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

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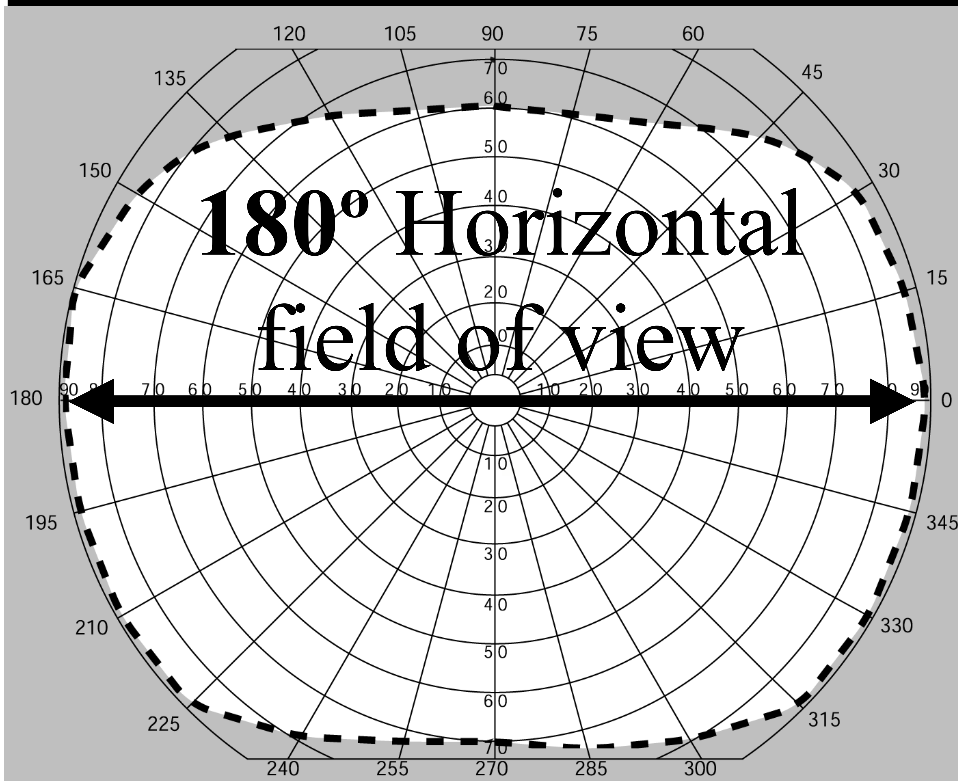
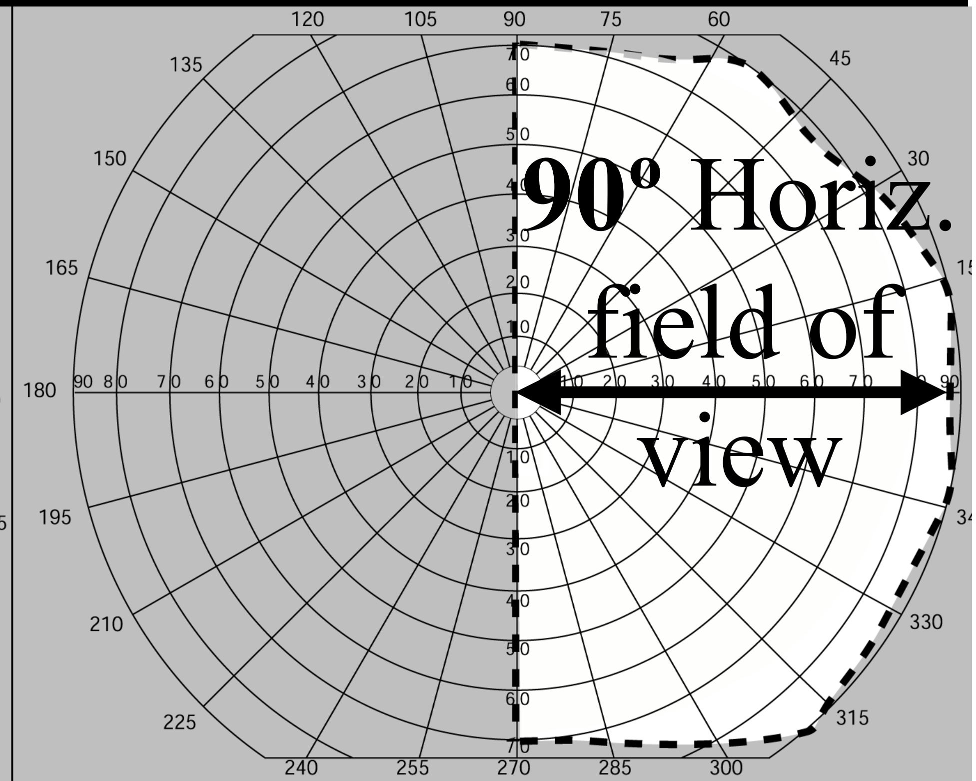
Loss of Vision's Influence on Driving

- 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)

Left Hemianopia (Binocular)

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

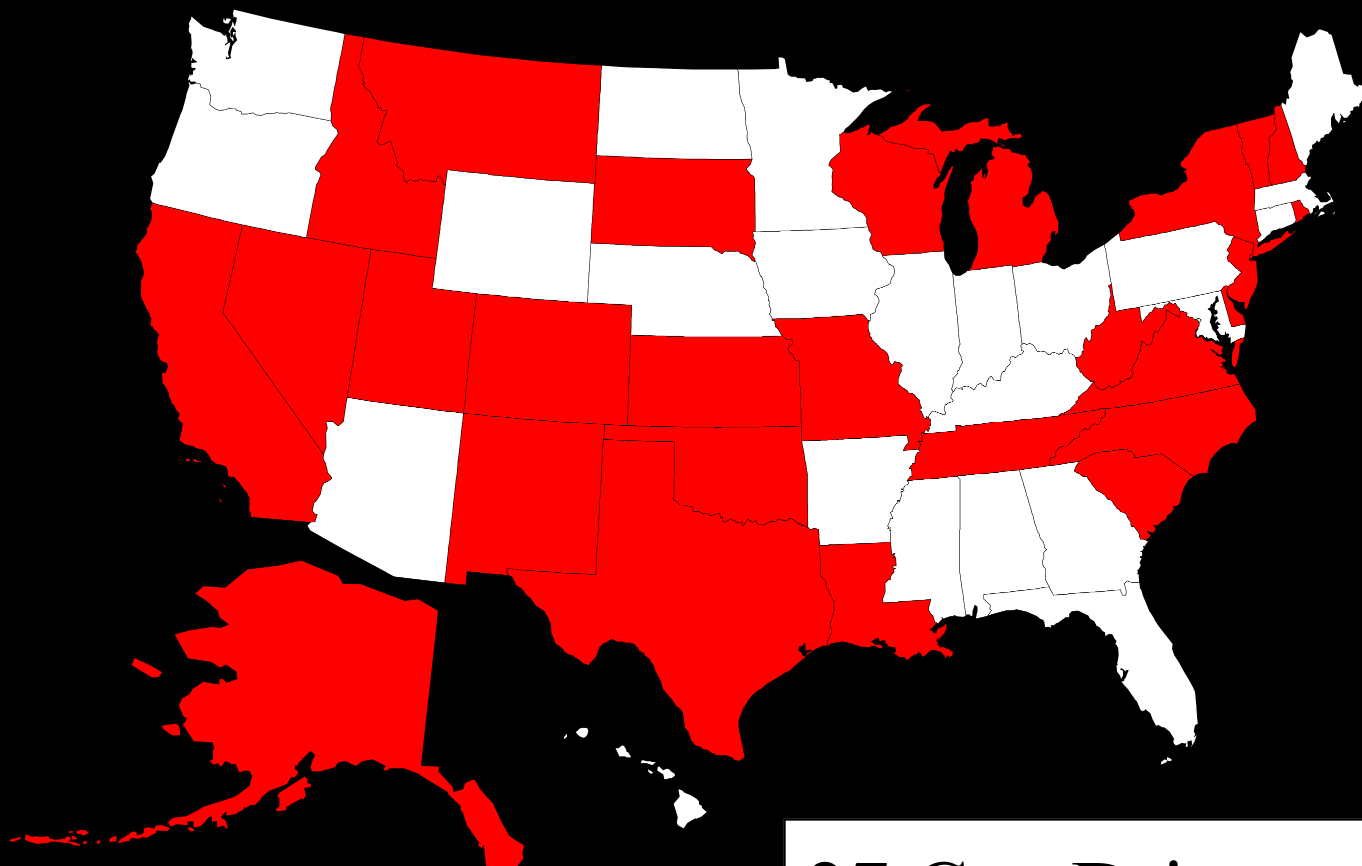
- About 5 million stroke survivors in Unites States*
- 30-45% of those have Hemianopia **

* 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

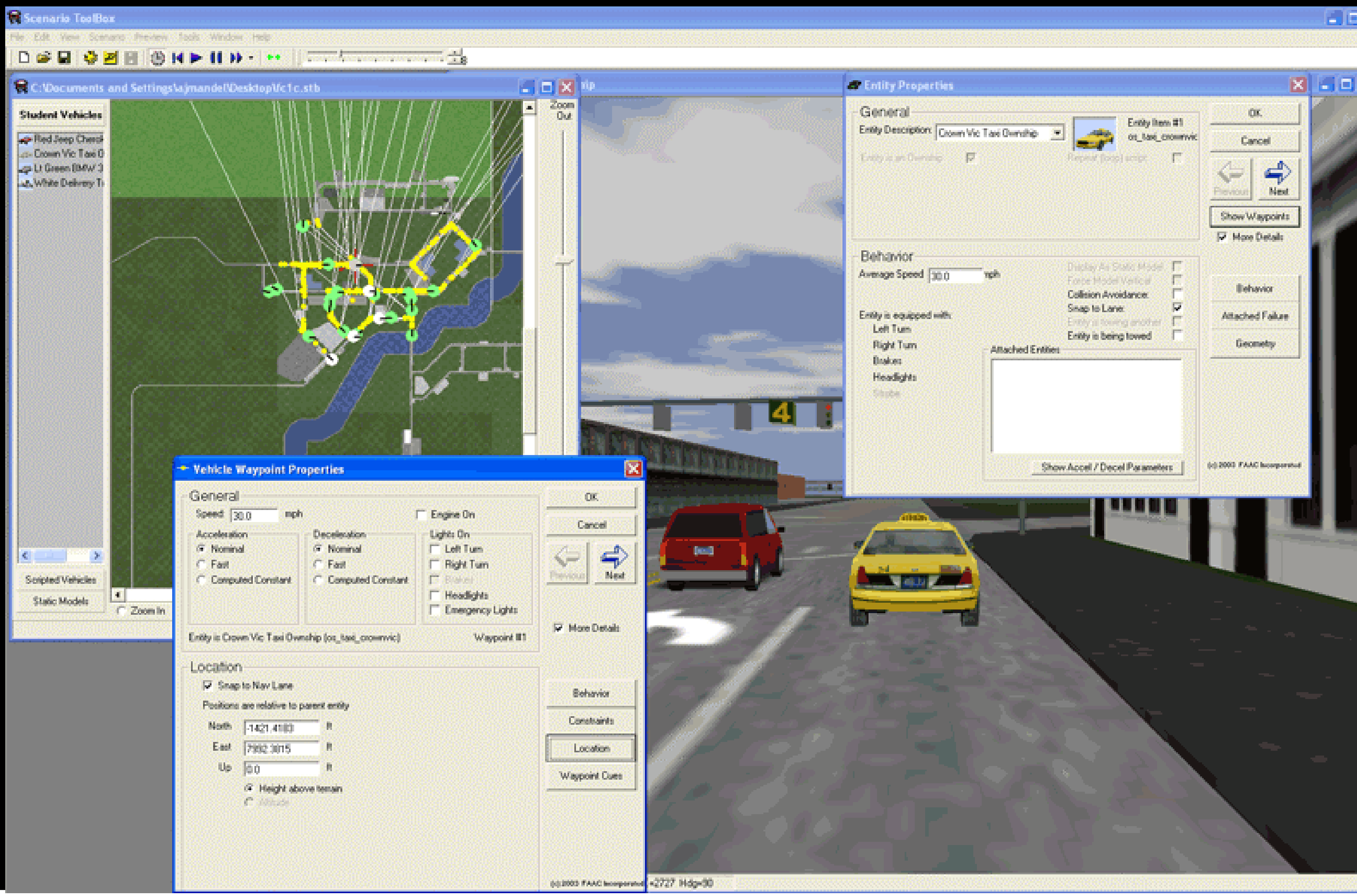
Driving With Hemianopia + Visual Aids?

- 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

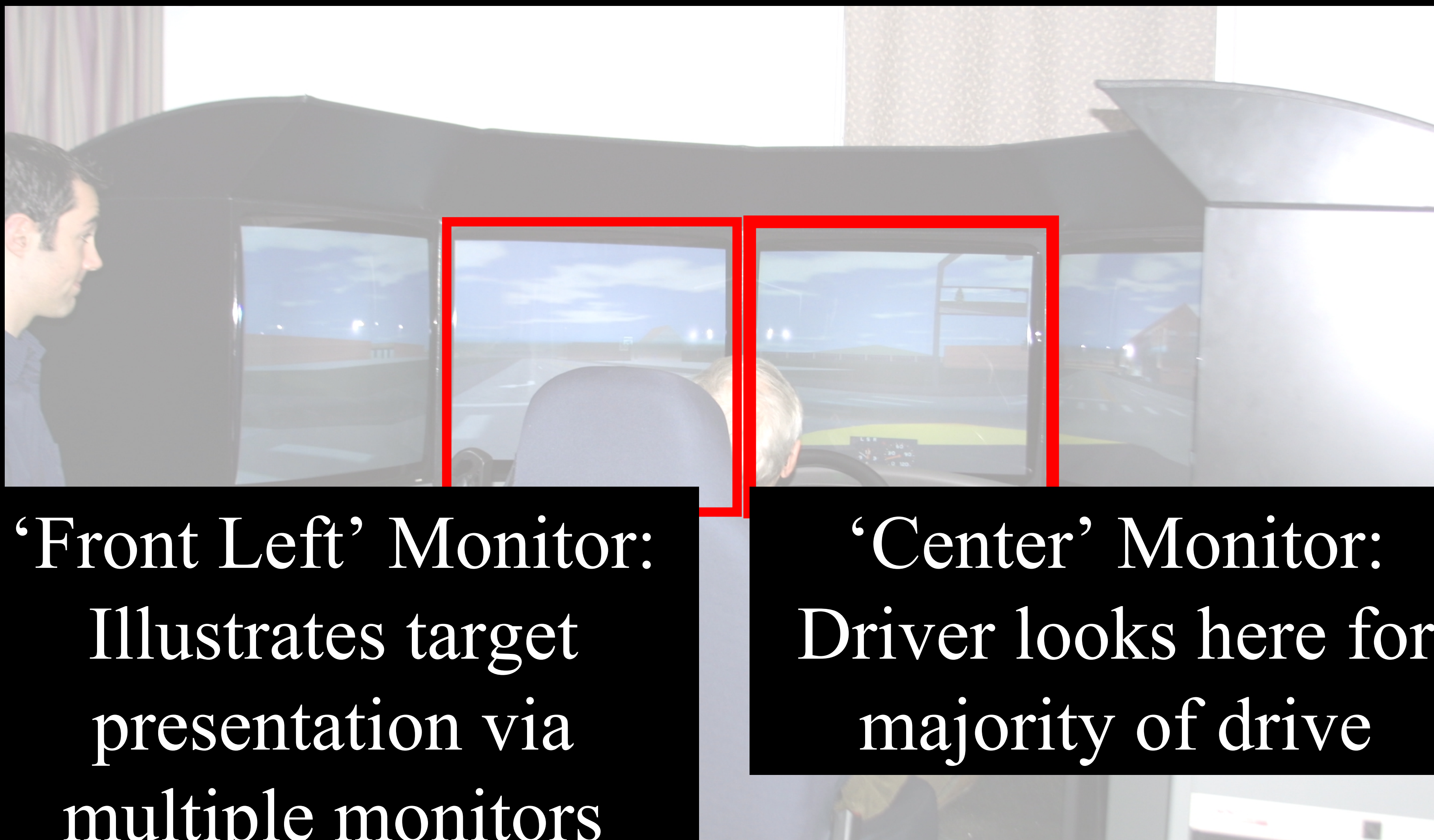
- Low & High (30 & 60 mph) posted speed limits
- 5 scenarios per test
  (high/low speed, scripted traffic)
- 12-14 targets appear per scenario
- Approximately 30 minutes of driving

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…**

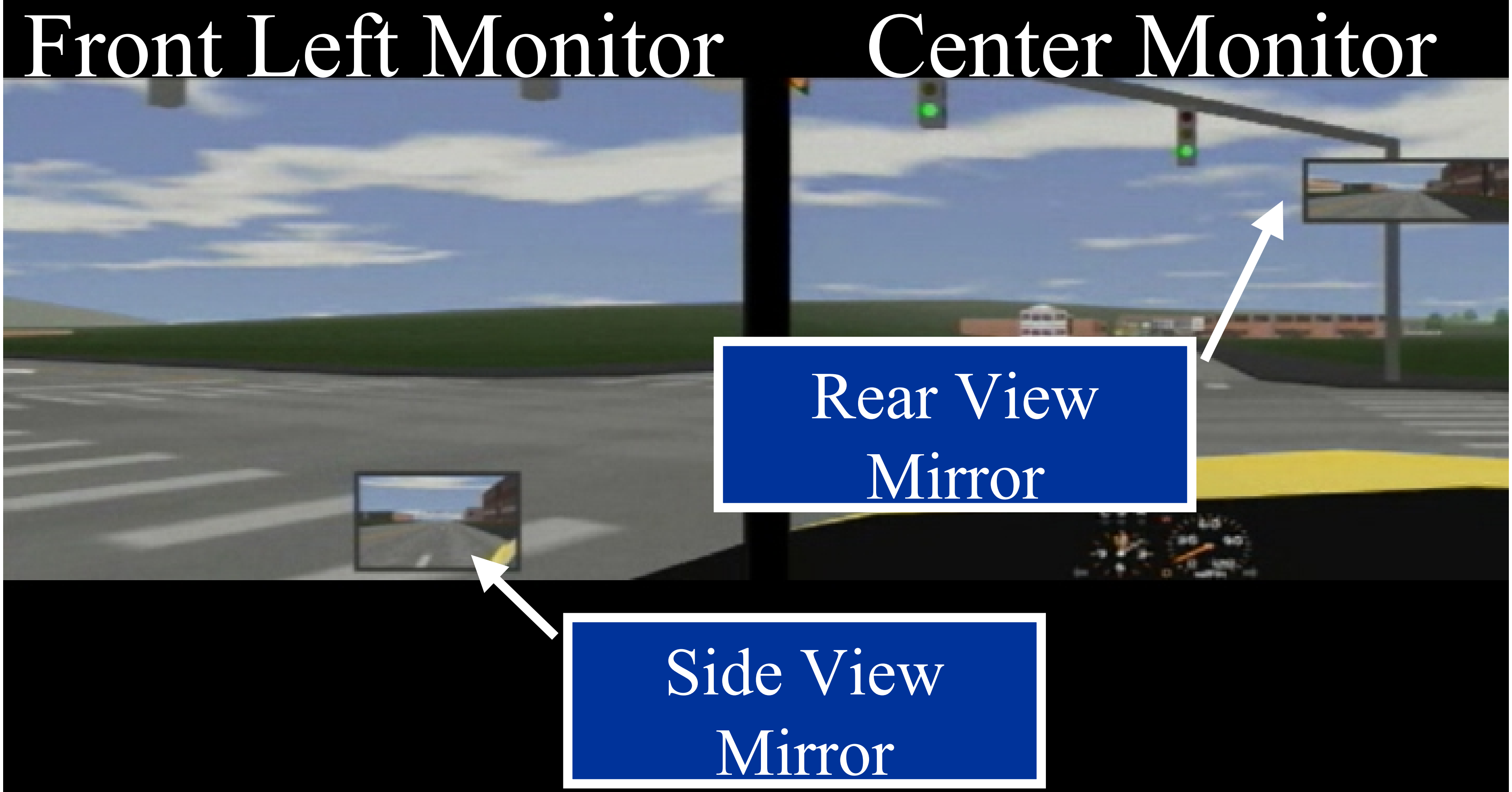
Video Examples



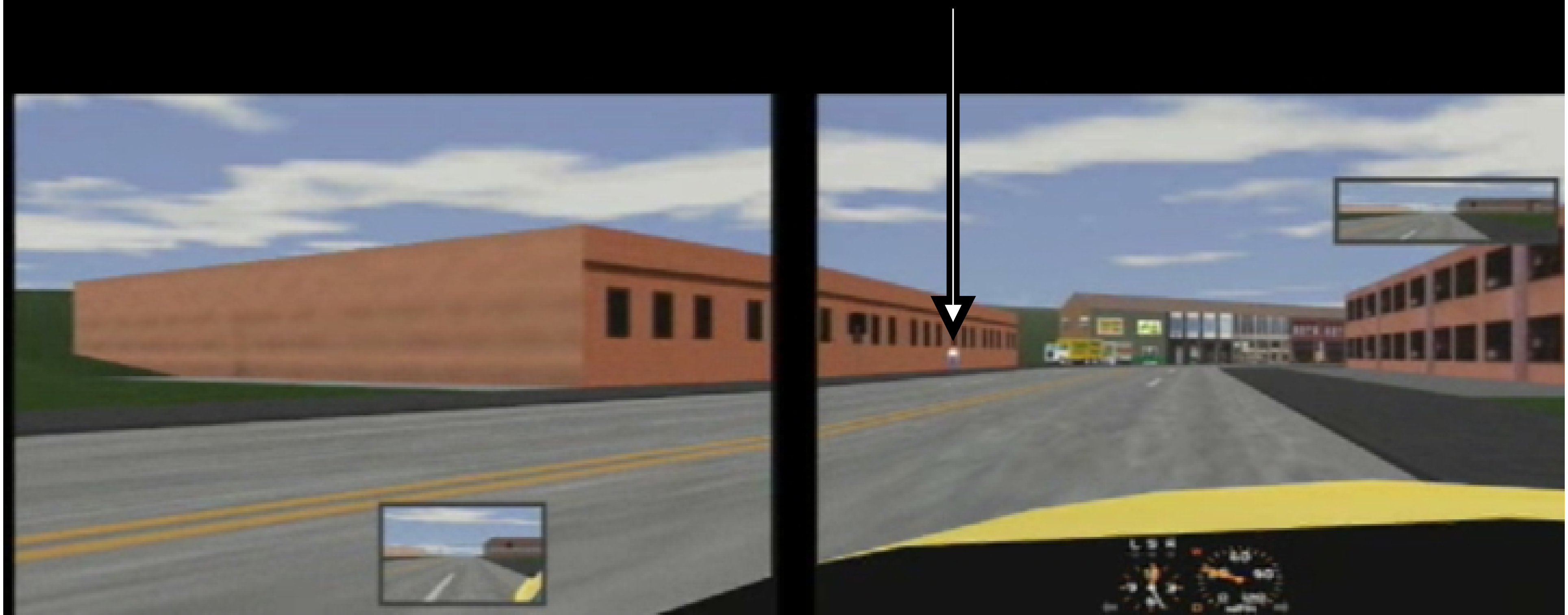
‘Front Left’ Monitor: Illustrates target presentation via multiple monitors

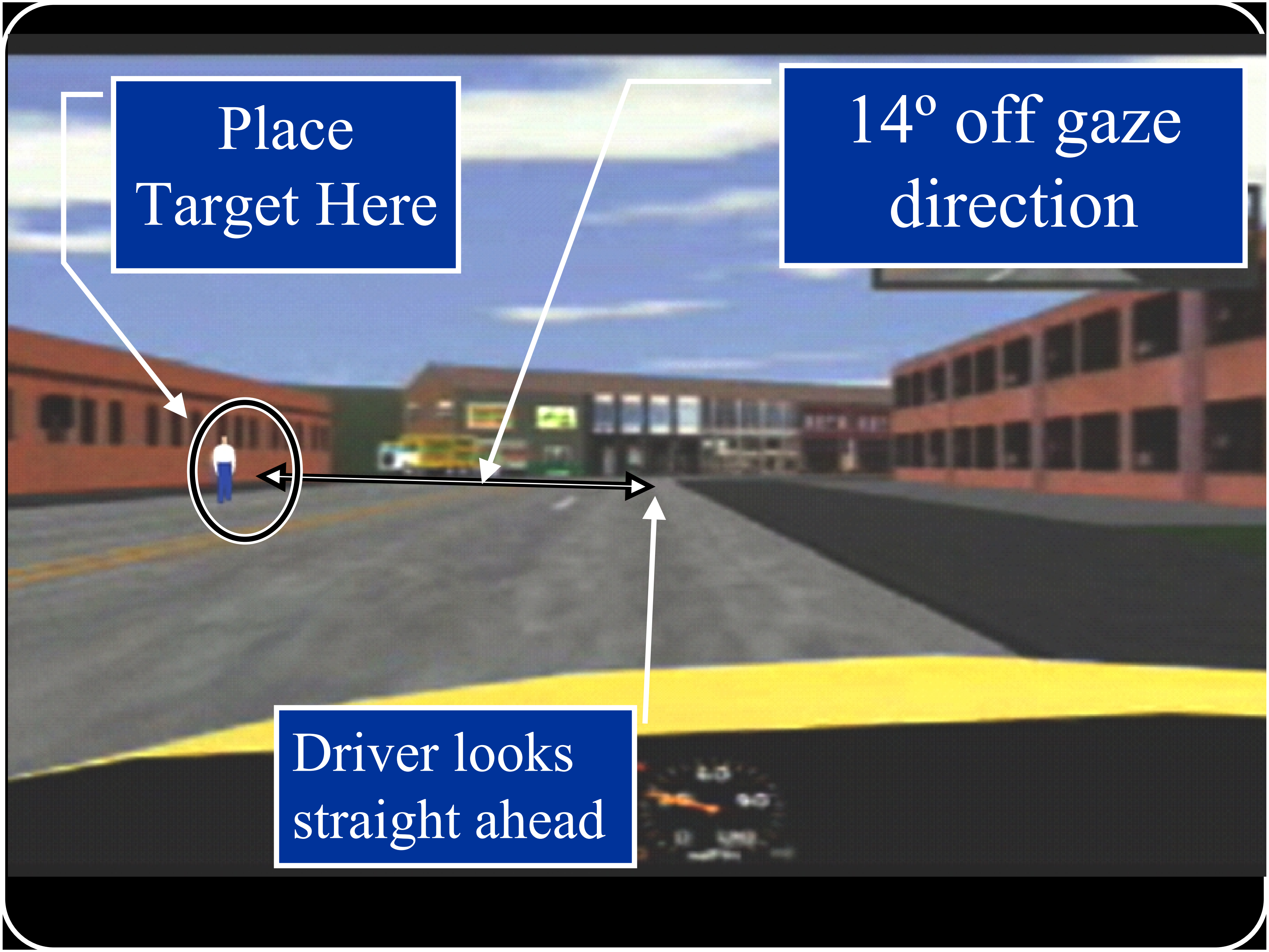
‘Center’ Monitor: Driver looks here for majority of drive

Target Appearance



Target Location at Instant of Target Appearance

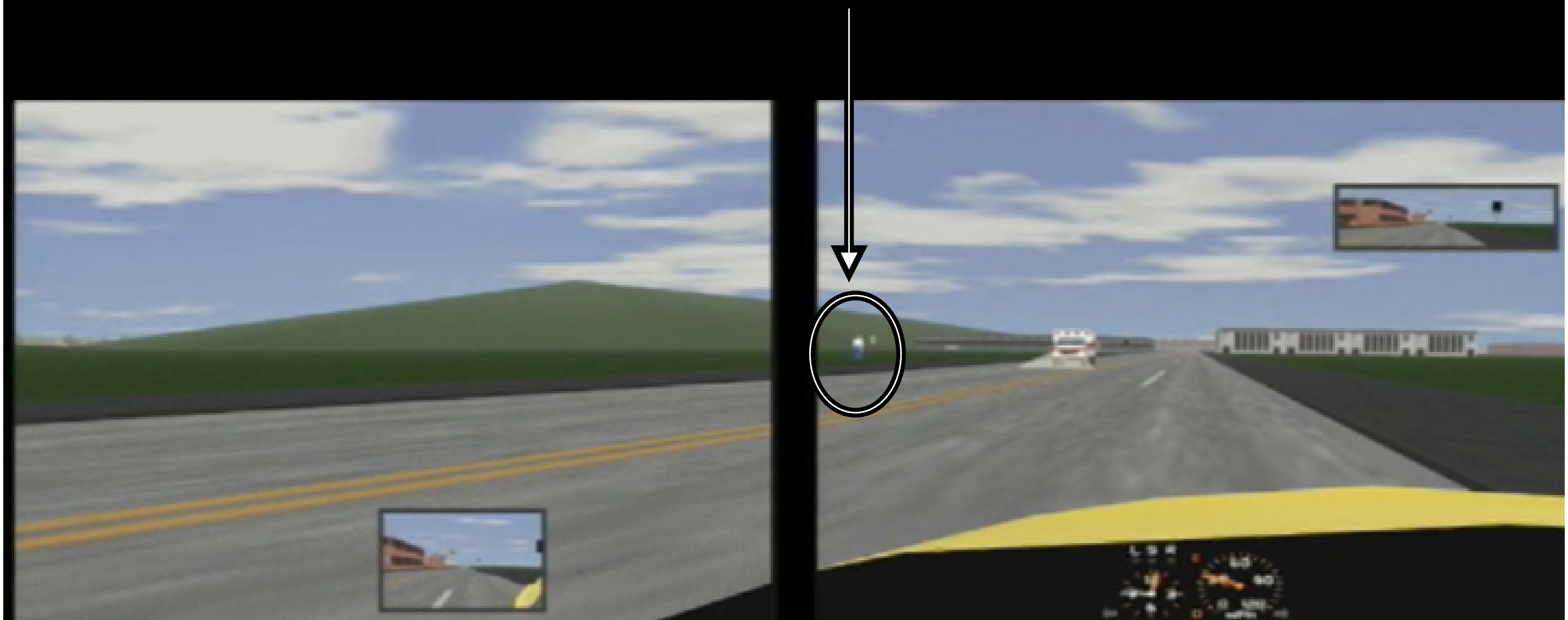




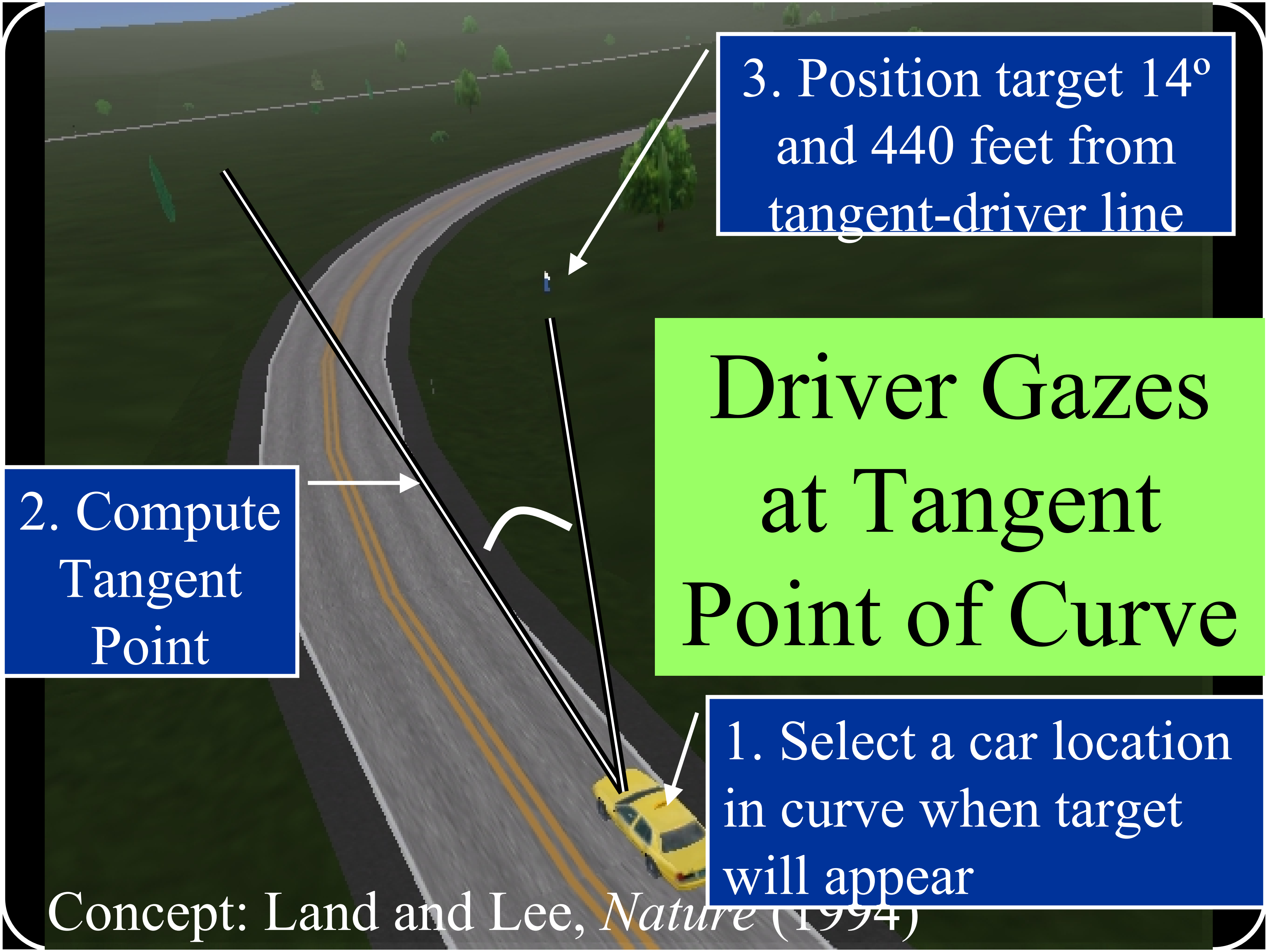
Place Target Here
14º off gaze direction
Driver looks straight ahead

Predict Fixation More Accurately with 'Attention-Getter'

Target Location at Instant of Target Appearance




L S R

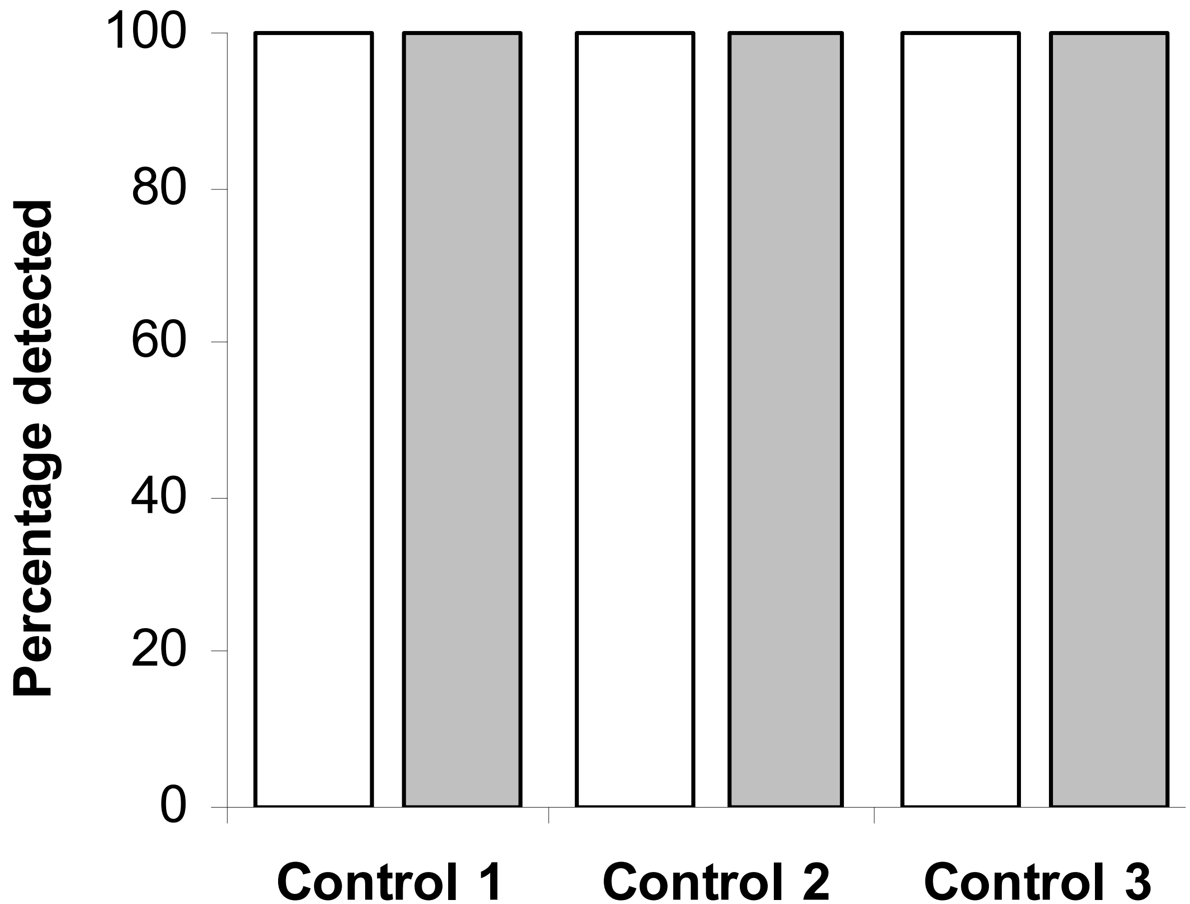

3. Position target 14º and 440 feet from tangent-driver line
Driver Gazes at Tangent Point of Curve
2. Compute Tangent Point
1. Select a car location in curve when target will appear
Concept: Land and Lee, *Nature* (1994)

First Pilot Study

Two drivers with Left Hemianopia (missing the left visual field)

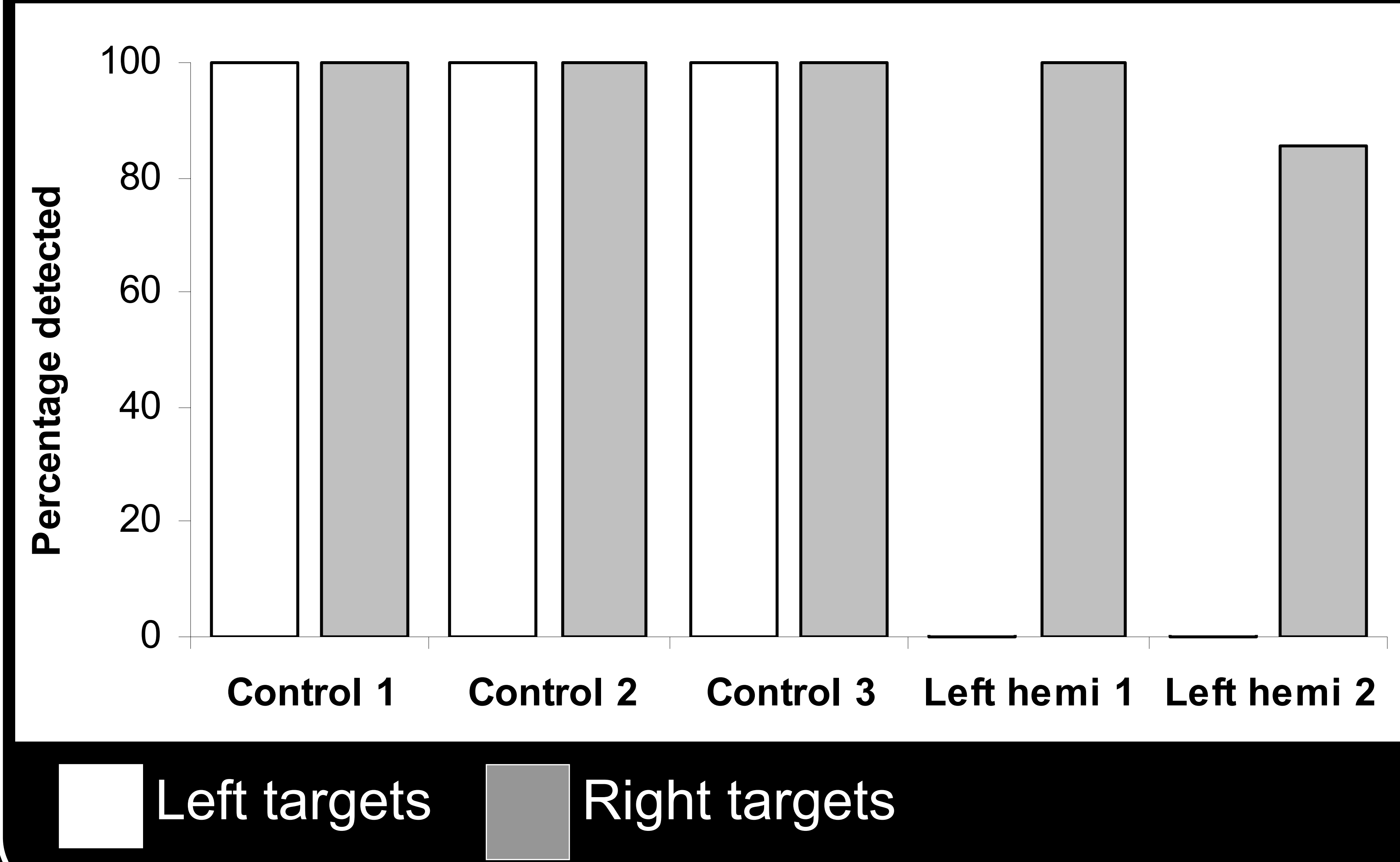
Three drivers with normal visual field

Percentage of Targets Detected

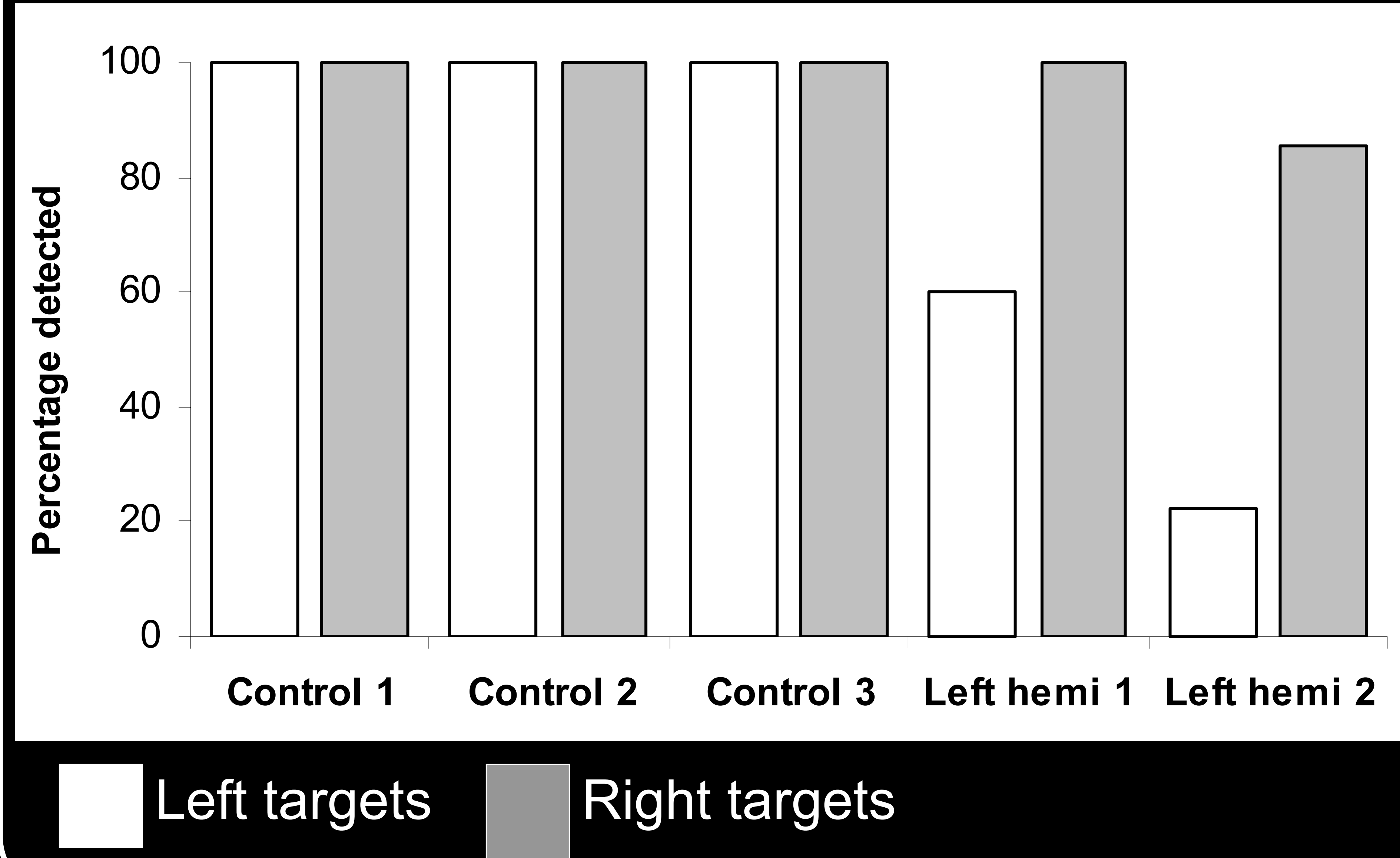


Left targets
Right targets

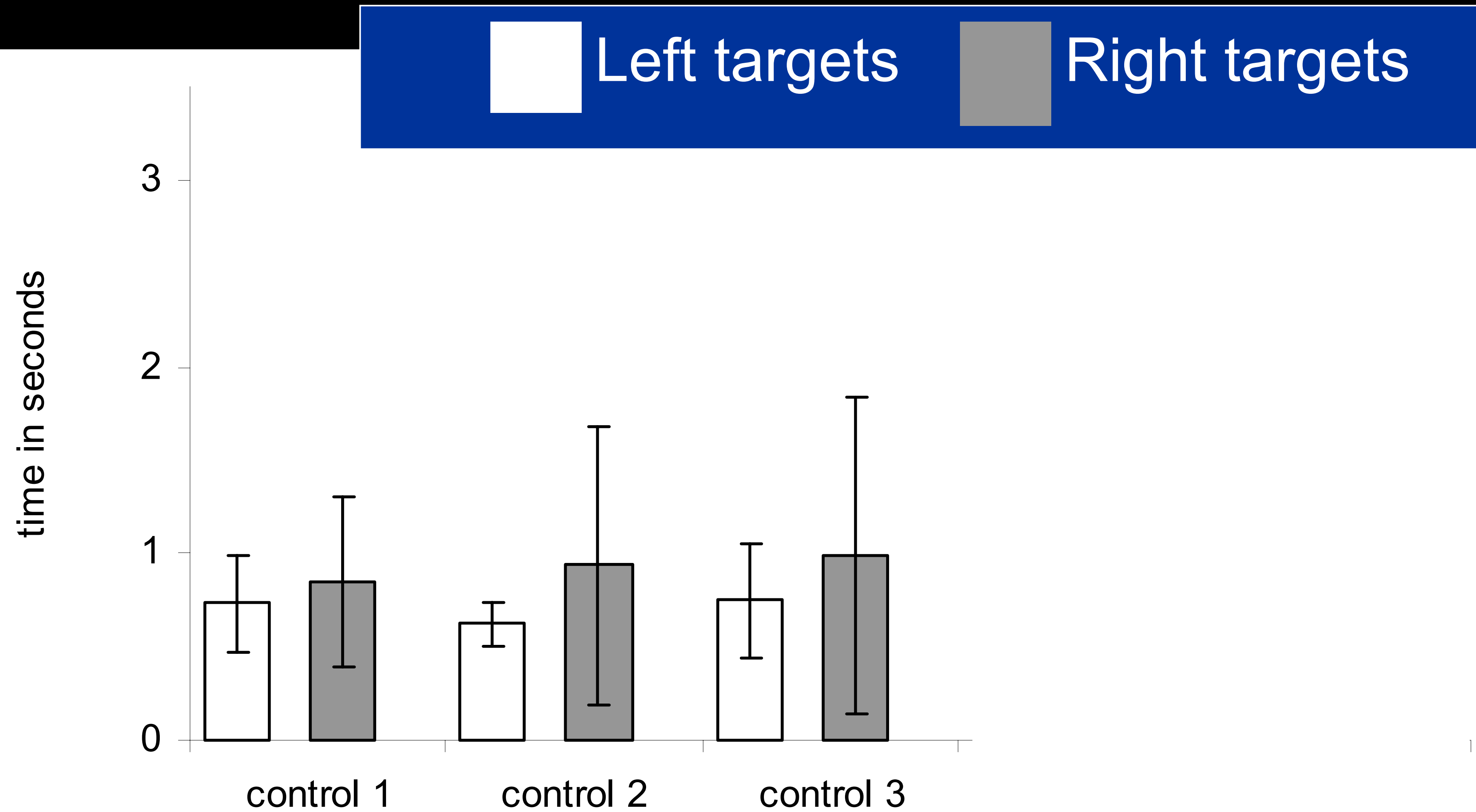
Percentage of Targets Detected



Percentage of Targets Detected



Mean Response Times



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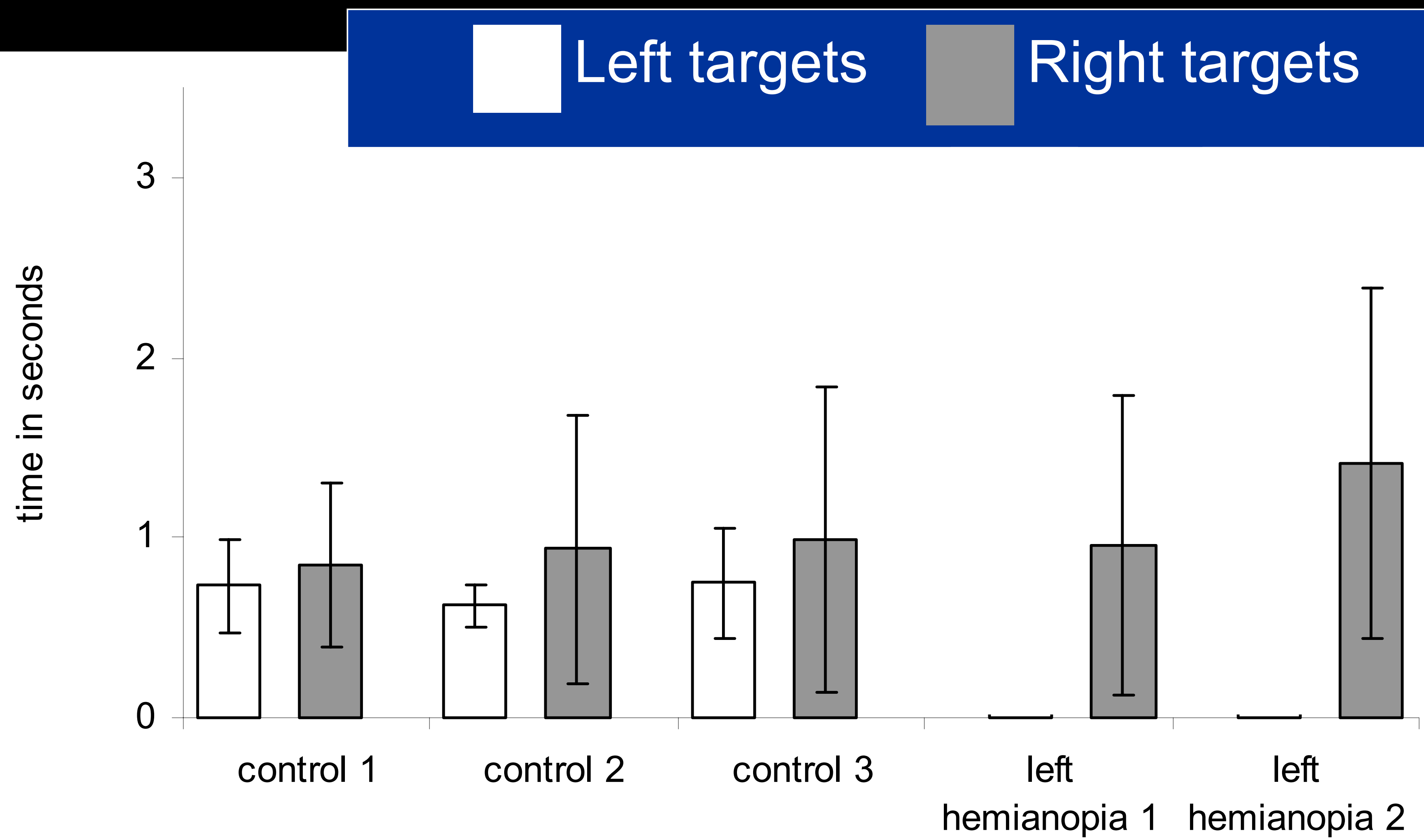

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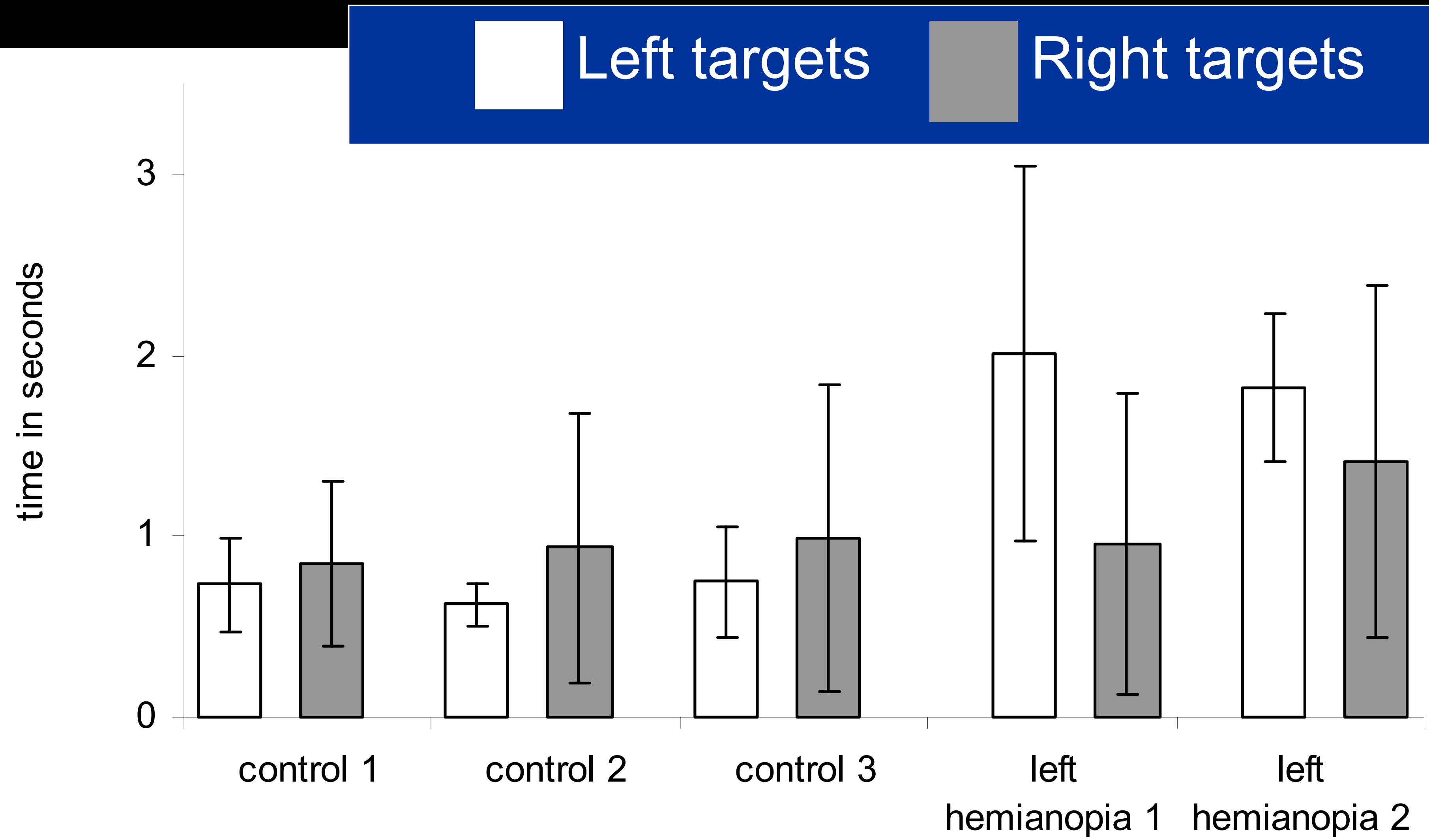
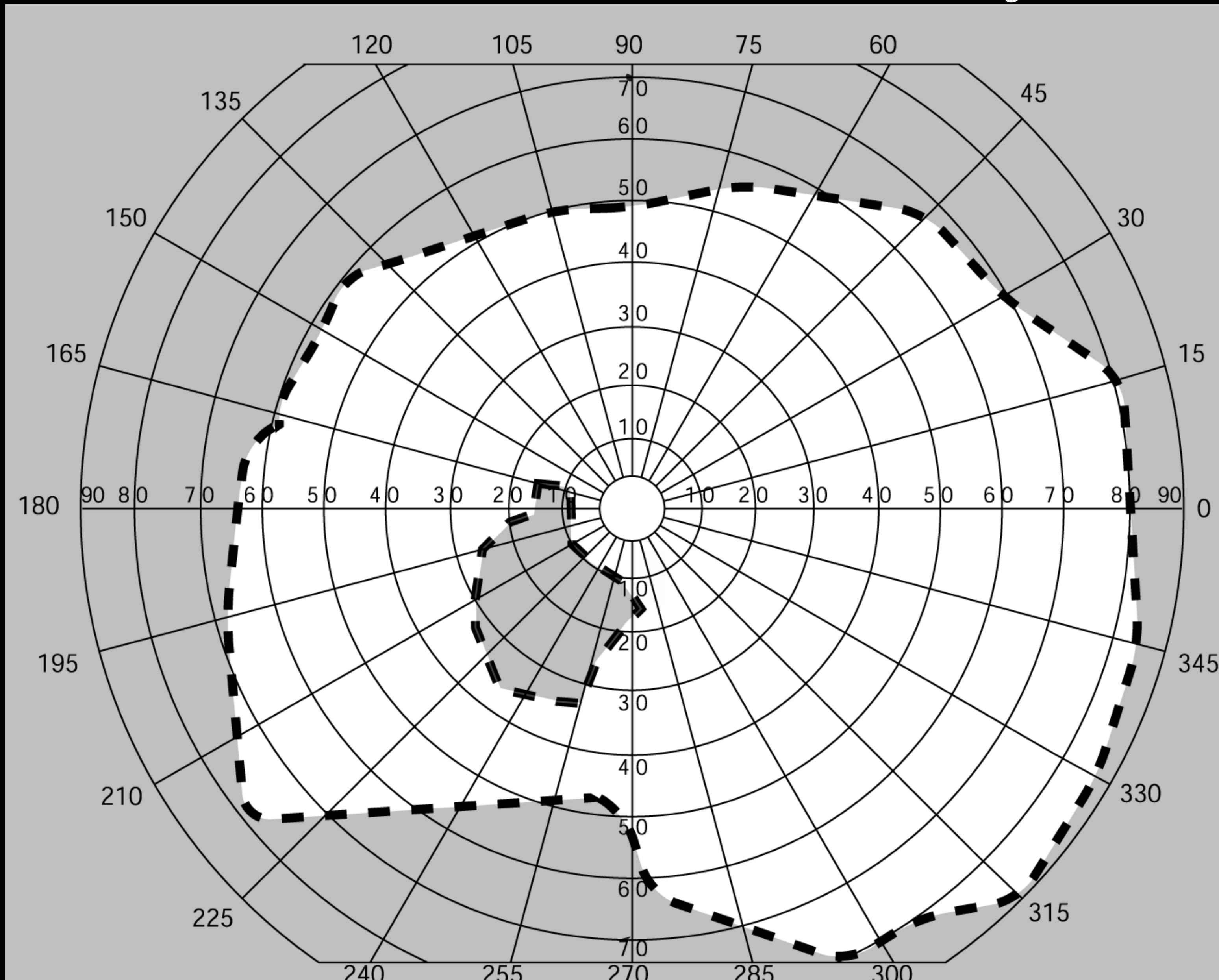
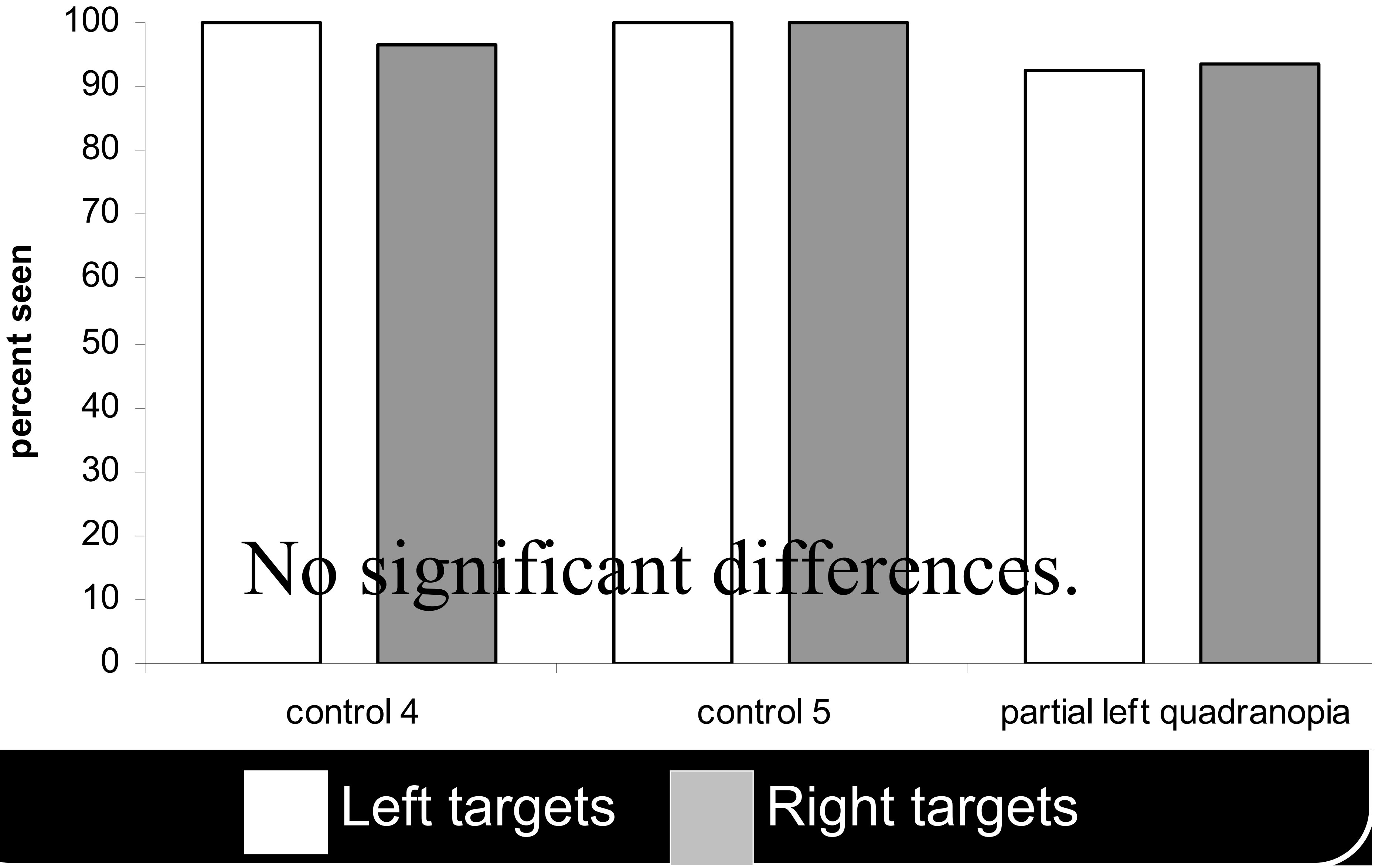


$F(1,155) = 8.5, P=.005$

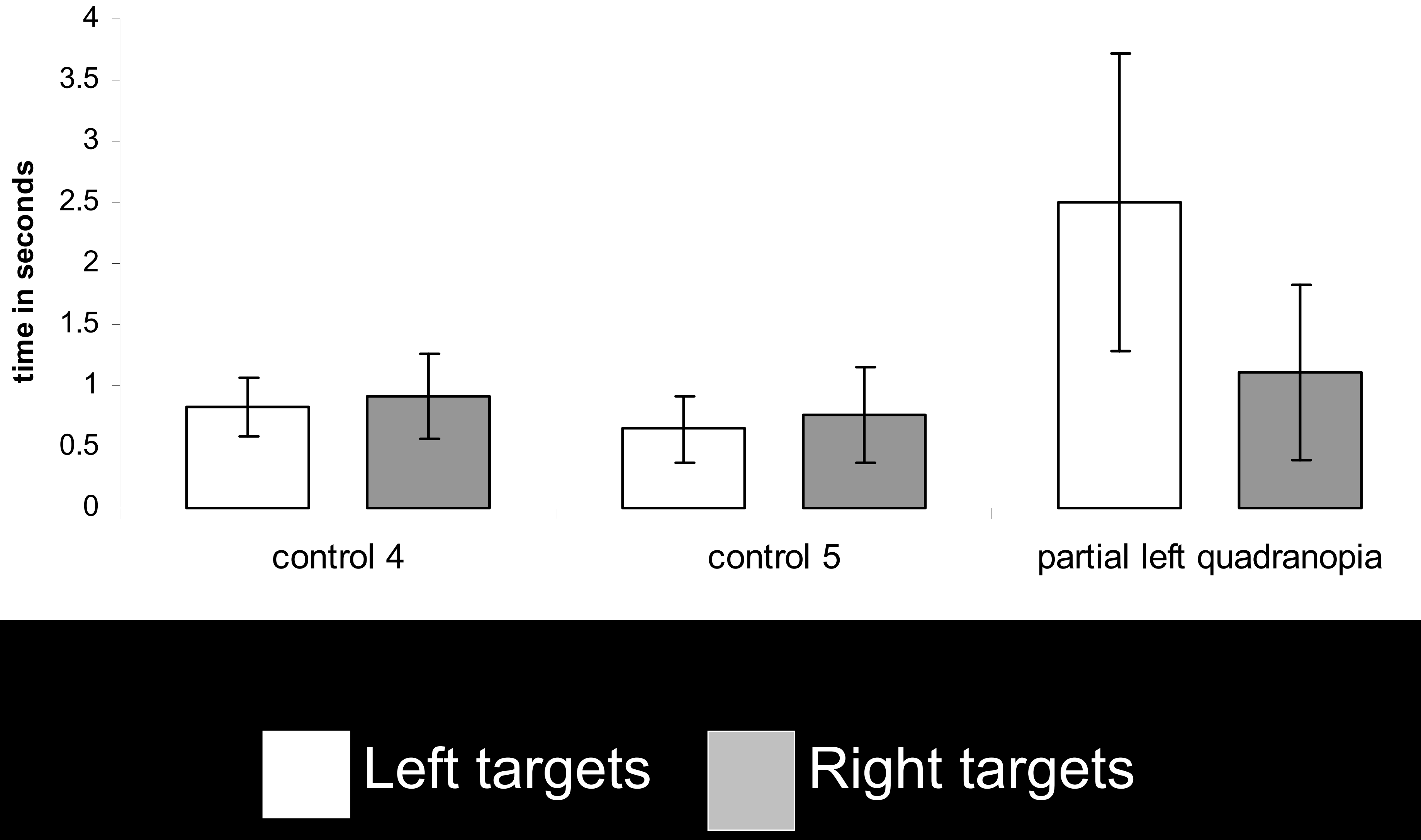
Second Pilot Study



Percentage of Targets Detected



Mean Reaction Times



Pilot Study Outcomes

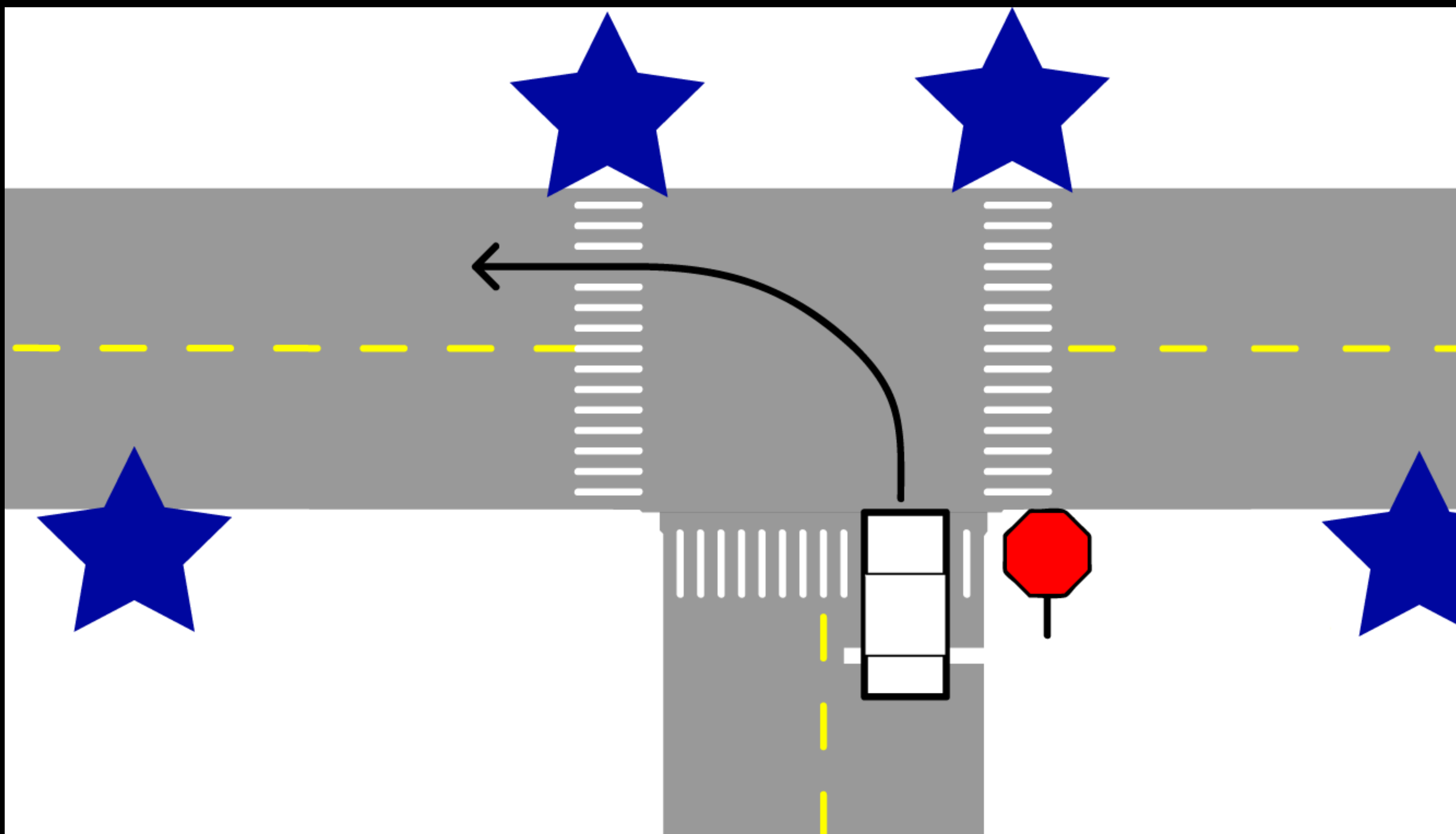
1. Complete hemianopia miss significantly more targets on blind side than seeing side or controls
2. When detected, response times are significantly greater
3. Partial hemianopia still shows difference (in reaction times, not % detected)

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

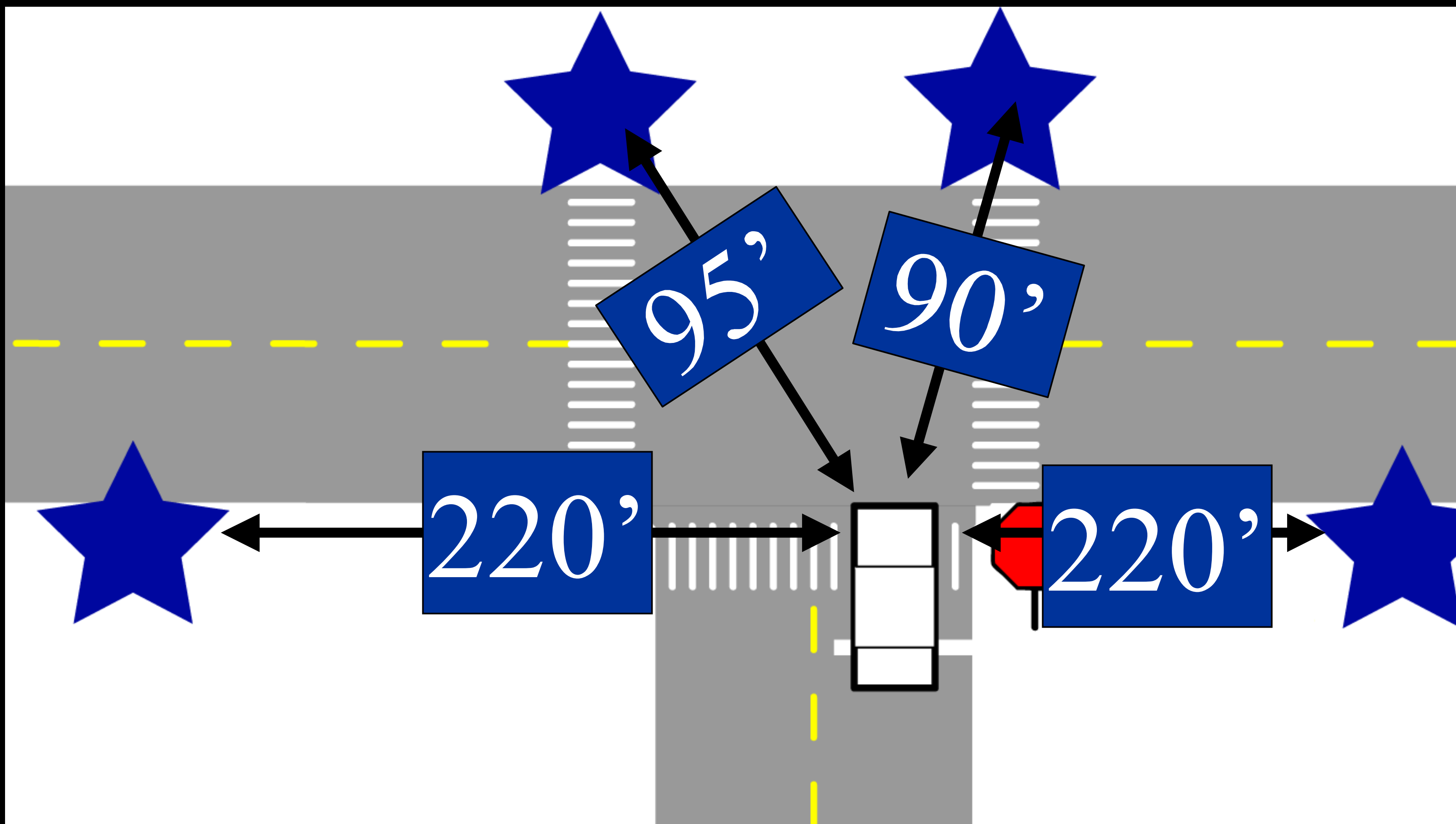
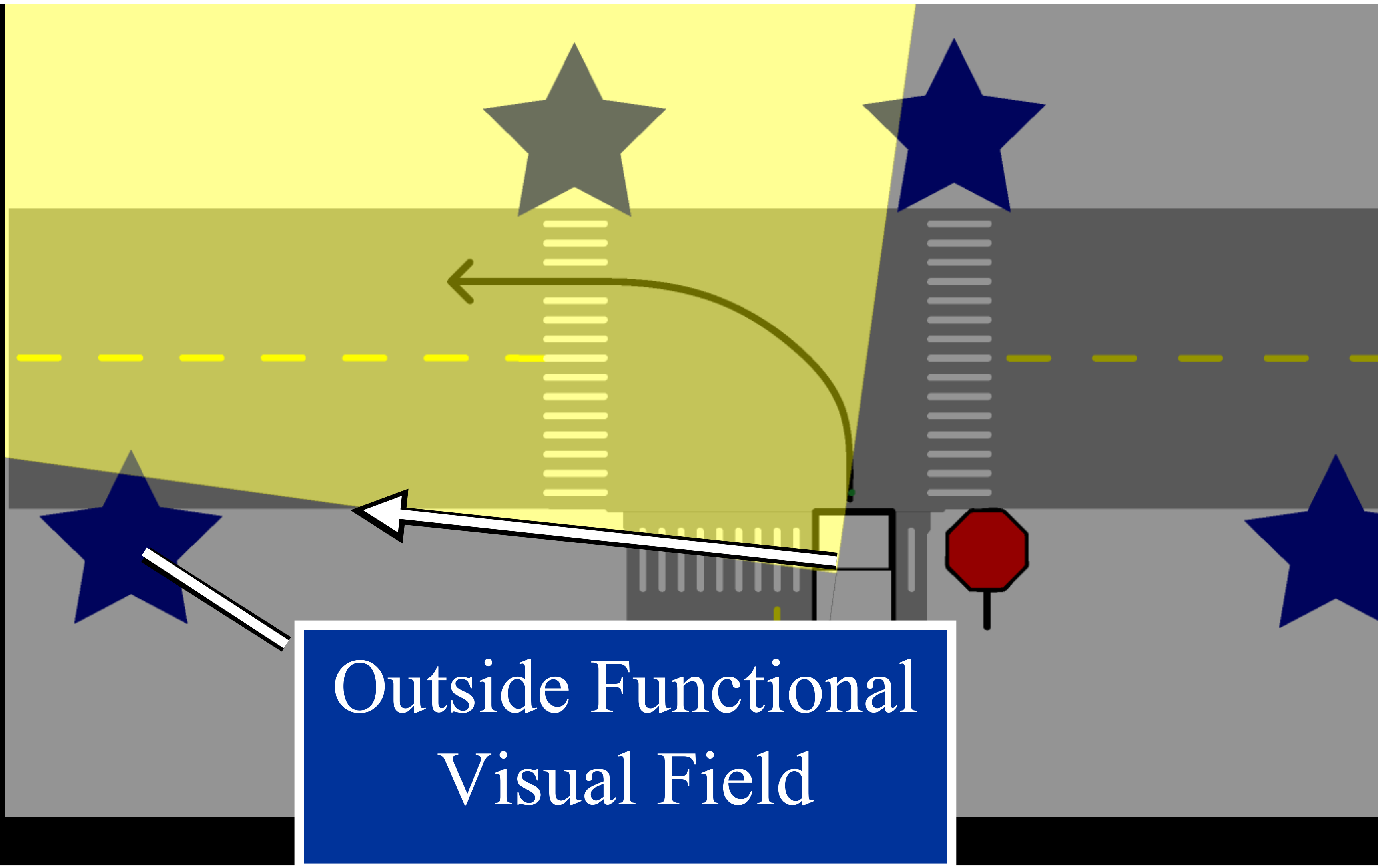
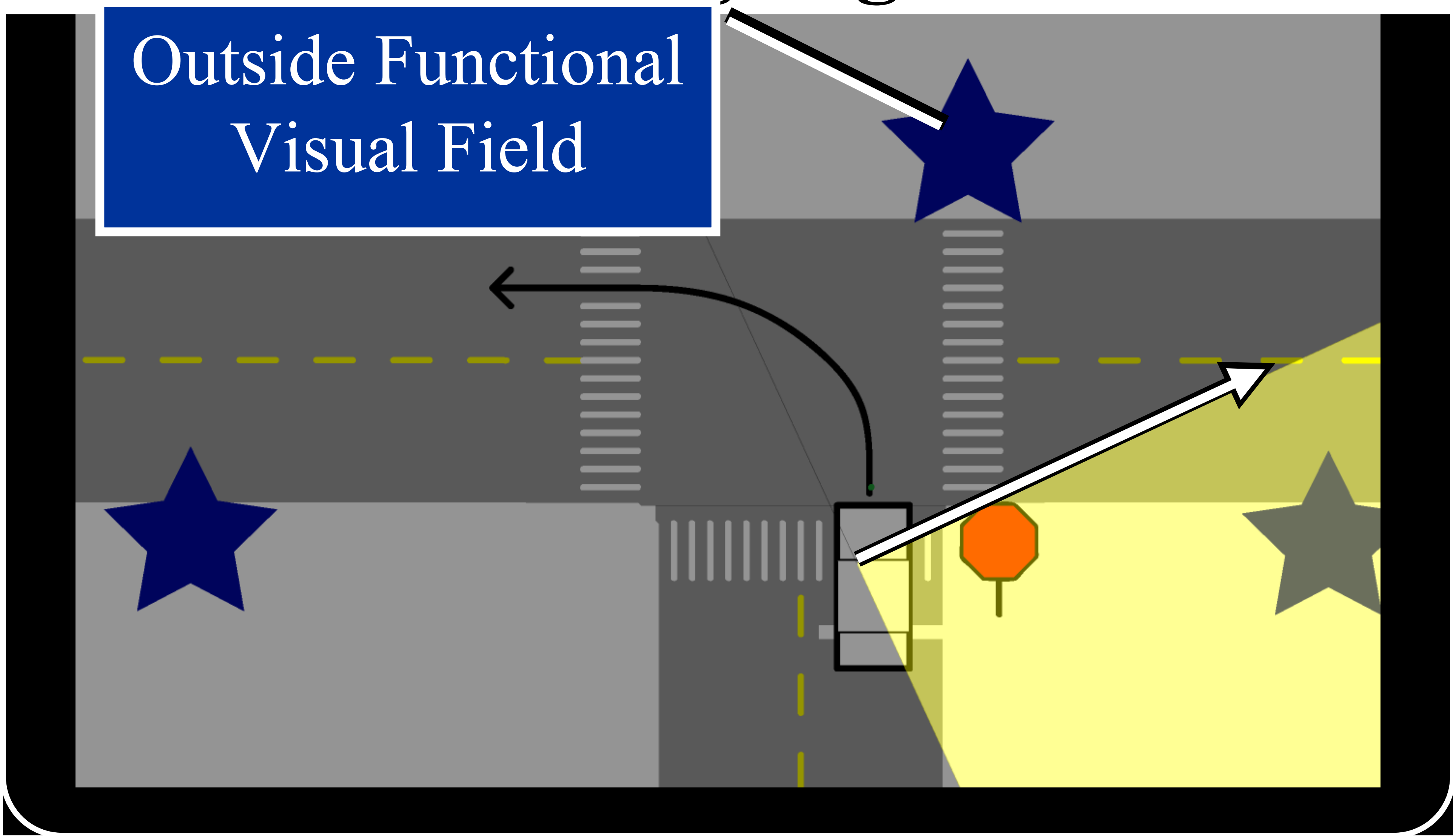


Illustration Not to Scale

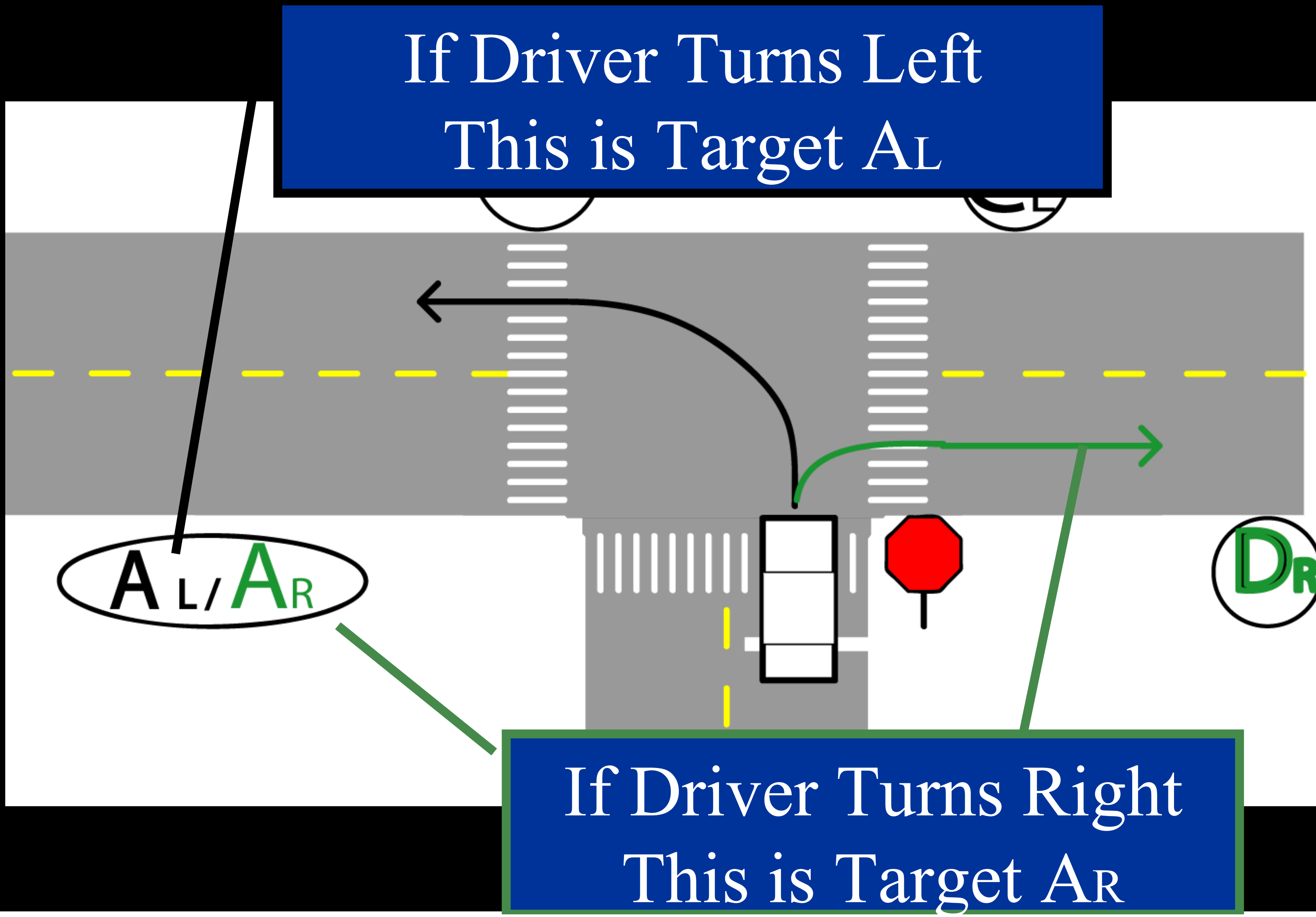
Left Hemianopic Driver Turning Left and Looking Left for Traffic



Left Hemianopic Driver Turning Left and Looking Right for Traffic



Labeled T-intersection Targets



Controls at T-Intersections

	AR	AL	BL	CL	DR
Control1	Miss	Seen	Seen	Seen	Seen
Control2	Seen	Seen	Seen	Seen	Seen
Control3	Seen	Seen	Seen	Seen	Seen

Hemianopes at Intersections

Field Loss	AR	AL	BL	CL	DR
Troublesome for…	Left	Left	Right +Left	Right +Left	Right

L. Hemianopes at Intersections

Field Loss	AR	AL	BL	CL	DR
L Partial Quad.	Seen	Miss	Miss	Seen	Seen
Left Hemi.	Miss	Miss	Seen	Seen	Miss
Troublesome for…	Left	Left	Right +Left	Right +Left	Right

Accuracy of Our Predictions

Visual Field	AR	AL	BL	CL	DR
L Partial Hemi.	Seen	Miss	Miss	Seen	Seen
Left Hemi.	Miss	Miss	Seen	Seen	Miss
Troublesome for…	Left	Left	Right +Left	Right +Left	Right

Hemianopes at Intersections

Field Loss	AR	AL	BL	CL	DR
L Partial Quad.	Seen	Miss	Miss	Seen	Seen
Left Hemi.	Miss	Miss	Seen	Seen	Miss
Right Hemi.	Miss	Seen	Seen	Miss	Miss
Right Hemi.	Seen	Seen	Seen	Seen	Miss
Right Hemi.	N/A	Seen	Seen	Seen	Miss
Troublesome for…	Left	Left	Right +Left	Right +Left	Right

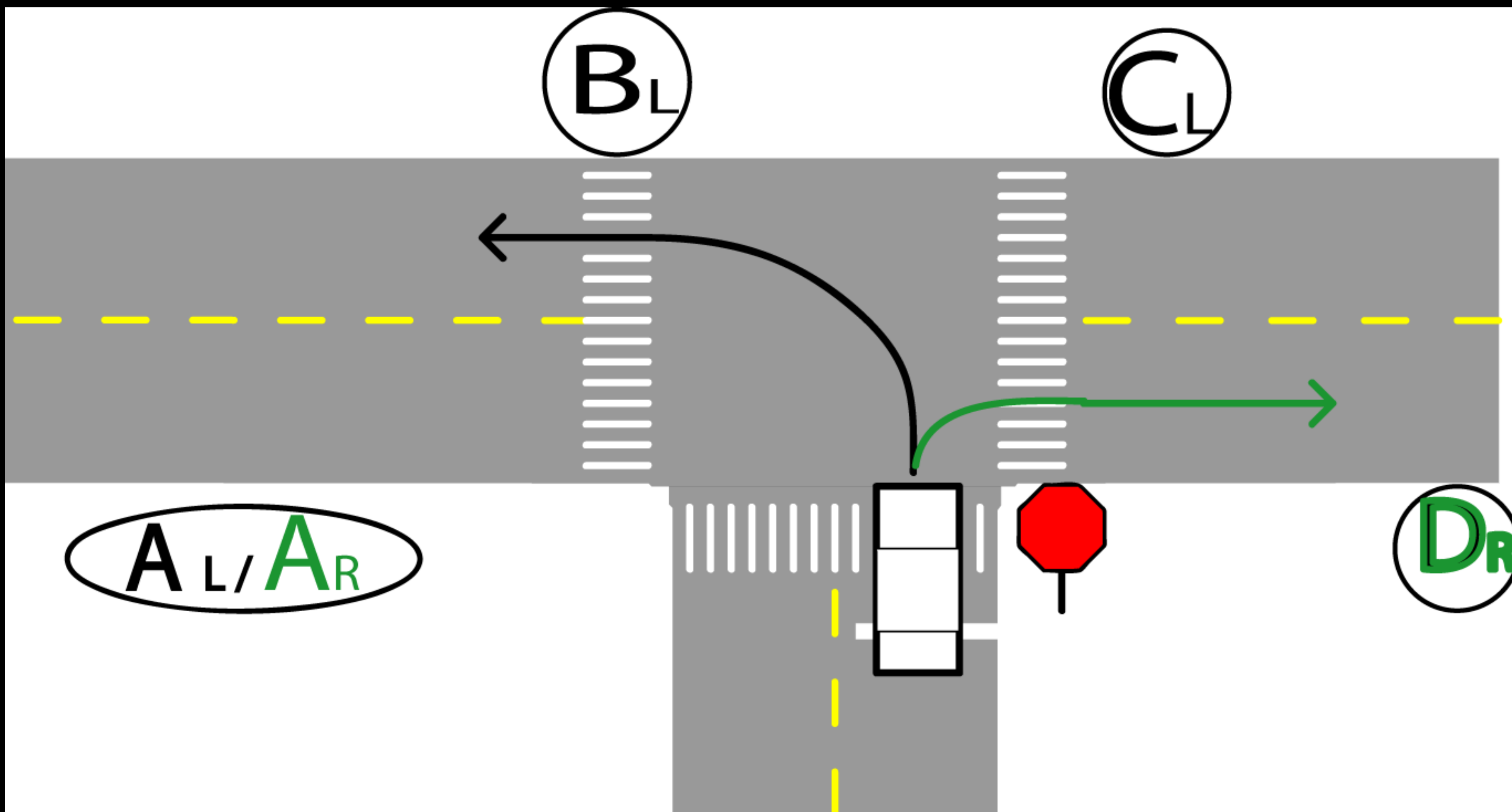
Hemianopes at Intersections

Visual Field	AR	AL	BL	CL	DR
L Partial Hemi.	Seen	Miss	Miss	Seen	Seen
Right Hemi.	Miss	Seen	Seen	Miss	Miss
Right Hemi.	Seen	Seen	Seen	Seen	Miss
Right Hemi.	N/A	Seen	Seen	Seen	Miss
Left Hemi.	Miss	Miss	Seen	Seen	Miss
Troublesome for…	Left	Left	Right +Left	Right +Left	Right

Accuracy of Our Predictions

Visual Field	AR	AL	BL	CL	DR
L Partial Hemi.	Seen	Miss	Miss	Seen	Seen
Left Hemi.	Miss	Miss	Seen	Seen	Miss
Right Hemi.	Miss	Seen	Seen	Miss	Miss
Right Hemi.	Seen	Seen	Seen	Seen	Miss
Right Hemi.	N/A	Seen	Seen	Seen	Miss
Accuracy of Prediction	50%	100%	20%	20%	80%

Labeled T-intersection Targets



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

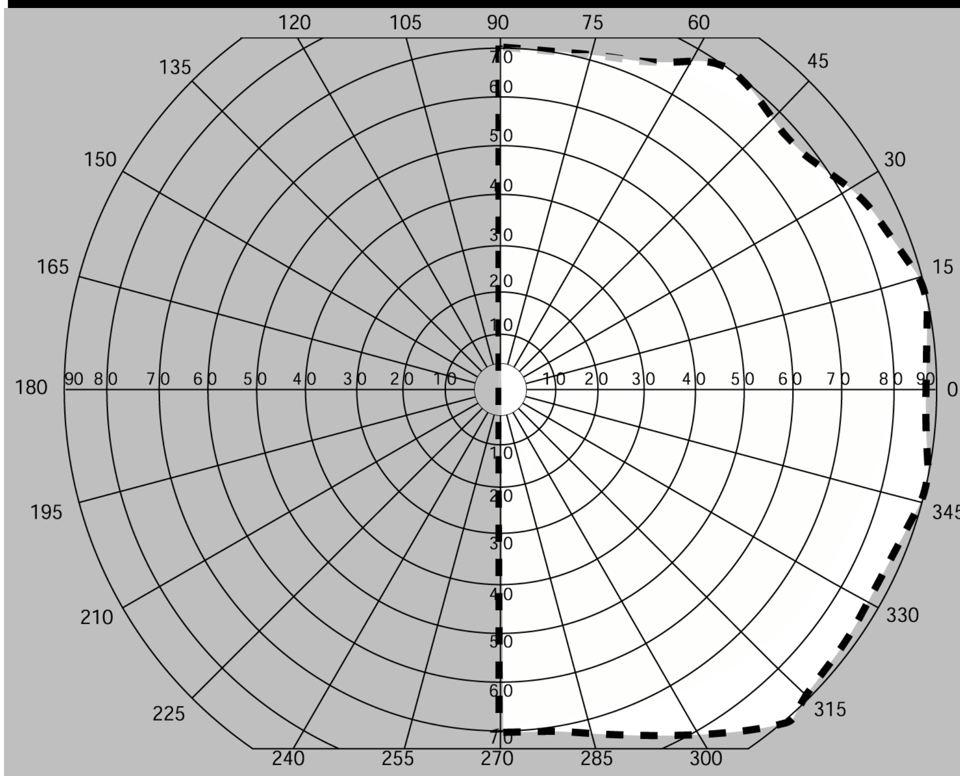
The Study (In Progress)

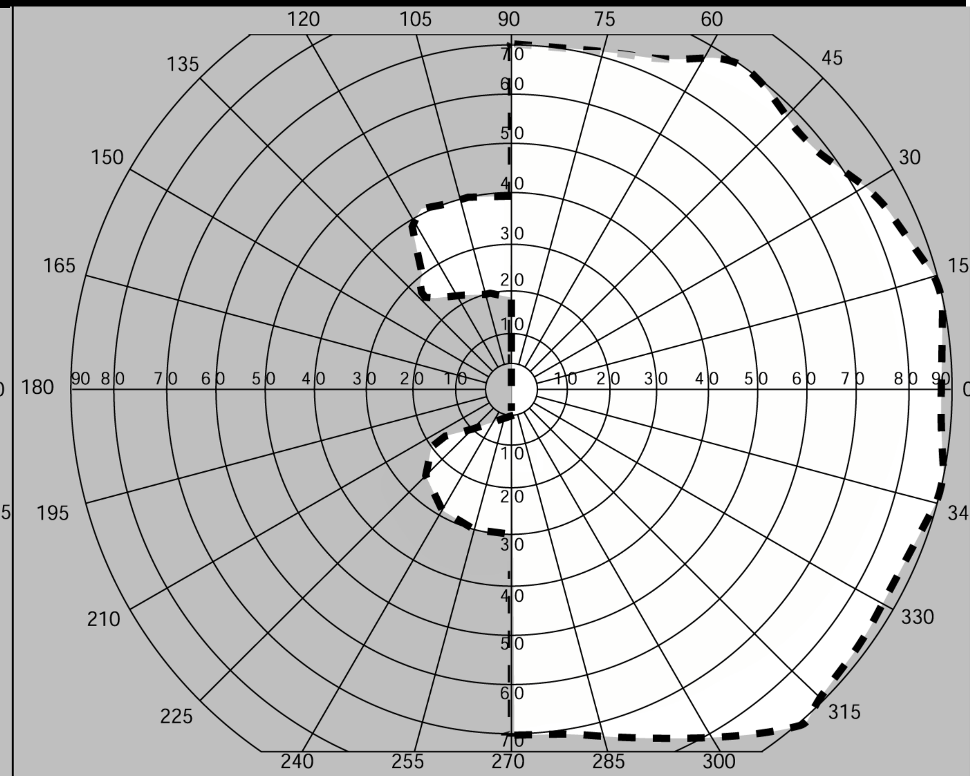
Peripheral Prisms: a visual aid for hemianopic visual field loss

Peripheral Prisms

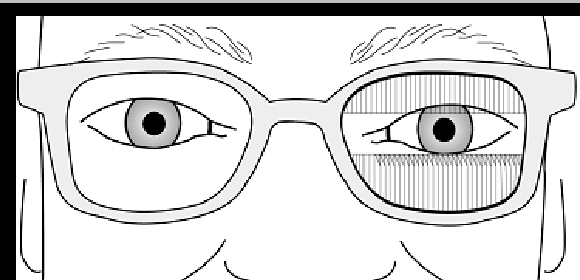
Without

With





Left Hemianopia



Thank You

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