SCARS 2017

J. Muttart

RESULTS OF WREX HUMAN FACTORS RESEARCH

Studies

- 1. Nighttime recognition while accounting for expectancy with a timed exposure technique
- 2. Eye tracking
  - Lane changes
  - Intersection glancing by trckers and passenger car drivers
  - Nighttime recognition
- 3. Recognition of closing and closing speed when approaching a slower moving vehicle ahead

SAE 2017-01-1366

TIMED EXPOSURE TECHNIQUE


Nighttime Recognition
Timed Exposure Methodology
SHRP-2 Responses

Nighttime Crashes

- An average of 4868 pedestrian fatalities between 2011-2015
  - In 2015- 74% of these crashes occurred in the dark
- An average of 742 Bicyclist fatalities between 2011-2015
  - In 2015- 47% of these crashes occurred in the dark

–These numbers **Increased** by 9.5% and 12.2% from 2014

•(Fatality Analysis Reporting System, FARS, 2016)

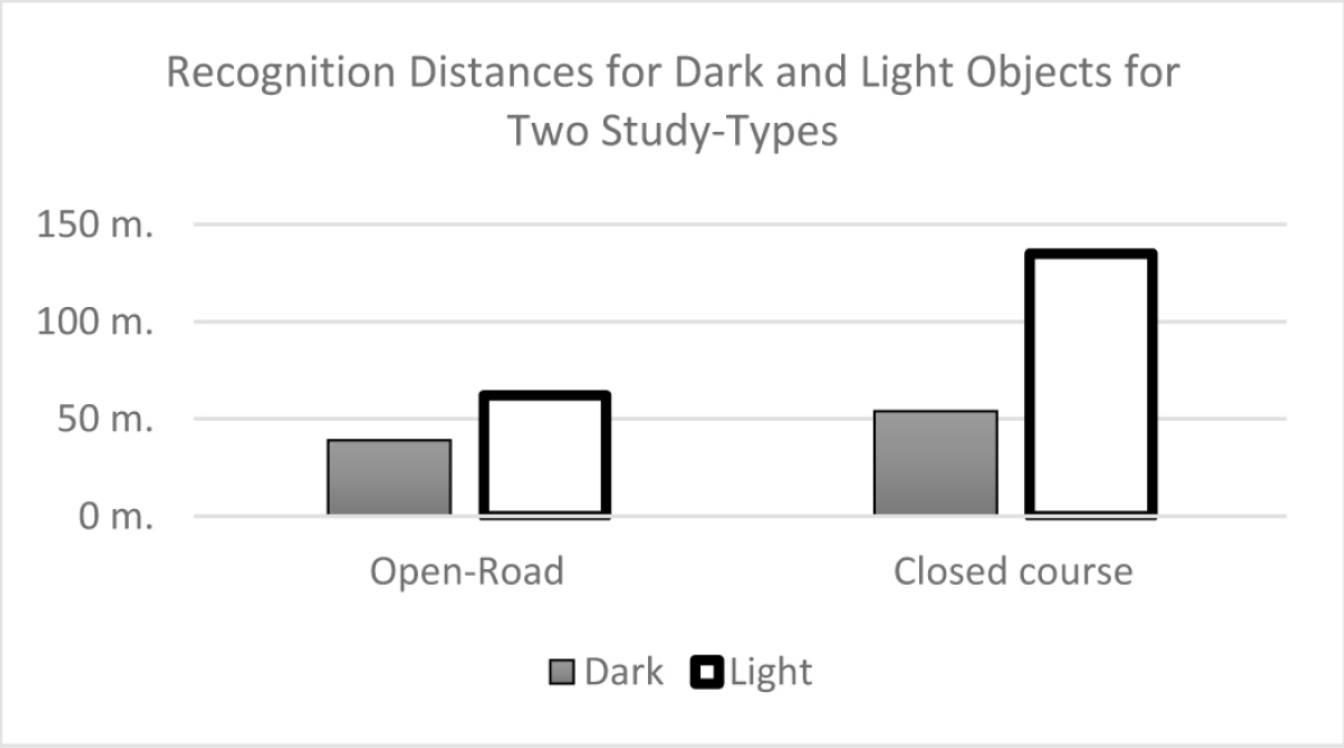
Why is this Research Necessary?

- Measure night recognition in a safe manner
- Limiting driver bias that we know is inherent in test track research
- To Determine what is reasonable when a driver strikes a pedestrian at night

Nighttime Recognition Studies

- Laboratory Studies
  - Limited Exposure- Blackwell (1959)
  - Photograph and Video- Owens et al (1994), Hildebrand et al (1997)
- Field Studies on Closed Courses
  - Driver position- Curry et al. (2007), Rogers et al(2006)
  - Passenger position- Blanco et at (2005), Fambro et al (1997)
- Field Studies on Open Roads
  - Targets on side of the road- Muttart et al (2009), Balk et al (2008)
  - Eye tracking- Kledus et al (2010)
- Naturalistic Studies
  - 100 car study
  - SHRP-2

Open Road vs. Closed Course Studies



C-A-P-L-E-T-S = INFORMATION!

CONTRAST

ANTICIPATION

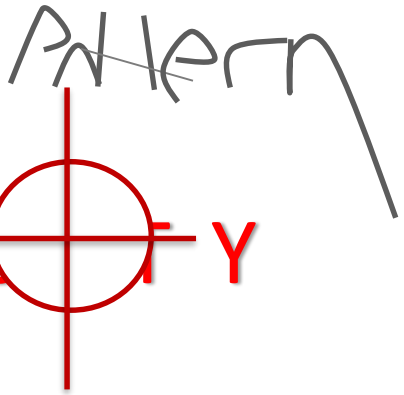
PATTERN versus

LIGHTING

E C C E N T R I C I T Y

Time of Exposure

SIZE



Paper # 2017-01-1366

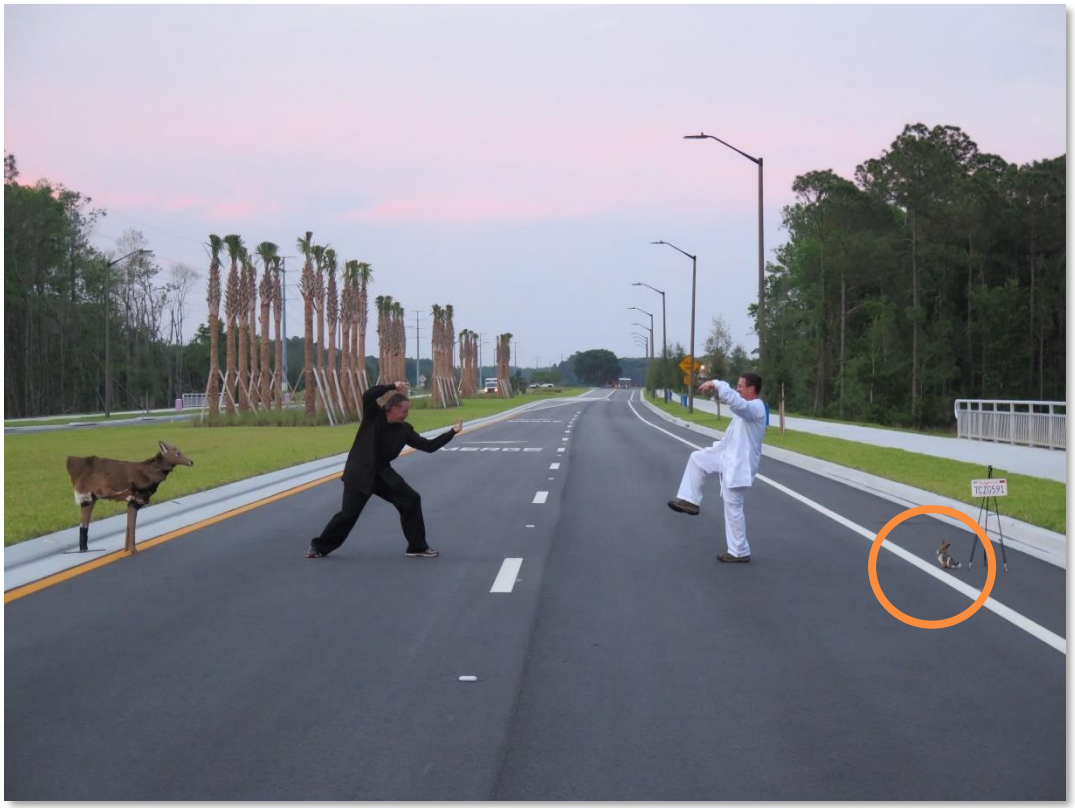
Limited Exposure Time = Limited Information = Limited Expectancy

- Limit the TIME = Limit the INFORMATION
- Limiting the time to 1 glance
  - Exposure Time= 0.285 seconds
- Experienced drivers make periodic glances
- Participants asked to recognize objects only “in the roadway”
- Unknown location of the object
  - Right vs Left; Near vs Far
- Possibility of False Alarms
  - Participants informed about *no-target* scenario

Methodology

- 2 Locations
  - –Indoor- Orlando, FL
    - 40 Participants
    - 9 female participants
    - Avg. Age: 44.6 years (S.D= 9.7)
    - Subaru Tribeca
  - –Outdoor- State College, PA
    - Rural roadway and 2 lane highway
    - 12 Participants
    - All Male
    - Avg. Age: 43.2 years (S.D= 8.6)
    - Subaru Tribeca & Ford Focus

Targets



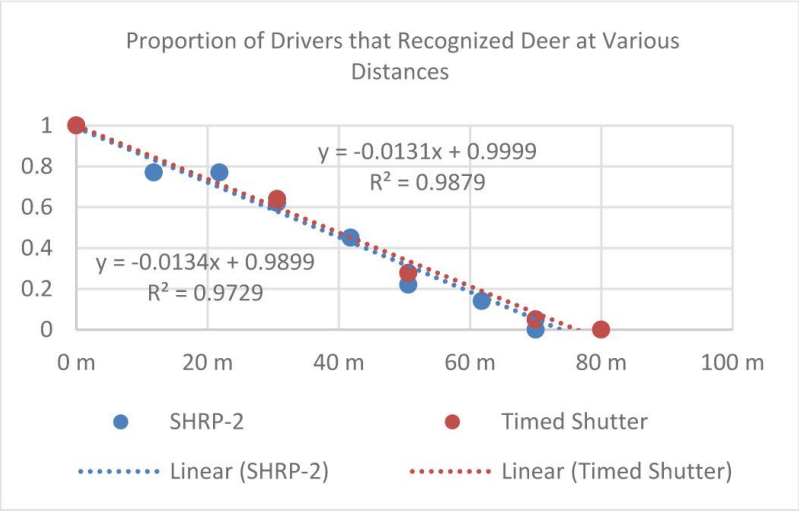
SHRP-2 Data

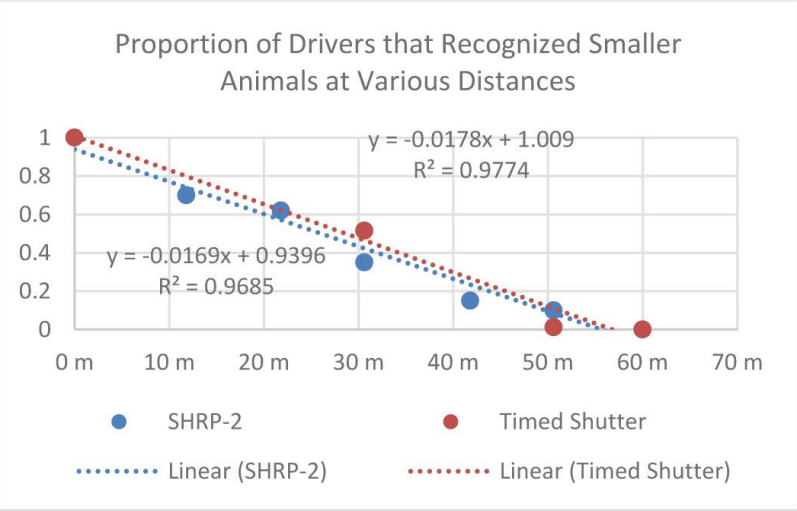
- 2nd Strategic Highway Research Program (SHRP-2)
- Over 3100 Drivers
- Over 1000 crashes and 3000 near crashes

For this study

- Distance measured when 0.4g braking achieved
- 45 Deer related events
- 58 Small animal related events
- Environmental factors
- Secondary task related
- Influence of on-coming vehicles

SHRP-2 vs Timed Exposure Method





SHRP-2 Results- Deer

Distance = when 0.4 g achieved

SHRP-2 Recognition of Deer	Age	N	Percent Recogn.	Speed Loss (km/h)	Recognition Dist. (m)	Z-Score	P
Total Averages	38.3	45	82%	18.3	25.0		
No Oncoming vehicle	37.1	34	83%	18.7	**26.1**		
Oncoming vehicle	44.5	11	60%	14.8	**18.0**	-2.45	**0.014**
Left	41.5	25	92%	18.8	**27.4**		
Right	34.5	20	70%	17.7	**16.4**	-3.67	**0.007**
No Secondary Task	38.6	14	79%	19.5	30.8		
Visual or Auditory Secondary Task	36.3	23	87%	19.8	24.6	-0.92	0.357
Visual and Manual Secondary Task	43.4	8	75%	11.8	15.7	0.08	0.936
Unlit Dark	39.5	19.0	68%	20.1	**34.5**		
Dusk / Dawn	37.0	6.0	100%	20.6	**11.9**	4.30	**.000**
Lighted Dark	37.4	20.0	90%	15.8	**19.0**	3.85	**.000**
Crash	36.5	11	73%	6.5	**10.6**		
Near Crash	38.9	34	85%	22.1	**29.6**	-5.32	**.000**
Age <20	19.0	12	83%	16.0	27.3	-0.64	0.522
Ages 20 - 50	33.5	20	79%	20.8	27.4		
Age >50	65.7	12	83%	15.5	19.3	-1.21	0.226

Oncoming veh = 27’ worse
31% worse

Visual & manual distraction = 50’ worse

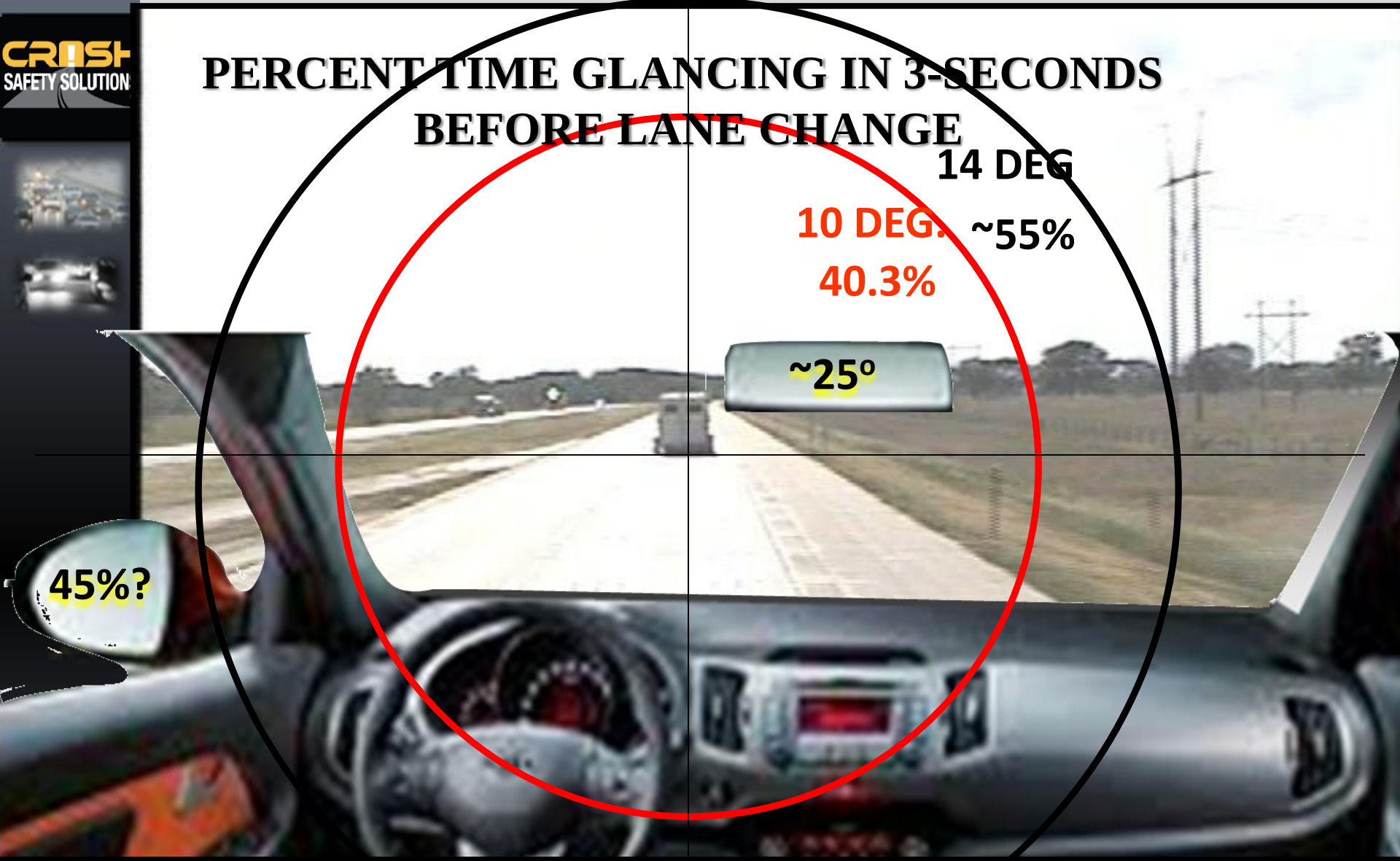
Lighted = 16’ better

SHRP-2 Results- Small Animals

SHRP-2 Recognition of Deer	Age	N	Percent Recogn.	Speed Loss (km/h)	Recognition Dist. (m)	Z-Score	P
Total Averages	33.6	58	81%	10.8	13.2		
Oncoming veh	25.9	8	88%	14.8	16.6		
No Oncom. Veh.	34.6	51	80%	10.0	13.1	-1.39	0.164
Left	31.8	18	83%	9.4	13.8		
Right	37.0	28	86%	10.1	14.3		.
Ahead	25.4	11	64%	11.0	11.7	-0.09	0.928
No Secondary Task	33.1	29	76%	10.9	15.4		
Visual or Auditory Secondary Task	36.9	12	75%	10.5	11.9	-1.21	0.226
Visual and Manual Secondary Task	30.3	16	94%	11.0	13.9	-0.48	0.631
Dark unlit	35.0	24	83%	12.7	16.8		
Dusk/dawn	20.3	4	100%	20.1	22.8	-1.30	0.193
Dark lighted	34.3	30	77%	8.0	9.6	4.17	**.000**
Crash	29.6	18	56%	8.3	14.7		
Near-Crash	35.5	40	93%	11.9	10.9	-3.58	**.000**
Small Slow Animal	31.9	19	84%	12.0	13.1	Slow / fast	
Small Fast Animal	32.3	25	80%	7.3	11.5	-6.16	**.000**
Medium Slow Animal	24.0	4	75%	28.6	21.2	Small/Med.	
Medium Fast Animal	62.8	4	100%	8.8	18.4	1.10	0.271
Undetermined Animal	31.5	6	67%	11.0	11.6		
Age <20	19.0	16	88%	11.8	13.3	-1.80	0.072
Age 20 - 50	28.8	29	83%	11.4	14.3		
Age >50	69.0	11	82%	8.5	12.0	-1.80	0.072

Distance = when 0.4 g achieved

EYE TRACKING



(Based upon Lee, Olsen, Wierwille, 2002)

ROUTINE PASSING MIRROR GLANCE TIMES

Passenger Cars & SUVs

Average 2.5 head turns - 3 to 7 sec. depending on traffic

Henning, M. J., Georgeon, O. & Krems, J. F. (2007). The quality of behavioral and environmental indicators used to infer the intention to change lanes, *Proceedings of the Fourth International Driving Symposium on Human Factors in Driver Assessment, Training and Vehicle Design,* 231

Finnegan, P., & Green P. (1990). The time to change lanes: A literature review. University of Michigan, *Transportation Research Institute* (IVHS Technical Report-90-13).

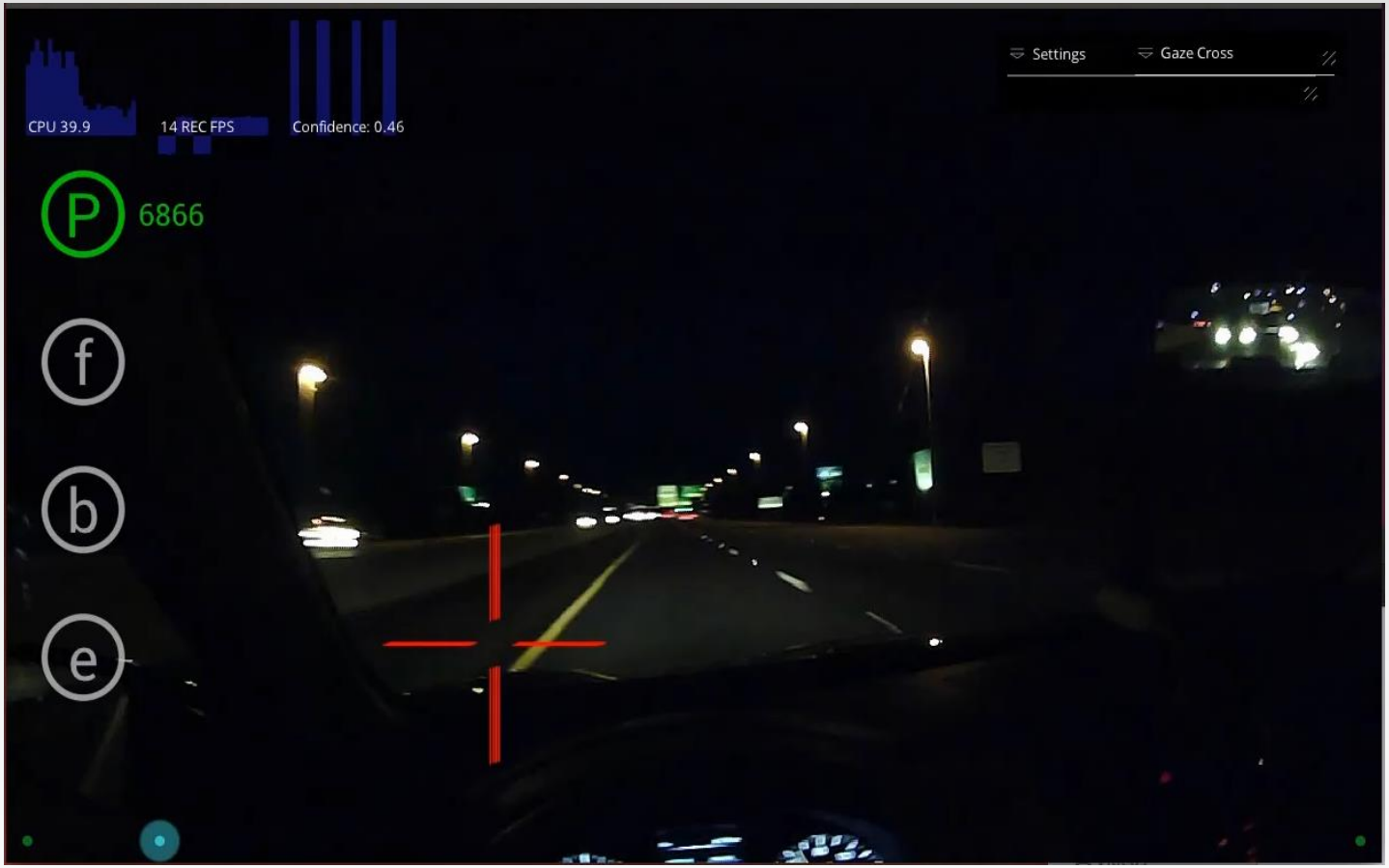
Fitch, G. M., Lee, S. E., Klauer, S., Hankey, J., Sudweeks, J., Dingus, T. (2009). Analysis of lane change crashes and near crashes, Washington, DC: NHTSA.

Lavalliere, M., Laurendeau, D., Simoneau, M., Teasdale, N. (2011). Changing lanes in a simulator: Effects of age on the control of the vehicle and visual inspection of mirrors and blind spot, Traffic Injury Prevention, 12, 191-200.

Robinson , G. H., Erikson, D.., Thurston, G., & Clark, R.. (1972). Visual search by automobile drivers, Human Factors, 14, 315-323.

Lane Change- Right - Average driver 2.5 head turns

2 glances (including shoulder check) in 7 seconds (w/ 1 car) - No LV



Consistent with:

Lavalliere, M., Laurendeau, D., Simoneau, M., Teasdale, N. (2011). Changing lanes in a simulator: Effects of age on the control of the vehicle and visual inspection of mirrors and blind spot, Traffic Injury Prevention, 12, 191-200.

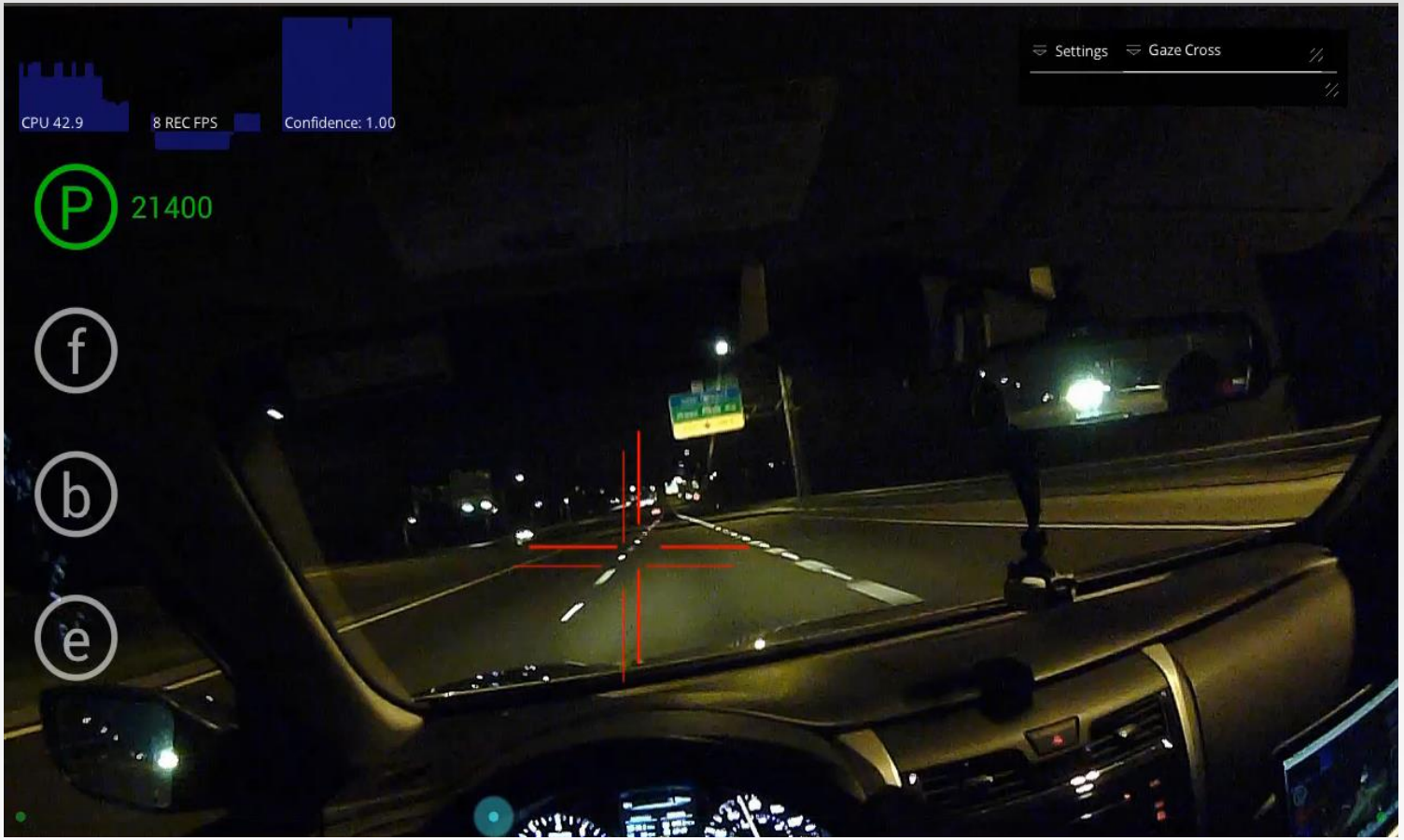
Lane Change- Left - Longer glance time when traffic is present

2 glances (including shoulder check) in 12 seconds (w/ 1 car) - Moves left ~ 240 feet – 75mph

Consistent with:
Finnegan, P., & Green P. (1990). The time to change lanes: A literature review. University of Michigan, *Transportation Research Institute* (IVHS Technical Report-90-13).

Lane Change- Left - Some drivers might make a longer single glance with no traffic

1 longer glance in 3.5 seconds (no traffic) -



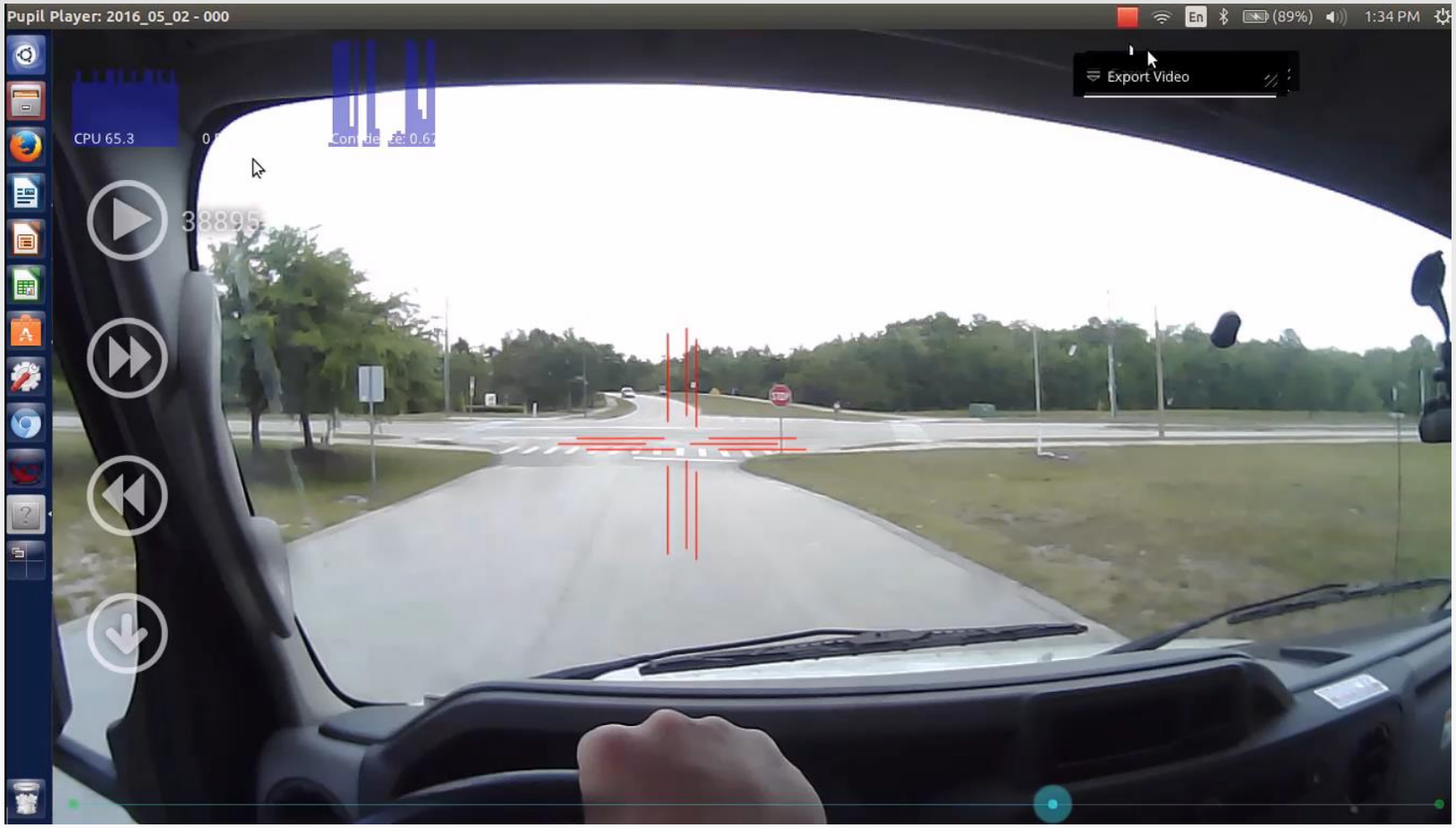
Consistent with:
Lavalliere, M., Laurendeau, D., Simoneau, M., Teasdale, N. (2011). Changing lanes in a simulator: Effects of age on the control of the vehicle and visual inspection of mirrors and blind spot, Traffic Injury Prevention, 12, 191-200.

CDL Truck Driver – 2 glances in 4.5 s

CDL Truck Driver with traffic – 3 glances in 8 s

Acceleration into Intersection

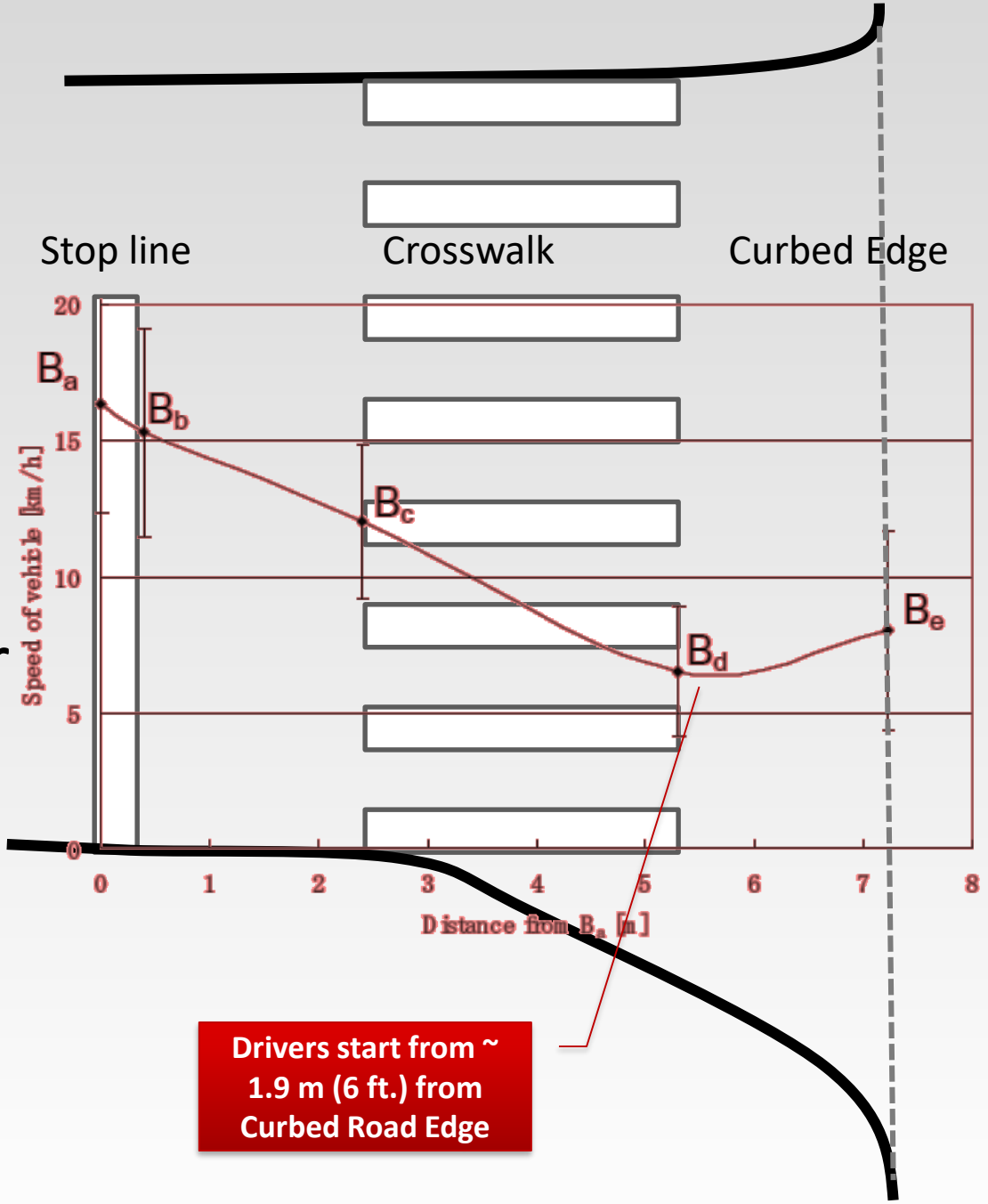
CDL Driver - Two phase stop – secondary glance



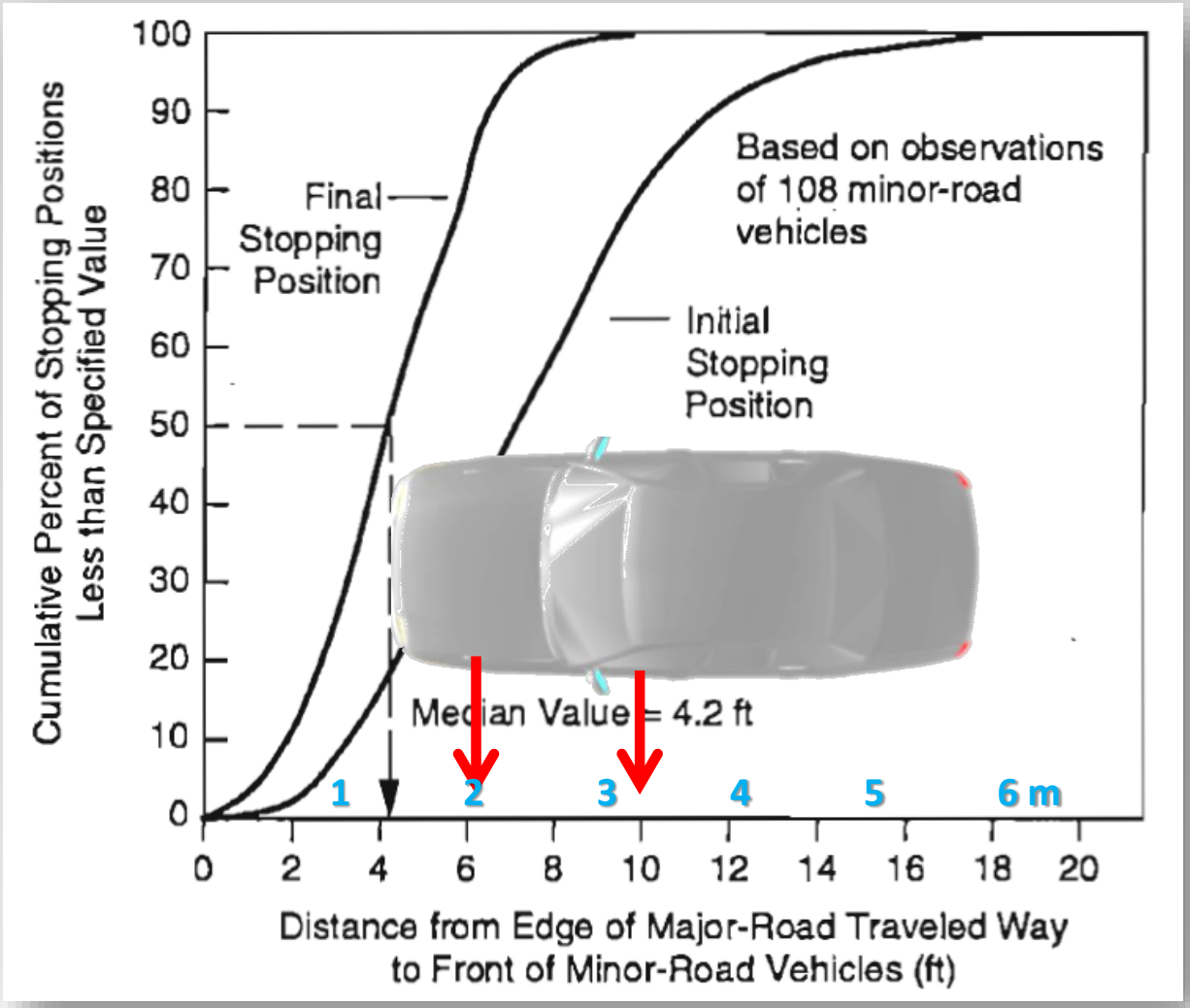
Motorcyclist - Two phase stop – Consistent with Harwood et al. – add pavement glance

Kosaka, et al., 2007

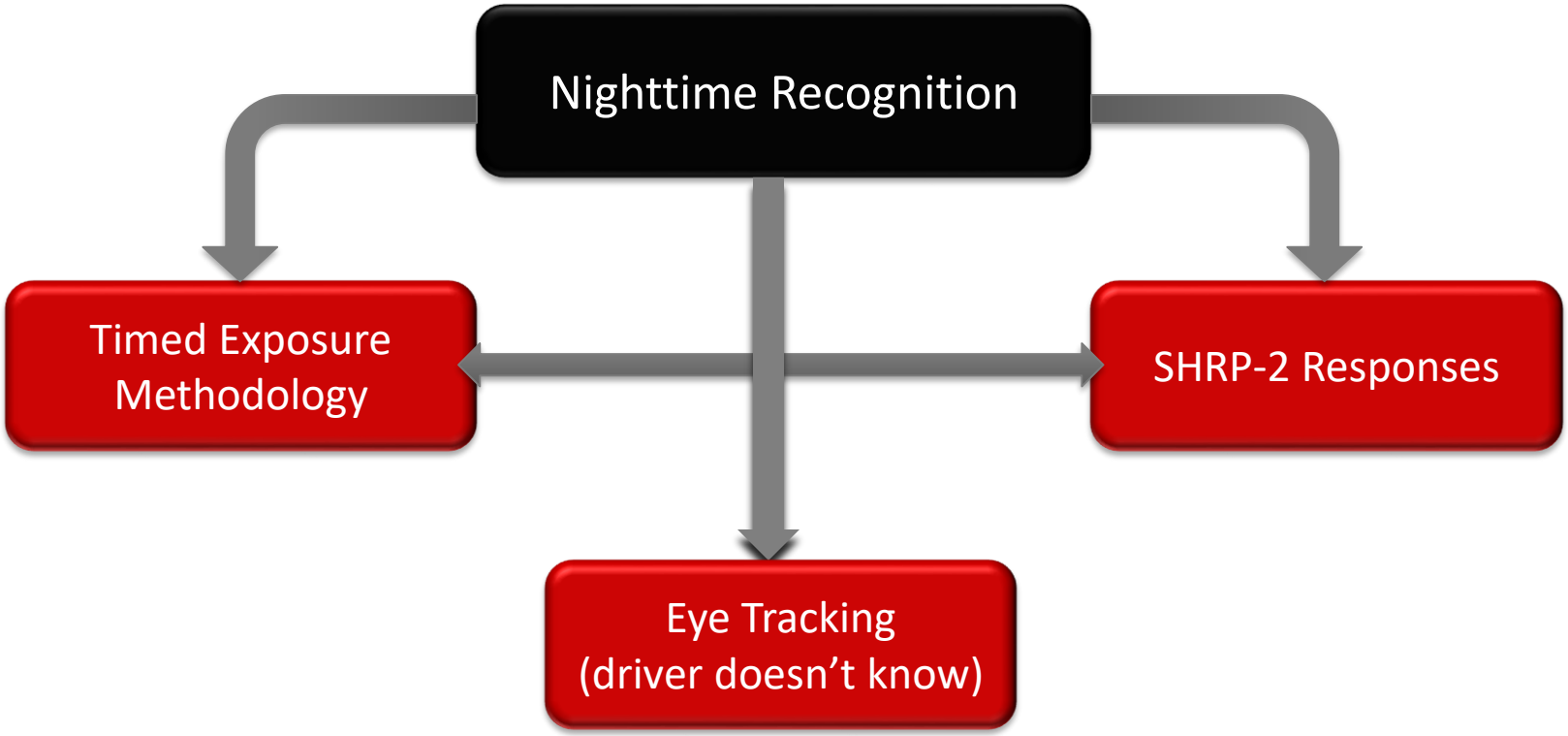
- At a narrowed Sight Line to passenger side
- Average driver reached Min Speed when 1.9 m (near 6 feet) from the curbed road edge



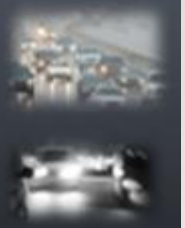
Cumulative distribution of vehicle stopping positions on a STOP-controlled approach with limited sight distance.



NCHRP 383
p. H4


Nighttime Recognition
Timed Exposure Methodology
SHRP-2 Responses
Eye Tracking (driver doesn't know)

Night Recognition Distance



MOST INFO

Trailer with lights around edges	> 1000 ft.	(300 m)
White vehicle (no lights) – near side	377 ft.	(115 m)
White vehicle (no lights) – opp. Side	253 ft.	(77 m)
Light colored pedestrian – near side	325 ft.	(99 m)
Light colored pedestrian – opp. Side	201 ft.	(61 m)
Grayish pedestrian – near side	192 ft.	(59 m)
Grayish pedestrian – opp. Side	144 ft.	(44 m)
Dark pedestrian – near side	126 ft.	(39 m)
Tree or branch across road (@0.4 g)	93 ft.	(28 m)
Dark pedestrian – opp. side	85 ft.	(26 m)
Deer – (combination both sides) (@0.4 g)	82 ft.	(25 m)
Rabbit, cat, opossum, armadillo, skunk	43 ft.	(13 m)
Dark pedestrian – on ground	0 ft.	(0 m)

LEAST INFO

Vehicle taillights - vehicle is facing ahead and lights on

Muttart, J. W., Bartlett, W., Kauderer, C., Johnston, G., Romoser, M., Unarski, J., Barshinger, D. (2013). Determining when an object enters the headlight beam pattern of a vehicle. Impact Journal, 21 (3), 4-29. (reprinted after copyright was purchased from SAE by ITAI)

Muttart, J., Dinakar, S., Suway, J., Kuzel, M. et al., "Comparing A Timed Exposure Methodology to the Nighttime Recognition Responses from SHRP-2 Naturalistic Drivers," SAE Technical Paper 2017-01-1366, 2017, doi:10.4271/2017-01-1366.

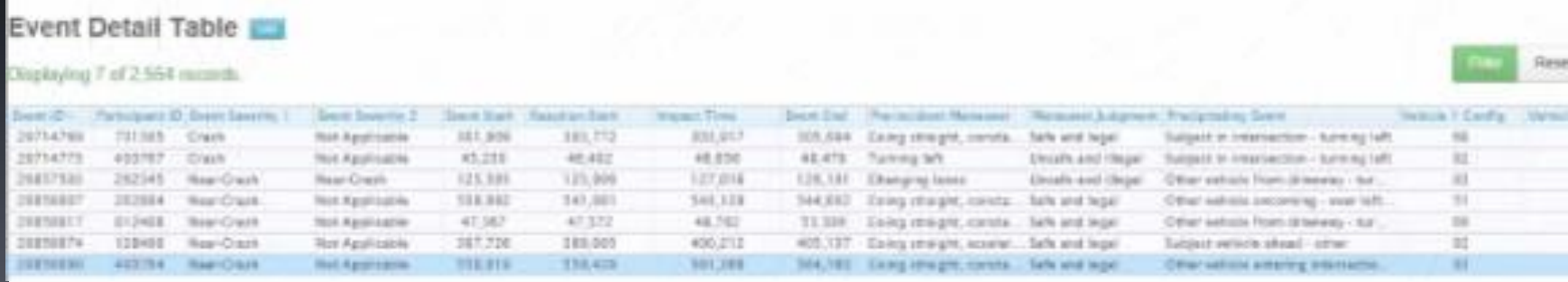
ASSUMPTIONS:

- Unlit road with subject drivers' headlights on
- driver is looking ahead (generally)
- Not a large eccentricity
- Movement might improve response if lighted or light color
- Must apply (PRT minus 0.5 s)
- These are AVERAGE times – for an lower bound of normal (1 standard deviation) multiply by 1.5
- Thus, a normal response time when responding to a deer is 130 ft. – (130 x 0.5) = 65 feet
- We recommend you use these distance minus Velocity x (PRT x 1.35) + 0.5 sec

Deer Target- Left - Fixation moves in that direction at 122 ft (37 m) – SHRP-2 – hard braking at 82 ft (25 m)

2nd Strategic Highway Research Program [SHRP-2]

- Over 3,100 instrumented vehicle
- As of 1 January 2015
  - Over 1,000 crashes
  - Over 3,000 near crashes
  - Many crashes are minor (curb strikes)



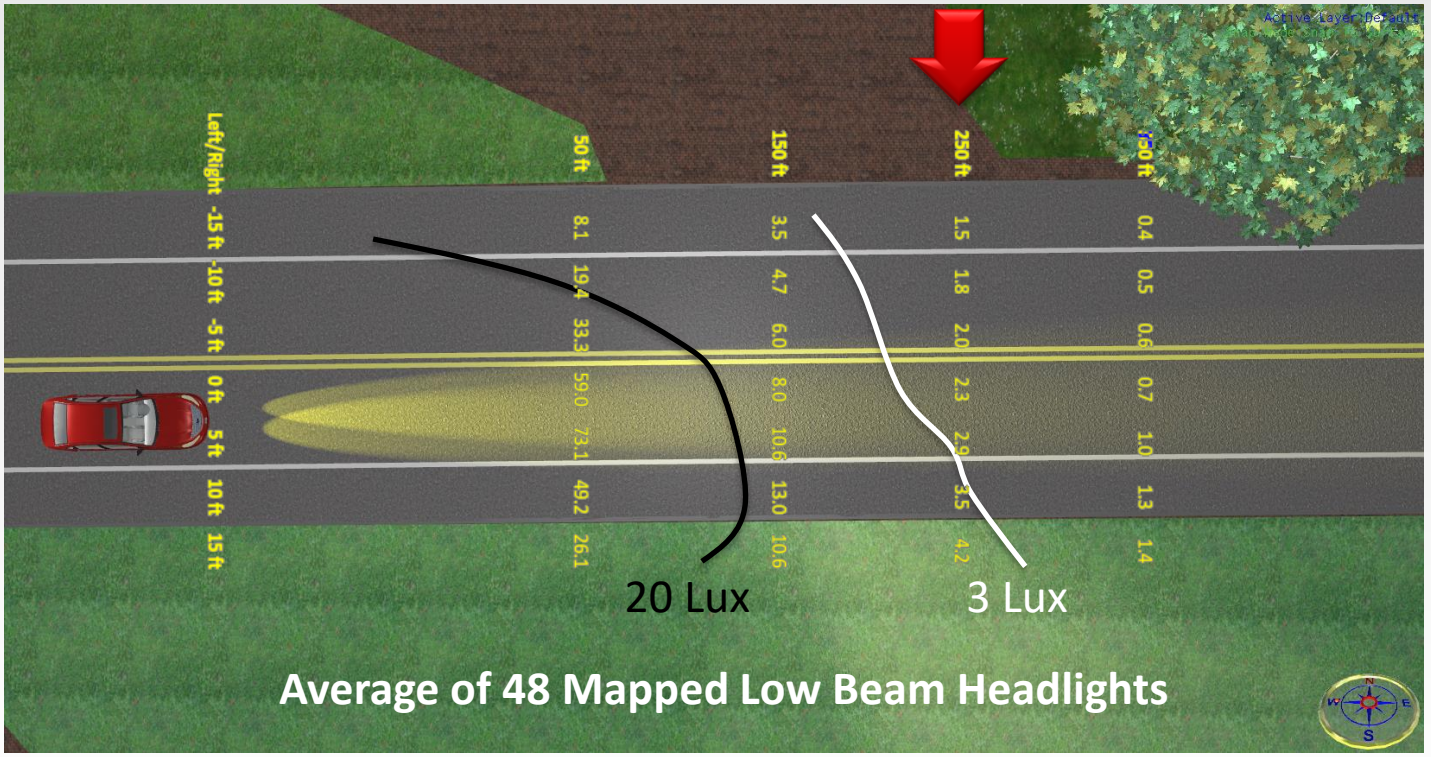
Forward video
(Driver-view video
cannot be shown)

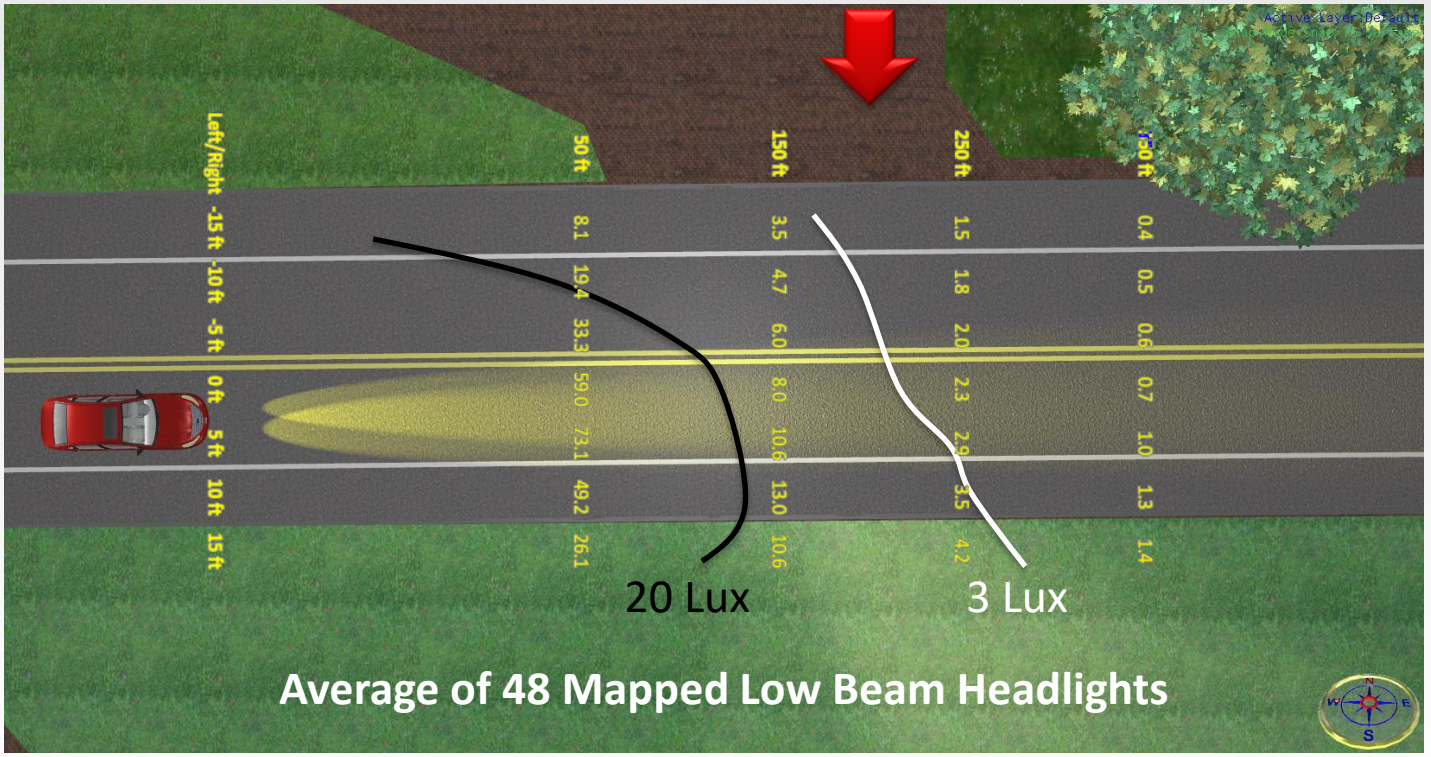
Small Animal

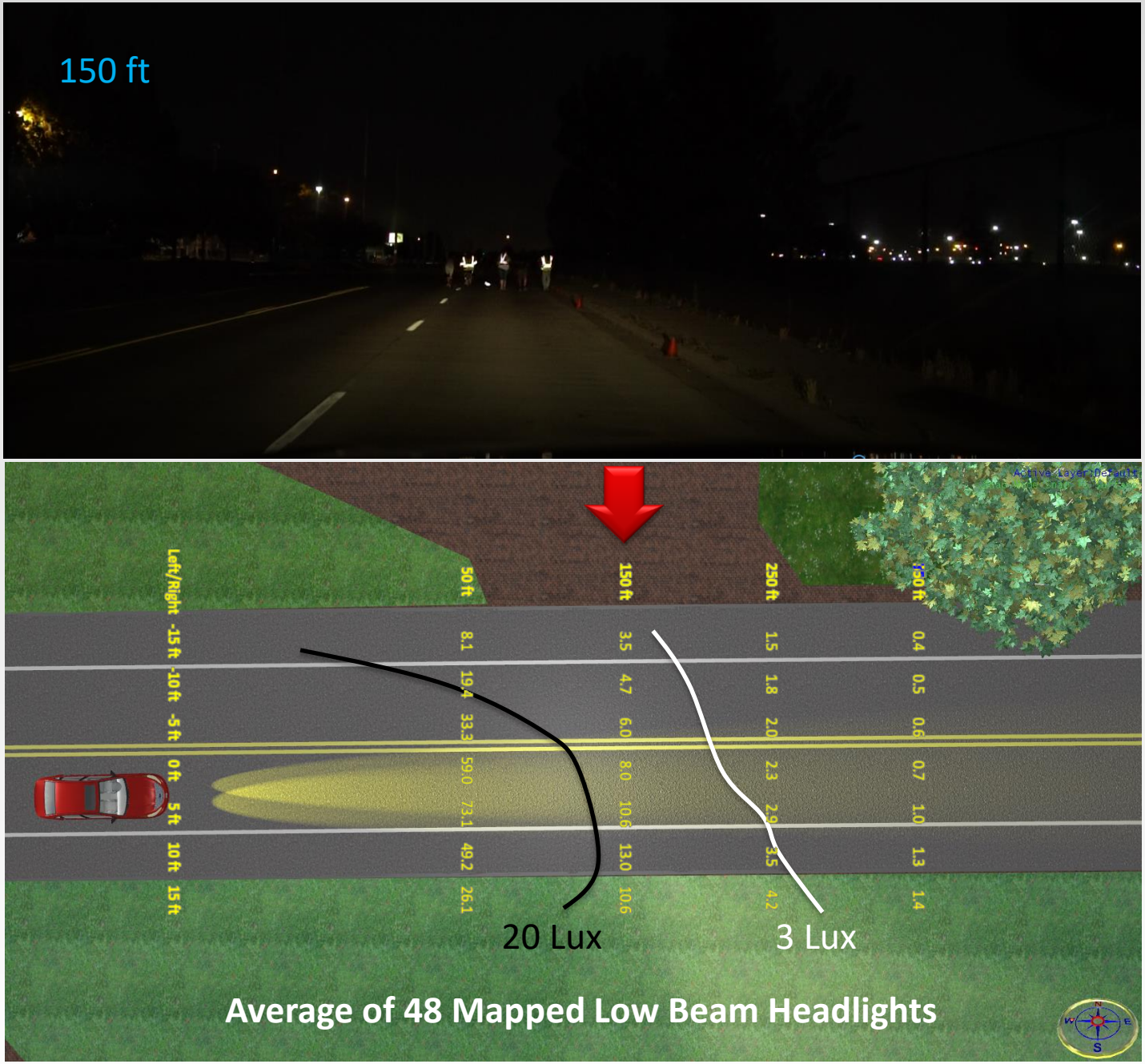
Recall, deer ~ 34 m fixation
~ 25 m 0.4 g

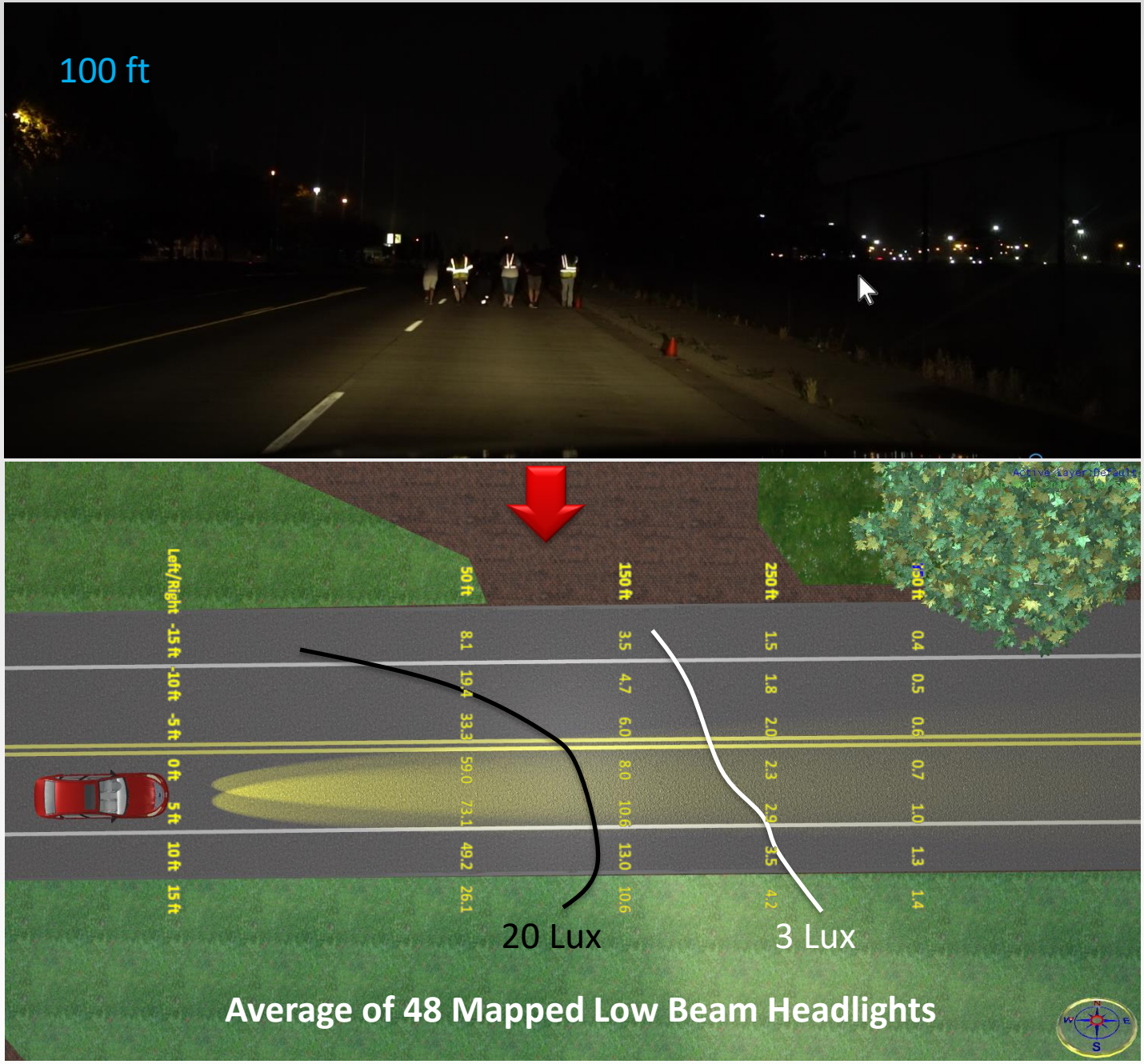
SHRP-2: At 13 m (43 ft) – 0.4 g

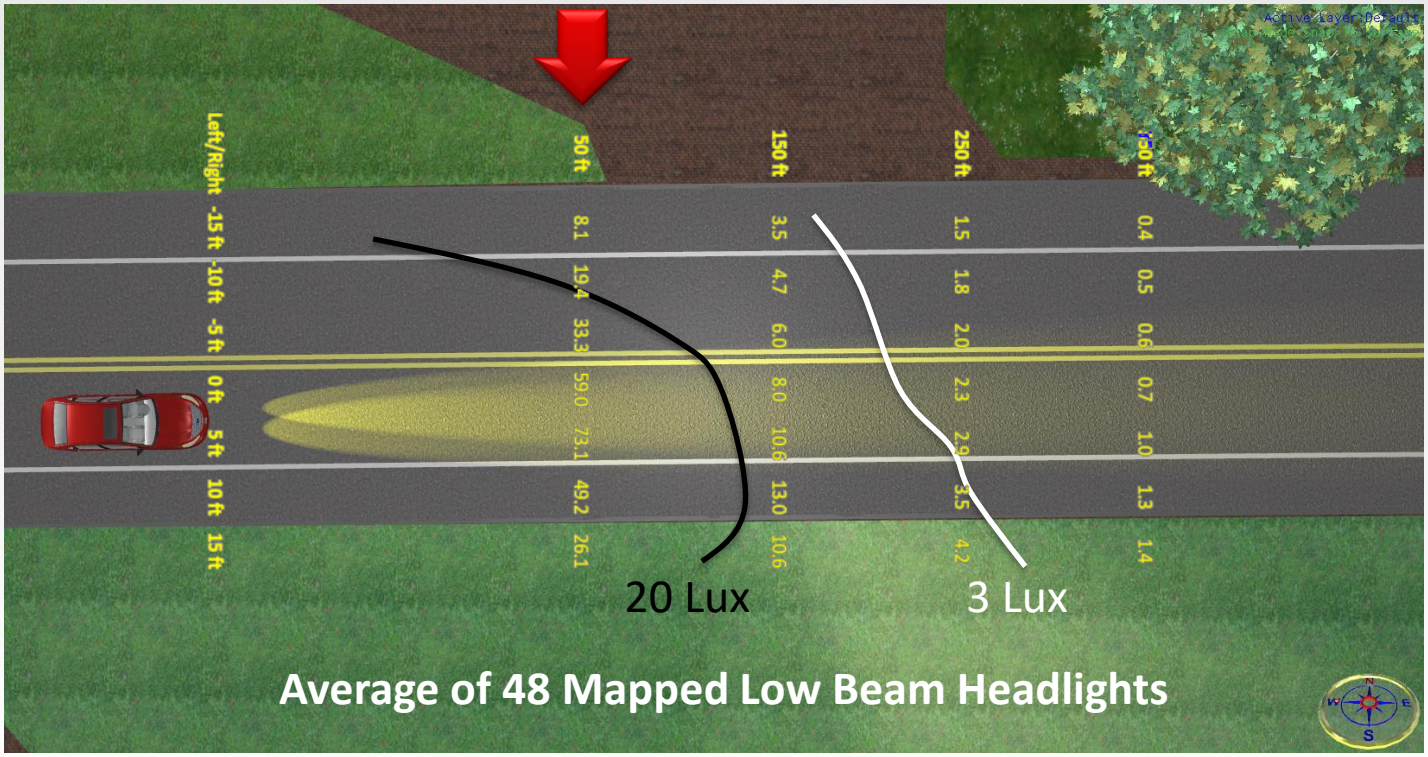
WREX 2017: ~14 m (45 ft) – fixation (decoy rabbit)



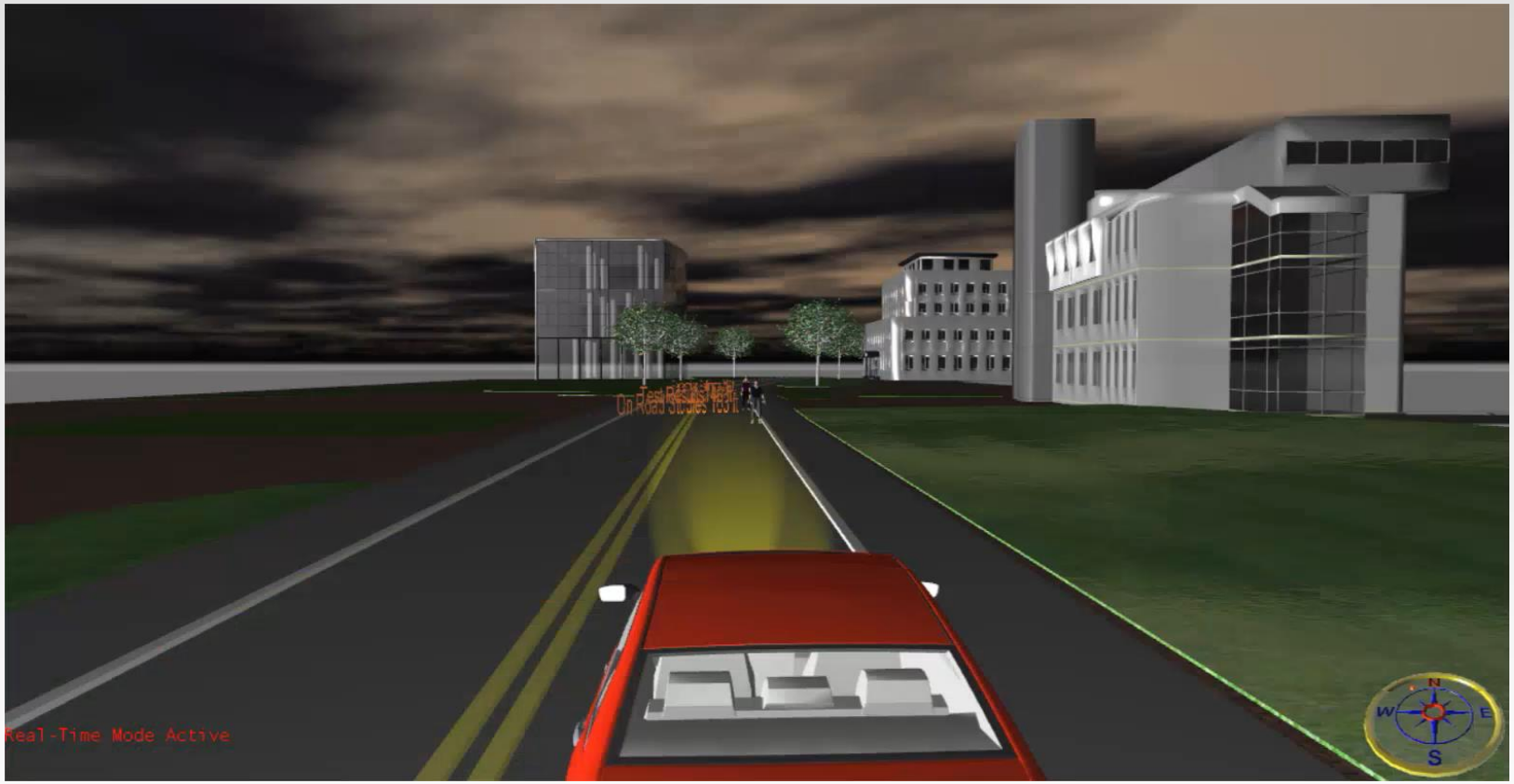








Pedestrians (And Investigators) Overestimate Their Visibility



HFES 2017

Influence of Taillight Width on the Ability to Recognize Closing Speed, Closing Distance, and Closing versus Separating

CLOSING SPEED RECOGNITION STUDY

Fatal Rear End Crashes

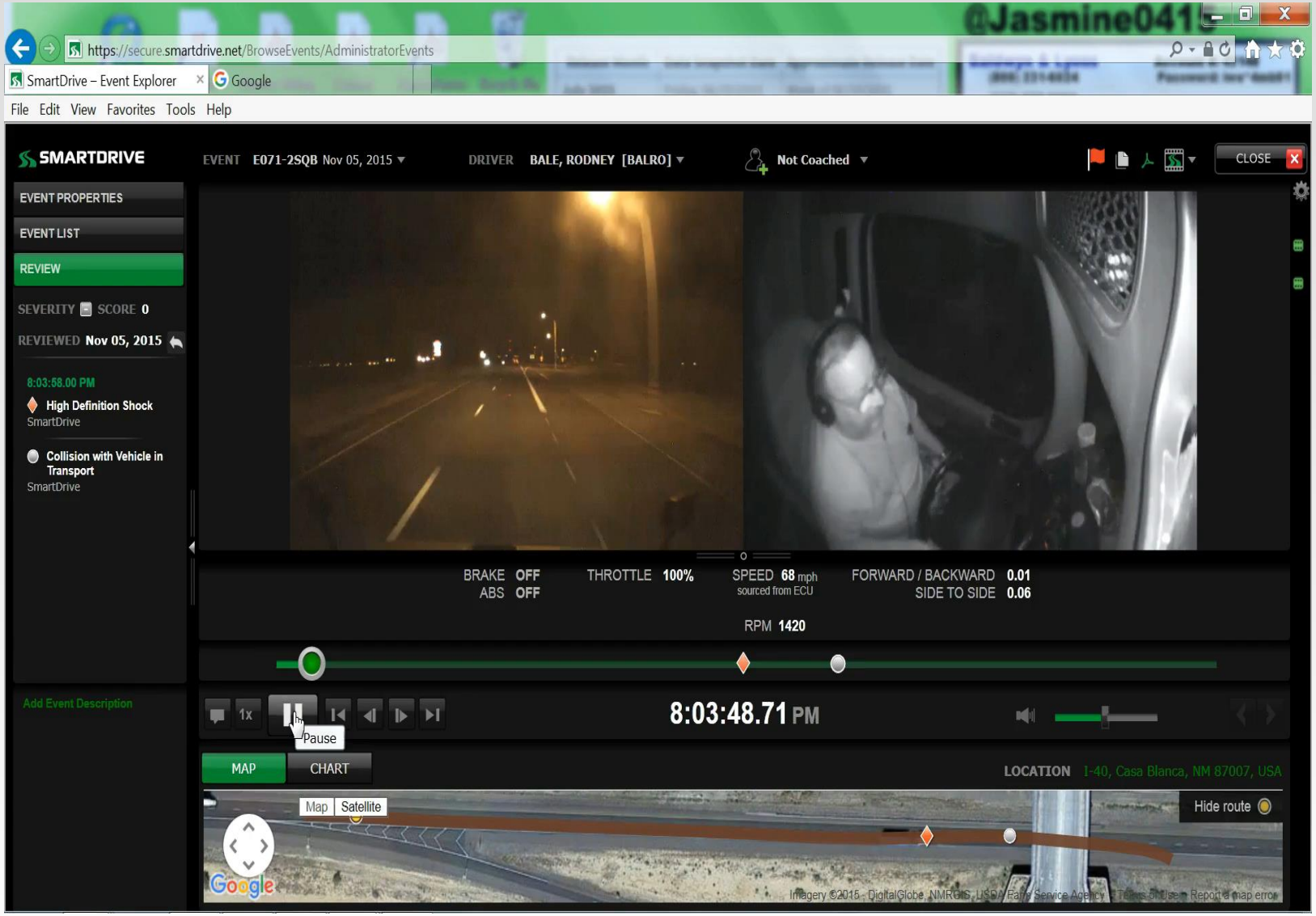
- 11,325 fatal crashes involving a front-to-rear impact in 2009 through 2015
  - [www-fars.nhtsa.dot.gov].
- Two types of front-to-rear (or rear-end) crashes:
  - 1) Those due to human error in the form of slips, lapses, or mistakes (Reason, 2000) and
  - 2) Those due to limitations of the human visual system.

Distance where drivers recognize dangerous closing rate

- $d = \sqrt{\frac{w \times (V_{Appr} - V_{LV})}{\theta}}$
  - W – discernible width
  - V_{Appr} – velocity of the approaching vehicle
  - V_{LV} – velocity of the lead vehicle
  - Θ – Closing speed recognition threshold (Subtended angular velocity measured in radians per second) – use 0.006 radians/sec

Imagine when you would brake

CRASH SAFETY SOLUTIONS LLC



IDRR: PRT applied to Closing Speed Recognition Threshold

J Muttart © CSS, LLC

Response to Lead Vehicle

Recognition Threshold

Fl	1. Brake lights and/or flashing lights
Ex	4. Road/HI Fidelity Sim ***DEFAULT***
O	1. Response to one object
E	0 deg (ahead)
Tp	1. Straight Road (Can't discern veh move relative to background)
Tr	Brake Lag 375 ms
Hv	Check if Hovering brake
D	1. Driving
Lt	2. Night

Vis. Expan. Thres. 0.0060 radian/sec

Closing Speed Detection Threshold

Check Box if mobile phone usage

Sight Distance (ft) 1000

Init. Speed Appr Veh (mph)	68
Eyes-2-F. Bump(ft)	8
LV Initial Speed (mph)	0
Speed of LV at Imp (mph)	0
Discernable Width (ft)	8

Braking Response

Deceleration (Gx) 0.75

EXPECTED PRE-IMPACT MANEUVER

Average Pre-Impact maneuver 132 feet — 85th %ile 51 feet

			85th %ile	
AVG PER-RESP TIME	2.2 sec		3.1 sec	Individuals
Equation	2.2 sec	Min Avg	Max Avg	
Studies Adjtd	2.3 Sec	1.4 Sec	2.9 Sec	Scenarios

Visual Expan Threshold (ft)	364.7	HEADWAY	3.66 sec	92.4%
Distance to Impact at Vis Exp Thres (ft)	356.7		3.58 sec	follow closer

393 x H + 509 x O + 26 x E – 703 x Tp + (Tr & constant) + Brake adj + Adj to VER

393 x 3.7 + 509 x 1 + 26 x 0 – 703 x 1 + 1335 + 125 + -527

AVG. Response Dist. = ~2.2 x 68 x 1.467 = 224 feet

85th percentile response Dist. = 305 feet

85th percentile response

Time to brake = SQRT(2 x d / (g x Gx)) = 4.1 sec

Stopping Dist. = (68 x 1.467)^2/((2 x 32.2 x 0.75))

Stopping Dist. = 206 ft.

TOT. STOPPING DIST. 430 ft.

85th %ile STOP. DIST. 511 ft.

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Replication of Hoffman & Mortimer with Modifications

- Participants show two 4-second clips showing a vehicle ahead
- Participants asked
  - Hoffman:
    - To give ratio of distance (many participants did not understand “ratio”)
    - Average headway 28 m (92 ft)
  - Current:
    - Closing or separating
    - Which is vehicle was closest (DISTANCE)
    - In which clip were you (observer) closing fastest (CLOSING SPEED)
- Medium
  - Hoffman: 4 second video
    - Observers can stare
    - closing speeds of 0.54 to 7.23 m/s (1.8 and 23.7 ft/s).
  - Current: 4-second
    - Fixations (snapshots) in accordance with Lee, Olsen & Wierwille (2005) – 1/s
    - Closing speeds 20 m/s (66 ft/s)

IN THE NEXT SLIDES, I SHOW THE VIEW WHEN CLOSING AT VARIOUS SPEEDS AND FROM VARIOUS DISTANCES

UNDERSTAND – YOU KNOW WHERE TO LOOK AND WHAT TO LOOK FOR

IF YOU WERE
DRIVING
SCANNING
LOOKING AWAY… HOW WELL WOULD YOU DO?

YOU WILL BE SHOWN A SERIES OF PHOTOGRAPHS OF CLOSING ON A LEAD VEHICLE. YOU WILL BE ASKED QUESTIONS LATER?

TEST 1

A7-1-P

B7-1-P

C7-1-P

D7-1-P

E7-1-P

F7-1-P

G7-1-P

H7-1-P

I7-P

CLOSING OR SEPARATING?

WHAT IS THE DISTANCE

A – I 71

900’

800’

700’

600’

500’

RELATIVE SPEED

CLOSING AT 25

CLOSING AT 45

CLOSING AT 65

NOT CLOSING

GAINING AT 20 MPH

Taillights 5.5 feet apart

TEST 2

A7-3-P

B7-3-P

C7-3-P

D7-3-P

E7-3-P

F7-3-P

G7-3-P

H7-3-P

I7-P

CLOSING OR SEPARATING?

What is the distance

900’
800’
700’
600’
500’

A – I 73

Relative speed

Not closing
Closing at 25
Closing at 45
Closing at 65
Gaining at 20 mph

TEST 3

A6-2-P

B6-2-P

C6-2-P

D6-2-P

E6-2-P

F6-2-P

G6-2-P

H6-2-P

I6-P

CLOSING OR SEPARATING?

What is the distance

900’
800’
700’
600’
500’

A – I 62

Relative speed

Not closing
Closing at 25
Closing at 45
Closing at 65
Gaining at 20 mph

TEST 4

A6-2-D

B6-2-D

C6-2-D

D6-2-D

E6-2-D

F6-2-D

G6-2-D

H6-2-D

I6-D

CLOSING OR SEPARATING?

What is the distance

900’
800’
700’
600’
500’

A – I 62

Relative speed

Not closing
Closing at 25
Closing at 45
Closing at 65
Gaining at 20 mph

Hypotheses

- 1. Observers will be able to accurately estimate closing from separating much earlier (farther away from the LV) than when estimating closing speed
- 2. Narrow taillights will be perceived to be farther away than wider taillights at similar distances
- 3. Drivers will be able to discern closing distance better than differences in closing speed.
- 4. The primary hypothesis of this research is that closing thresholds are a human limitation, not a human error situation. Therefore, drivers with CDL licenses (professional drivers) who are familiar with a bobtail tractor will perform similarly to those with a standard license.

Participants

- 100 participants (19 female) –
  - 1848 trials
- Age
  - Average: 47.1
  - Range: 20 – 71 years
- CDL Drivers: 13
  - 234 trials
- CDL in past: 4
  - 72 trials

Equipment

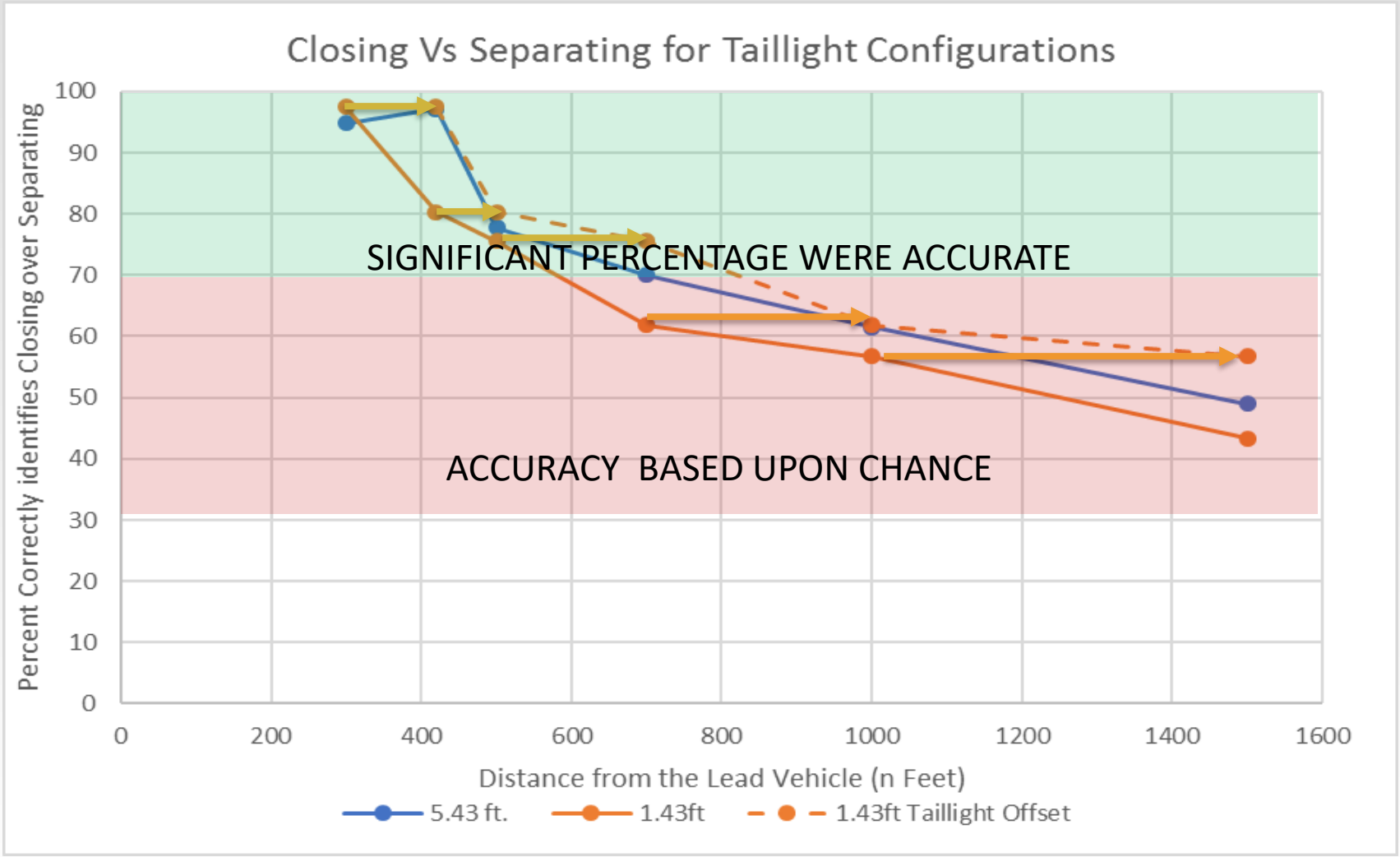
Figure 1. The lead vehicle that was utilized in the experiments

Procedure

- Each trial comprised of two 4-second video clips. separated by a black screen
- At the end of each trial the participant would be asked four questions.
  - 1. In the first clip, were you closing (getting closer to) or separating (getting farther apart)?
  - 2. In the second clip, were you closing (getting closer to) or separating (getting farther apart)?
  - 3. In which clip was the lead vehicle closer? (Or were they at the same distance.)
  - 4. In which clip was the closing or separating speed the quickest? (Or were they closing or separating at the same speed.)

Closing versus separating –

Std Taillights 650 ft (200 m) < 500 ft (150 m) with narrowed taillights



HFES 2017 Muttart, Dinakar, Suway, Kuzel, et al.

Percent of observers who correctly identified the closer vehicle (Red signifies guesses – by chance)

STANDARD TAILLIGHT WIDTH

		1.65 m (5.43 ft)					
	Distance in m (ft)	91 (300)	128 (420)	152 (500)	213 (700)	305 (1000)	457 (1500)
0.4m (1.43 ft)	91 (300)	9%	50%	73%	84%	96%	98%
	128 (420)	88%	5%	38%	65%	94%	90%
	152 (500)	90%	84%	0%	40%	52%	88%
	207 (700)	96%	88%	85%	14%	35%	58%
	305 (1000)	91%	94%	92%	80%	5%	54%
	457 (1500)	96%	90%	85%	96%	95%	14%

Near chance Guess (40% correct)

700 ft – Standard taillight width

I7-P

500 ft – Narrow taillights

I6-D

0% Correct – Every observer reported vehicle on right to be farther away

500 ft

I6-P

500 ft

I6-D

Tuft of headlights did not help until 300 ft

Brighter taillights attract attention over dim taillights

The percent of observers who selected the wider taillight configuration over narrow taillight as being closer (Significance P < .05 indicated in bold)

		1.65 m (5.43 ft)					
	Distance in m (ft)	91 (300)	128 (420)	152 (500)	213 (700)	305 (1000)	457 (1500)
0.4m (1.43 ft)	91 (300)	**64%**	36%	27%	0%	4%	2%
	128 (420)		**76%**	38%	30%	6%	10%
	152 (500)			**86%**	**53%**	33%	8%
	207 (700)				**73%**	**57%**	33%
	305 (1000)					**75%**	38%
	457 (1500)						**50%**

Percentages closest to 33% are pure guesses

1. Closer
2. Same
3. Farther apart

Implications

- Narrow taillight at 152 m (500 ft) and the standard taillight at 213 m (700 ft),
- 53% of observers believed the narrow taillight vehicle was farther away.
- Assume 152 m (500 ft) from impact
  - Speed of 30 m/s (100 ft/sec.) – 68 mph
  - Imagine driver believes the LV was 61 m (200 ft) farther away than its actual distance.
  - The likelihood of a crash in this scenario is near certain without other cues

The percent of observers accurately identified the closing or separating speed (Significance P < .05 indicated in bold)

		1.65 m (5.43 ft)					
	Distance in m (ft)	91 (300)	128 (420)	152 (500)	213 (700)	305 (1000)	457 (1500)
0.4m (1.43 ft)	91 (300)	**9%**	**14%**	**8%**	**11%**	**17%**	**9%**
	128 (420)	**4%**	**14%**	21%	22%	**12%**	**14%**
	152 (500)	**10%**	**4%**	**10%**	**18%**	**14%**	**17%**
	207 (700)	**13%**	**12%**	**0%**	18%	**13%**	**13%**
	305 (1000)	**4%**	**9%**	**12%**	20%	40%	21%
	457 (1500)	**6%**	**5%**	19%	**13%**	24%	36%

Recognition of Closing Speed is Much More Difficult than Recognition of Closing versus Separating

Frame-By-Frame Method

- Results match those of previous research
  - the SAV when looking ahead was 0.0044 rad/sec
  - 1/Tau (θ/δθ) was a ratio of 0.22.
- Frame-by-frame exposure technique resulted in recognition thresholds that were consistent with previous research.
- However, most drivers are sampling mirrors and the environment periodically (Lee et al., 2005) which causes the real-life closing speed recognition threshold to increase to approximately 0.006 rad/sec (Lamble et al, 2000; Muttart et al, 2005).
- Consider this for reenactments

Exceptions

- Cues where drivers could recognize closing speeds include:
  - Intersections (Muttart et al, 2005),
  - Heavier traffic volumes with other slow-moving traffic ahead (Levulis et al., 2016).
- Areas where drivers perform worst:
  - Bridge inclines (Todosiev, 1965),
  - Foggy weather (Caro, Cavallo, Marendaz, Boer, Vienne, 2009).
  - In general
    - Brighter = closer
    - Higher = farther away