The Design of Driving Simulator Performance Evaluations for Driving With Vision Impairments and Visual Aids

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Loss of Vision’s Influence on Driving

• Design and evaluate visual aids for specific vision impairments/ vision loss

• Today: Detection task while driving with visual field loss
Normal Vision vs. Hemianopia

Normal Visual Field (Binocular)

180° Horizontal field of view

Left Hemianopia (Binocular)

90° Horizontal field of view
Hemianopia

Hemi • an • opia = Half • Non • Seeing
Causes of Hemianopia

Hemianopia is an issue with the **brain**; *not the eye.*

- Stroke
- Brain tumor (or surgical removal of)
- Head trauma
Prevalence

• About 5 million stroke survivors in United States*

• 30-45% of those have Hemianopia **

* National Health Interview Survey, 2002
** Gray et. al, Age Aging, 1989
** Rossi et al, Neurology, 1990
Hemianopes Can Drive Legally

27 Can Drive
23 Cannot Drive
Driving With Hemianopia

Non-uniform state laws between states:

– Little empirical research to justify such laws
– For the safety of other road users
– For the safety drivers with hemianopia

– Denying anyone driving privileges is a serious issue – removal of independence
Driving With Hemianopia + Visual Aids?

• Little information about driving with field expanding visual aids

• No states currently endorse the use of field expanding visual aids to qualify.
A Visual Field Plot Does Not Represent Real World Conditions
FAAC Incorporated: PP-1000
Custom Scripting Software (Scenario Tool Kit v 1.3)
Honk at Pedestrian
Pedestrian At 220 Feet
Primary Measures

- Detection (seen/not seen)
- Reaction Time (when seen)
Where We Put Pedestrians

Right and Left Sides

- Applicable to Right Hemianopia or Left Hemianopia
  (Between Subject Comparison)

- Compares Blind Side to Seeing Side
  (Within Subject Comparison)
Additional Methodology

- Low & High (30 & 60 mph) posted speed limits
- 5 scenarios per test (high/low speed, scripted traffic)
- 12-14 targets appear per scenario
- Approximately 30 minutes of driving
Targets Appear at Reasonable Distance

- 220’ (67m) away for low speed scenario, 440’ for high speed scenario
- 6’ target is visible
- This distance equates to 5 seconds from driver
- AASHTO guidelines 2.5 seconds to react
• We place targets and want to know where they appear in a person’s visual field.

• A target appears either left or right of anticipated gaze direction.

• We must make assumptions about where the person is looking...
Video Examples

‘Front Left’ Monitor: Illustrates target presentation via multiple monitors

‘Center’ Monitor: Driver looks here for majority of drive
Target Appearance

Front Left Monitor  Center Monitor

Rear View Mirror

Side View Mirror
Target Location at Instant of Target Appearance
Driver looks straight ahead

Place Target Here

14° off gaze direction
Predict Fixation More Accurately with ‘Attention-Getter’
Target Location at Instant of Target Appearance
Driver looks at Ambulance 14º left of anticipated fixation location.
Driver Gazes at Tangent Point of Curve

1. Select a car location in curve when target will appear

2. Compute Tangent Point

3. Position target 14° and 440 feet from tangent-driver line

First Pilot Study

Two drivers with Left Hemianopia (missing the left visual field)
Three drivers with normal visual field
Percentage of Targets Detected

Left targets | Right targets

Control 1 | Control 2 | Control 3

Percentage detected

0 | 20 | 40 | 60 | 80 | 100
Percentage of Targets Detected

- Control 1
- Control 2
- Control 3
- Left hemi 1
- Left hemi 2

Percentage detected
- Control 1: 100%
- Control 2: 100%
- Control 3: 100%
- Left hemi 1: 100%
- Left hemi 2: 80%

Legend:
- Left targets
- Right targets
Percentage of Targets Detected

<table>
<thead>
<tr>
<th></th>
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<th>Control 2</th>
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<th>Left hemi 1</th>
<th>Left hemi 2</th>
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<tbody>
<tr>
<td>Left targets</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>20</td>
<td>0</td>
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<tr>
<td>Right targets</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>80</td>
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Legend:
- Left targets
- Right targets
Mean Response Times

- Left targets
- Right targets

Control 1  Control 2  Control 3  Left hemianopia 1  Left hemianopia 2

Time in seconds

Left targets  Right targets

Control 1  Control 2  Control 3
Mean Response Times

- Control 1
- Control 2
- Control 3
- Left hemianopia 1
- Left hemianopia 2

Time in seconds
- Left targets
- Right targets

- Time in seconds
  - 0
  - 1
  - 2
  - 3
Mean Response Times

\[ F(1,155) = 8.5, \ P = .005 \]
Second Pilot Study
No significant differences.
Pilot Study Outcomes

1. Complete hemianopia miss significantly more targets on blind side than seeing side or controls

2. When detected, response times are significantly greater

3. Partial hemianopia still shows difference (in reaction times, not % detected)
Summary

Scenarios working as designed
→ We can measure clear performance differences with our scenarios
Additional Measurements
Analysis of Driver Behavior at T-Intersections

Specific challenges to drivers with Hemianopia
Analysis of Driver Behavior at T-Intersections

Illustration Not to Scale
Left Hemianopic Driver Turning Left and Looking Left for Traffic

Outside Functional Visual Field
Left Hemianopic Driver Turning Left and Looking Right for Traffic

Outside Functional Visual Field
Labeled T-intersection Targets

If Driver Turns Left
This is Target $A_L$

If Driver Turns Right
This is Target $A_R$

$A_L$/$A_R$

If Driver Turns Left
This is Target $A_L$

If Driver Turns Right
This is Target $A_R$
## Controls at T-Intersections

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<tr>
<td>Control1</td>
<td>Miss</td>
<td>Seen</td>
<td>Seen</td>
<td>Seen</td>
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<tr>
<td>Control2</td>
<td>Seen</td>
<td>Seen</td>
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<td>Control3</td>
<td>Seen</td>
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## Hemianopes at Intersections

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<td>Right</td>
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Troublesome for...  
- Left  
- Left  
- Right +Left  
- Right +Left  
- Right
## Accuracy of Our Predictions

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**Accuracy of Prediction**

- 50%  
- 100%  
- 20%  
- 20%  
- 80%
Additional Measure: Steering Stability

Do Hemianopic Drivers swerve more than drivers with full visual field?

Do Hemianopic Drivers tend to hug one side of the road?
Additional Measure: Steering Stability

We defined *segments* and perform analysis through straight, curved and intersection segments

(Coeckelbergh et. al, *Vision Research*, 2002)
• Scenarios are sensitive to what we are looking to evaluate
• Now using in study
The Study (In Progress)

Peripheral Prisms: a visual aid for hemianopic visual field loss
Peripheral Prisms

Without

With

Left Hemianopia
Thank You

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- R. Goldstein
- L. Bobrow

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