 minutes. Central fixation targets are present for certain scenarios.
- All tasks are repeated twice to test for reproducibility

Task1: The DSVF with a fixation target and grey background monocularly and binocularly in conditions similar to the HVF.

Task 2: The DSVF with free eye and head movements with a naturalistic background
Task 2A: DSVF in a no-driving condition
Task 2 B: DSVF task with driving
Task 2C : DSVF with driving and PASAT (Paced Auditory Serial Addition Test)



Results

17 controls- glaucoma suspects (HVF-VFI range 98-100%, mean age 63 years) and 18 subjects with glaucoma (HVF-VFI range 16-94% worse eye and 21-100% better eye ,mean age 70 years) participated.

Task 1 results:
Glaucoma suspect DSVF -VFI was 98±1.% (mean ±SD) for binocular fields, 93±4% right eye and 90±4 % left eye fields (Figure 3 A and 3 B)

Glaucoma DSVF -VFI was 67±3% (mean ±SD) for binocular fields, 54±3% right eye and 74±2 % left eye fields

DSVF were highly reproducible. The ICC varied from 0.7-1 for the 2 trials of the DSVF

Affected areas on DSVF and HVF grayscales were subjectively similar (Figure 3- Ca) and highly correlated (Figure 2)ICC ranged from 0.8-0.9) .

Blind spot mapped correctly (15˚location) in all monocular fields (Figure 3- light blue circle).

A-pillar scotoma: In all DSVF trials (aim 1 and 2), there was a vertical scotoma in the left hemifield 21˚- 27˚ location in the DSVF corresponding to the vehicle's A-pillar (green circle- figure 3). This was calculated as HVF-VFI-DSVF VFI in glaucoma suspects and caused a 7±4 % decrease in VFI OD, 9±3 % decrease in VFI OS and 2±3 % decrease in VFI OU

Task 2 results:
Data was analyzed separated for task 2a and 2 b (n=35) and all 3 tasks together (n=19)

The EFOV decreased with increasing attention demand in both glaucoma subjects and controls

This decrease in EFOV was analyzed using linear mixed models and was found to be significantly affected by both the task assigned ($p < 0.001$) and diagnosis ($p < 0.001$).

There was also significant interaction between the diagnosis and the task ($p=0.041$ for all subjects and $p=0.76$ for the 19 subjects with the PASAT task)

A predictive formula was developed to use HVF data to predict EFOV while driving

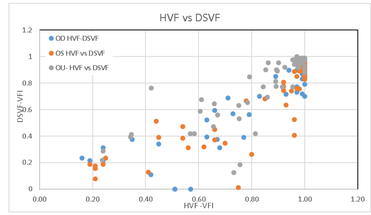


Figure 2 A: scatter graph of monocular and caculated binocular HVF-VFI and DSVF-VFI .

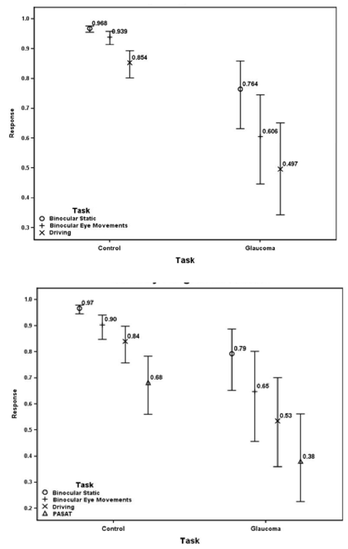


Figure 2 B: DSVF -VFI with increasing attention demand in all subjects (n=35) and in subjects with PASAT task (n=19)

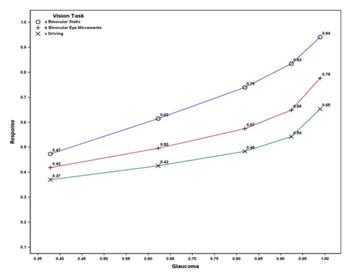


Figure 2 C: DSVF -VFI prediction using HVF (x axis) under conditions of static DSVF and driving in glaucoma subjects

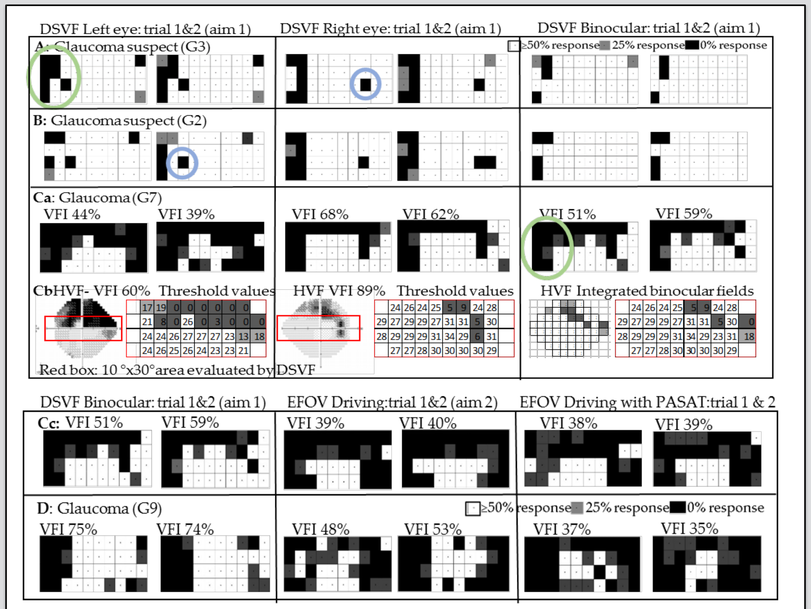


Figure 3: Each column represents 2 DSVF trials demonstrating reproducibility. Rows A, B: Monocular and binocular Driving Simulator Visual Fields (DSVF) of glaucoma suspects. Accurate positioning of blind spots (blue circle) is seen in monocular fields and A-pillar scotoma (green circle) is seen in all fields. Row Ca: DSVF of glaucoma subject Row Cb: HVF gray scale and absolute threshold values from HVF field in red box (aim 1) demonstrating similarity of gray scales in DSVF and HVF apart from the A-pillar scotoma (green). Rows Cc and D represent 2 different glaucoma subjects with Binocular DSVF from aim 1 (in column 1) and Effective Field of View (EFOV) with driving (column 2) and EFOV with driving with PASAT tasks (in column 3). The EFOV shrinks (VFI decreases) with increasing attention.

Conclusions

- The DSVF is a novel technique to study the EFOV in a naturalistic setting. Global VFI on DSVF correlated well with HVF
- In cab geometry, particularly the A-pillar decreased the EFOV by 2% binocularly and 7% monocularly for the right eye and 9% for the left eye.
- EFOV shrinks with driver distraction and increasing attention demand in subjects with full and compromised visual fields .
- The decrease in EFOV with increasing cognitive load is more pronounced in the glaucoma group than in the control group
- EFOV mapping may guide rehabilitation strategy design for safer driving

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