Learning Objectives

1. Describe the relationship between visual attention and cognition during the driving task.
2. Explain Oregon driver behavior in the dilemma zone.
3. Apply the visual attention of Oregon drivers during permitted left turns to provided an improved design of signal displays and reduce potential conflict between turning vehicles and pedestrians.
4. Evaluate the level of comprehension Oregon drivers have for right turn indications at signalized intersections.
5. Explain in your own words how the situational awareness of Oregon drivers can contribute to a right-hook crash.
Relationship between Visual Attention and Cognition

An Oregon Example: Driver Response to Change Intervals (Moore & Hurwitz, 2013)
MUTCD and the Circular Yellow Indication

Circular Yellow Indication should be 3 to 6 seconds in duration

Related Green Movement is being terminated

or

A red signal will be exhibited immediately thereafter, unless preemption

ITE Timing Practice: Yellow and All-Red Intervals

\[ Y = t + \frac{1.47V}{2a + 2Gg} \]

\[ R = \frac{W + L}{1.47V} \]

Where:
- \( Y \) = length of the yellow change interval (sec)
- \( V \) = 85th percentile approach speed (mph)
- \( t \) = perception-reaction time, generally assumed as 1.0 sec
- \( a \) = average deceleration rate, generally assumed as 10.0 fps\(^2\)
- \( g \) = grade of approach, (percent divided by 100, negative for downgrade)
- \( G \) = the acceleration due to gravity, (32.2 fps\(^2\))
- \( R \) = length of the red clearance interval (sec)
- \( W \) = Intersection width (ft)
- \( L \) = vehicle length, generally assumed to be 20 ft
NCHRP Report 731: Guidelines for Timing Yellow and All-Red Intervals at Signalized Intersections

\[
Y = t + \frac{1.47V}{2a + 64.4g} \quad R = \frac{W + L}{1.47V} - 1
\]

Where:
- \(Y\) = length of the yellow change interval (sec)
- \(V\) = 85\(^{th}\) percentile approach speed (mph)
- \(t\) = perception-reaction time, generally assumed as 1.0 sec
- \(a\) = average deceleration rate, generally assumed as 10.0 fps\(^2\)
- \(g\) = grade of approach, measured 5 sec upstream (percent divided by 100, negative for downgrade)
- \(G\) = the acceleration due to gravity, (32.2 fps\(^2\))
- \(R\) = length of the red clearance interval (sec)
- \(W\) = Upstream edge of the approaching movement stop line to the far side of the intersection as defined by the extension of the curb line or outside edge of the farthest travel lane (ft)
- \(L\) = vehicle length, generally assumed to be 20 ft

Change Interval Calculation Practices – ITE Survey

<table>
<thead>
<tr>
<th>Method</th>
<th>Responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kinematic Equation</td>
<td>85</td>
</tr>
<tr>
<td>Uniform Value for All Intersections</td>
<td>12</td>
</tr>
<tr>
<td>Uniform Value for All Intersections, Excluding Where Conditions WARRANT an Exception</td>
<td>42</td>
</tr>
<tr>
<td>Table of Values by Approach Speed Applied to All Intersection</td>
<td>38</td>
</tr>
<tr>
<td>Other</td>
<td>40</td>
</tr>
<tr>
<td>TOTAL</td>
<td>217</td>
</tr>
</tbody>
</table>

(ITE, 2009)
Varying Legal Requirements

Permissive Yellow Law (37 states)
- Can enter the intersection on yellow, and
- Vehicle can be in the intersection on red, as long as the intersection was entered on yellow

Restrictive Yellow Law (13 states)
- Not allowed to enter or be in the intersection on red (4), or
- Stop on yellow unless unsafe to do so (9)

(NCHRP 731)
Type I Dilemma Zone (Gazis et al., 1960)

Type II Dilemma Zone (ITE Southern Section, 1974)
**Type II DZ Boundaries**

- Driver decision making  
  Zeeger & Deen, 1978
- 90% of drivers stop
- 10% of drivers stop
- Time to stop line  
  Chang et al., 1985
  - 85% of drivers stop if > 3 sec
  - 99% of drivers go if < 2 sec
- Range 2.5 to 5.5 sec  
  Bonneson et al., 2002
- Confirmed 2.5 to 5.5  
  Gest et al., 2007
OSU Driving Simulator

Vehicle Trajectories – 1 Vehicle at 45 mph
30 Vehicle Trajectories – TTSL = 1 sec

30 Vehicle Trajectories – TTSL = 6 sec
30 Vehicle Trajectories – TTSL = 3.5 sec

Fuzzy DZ Model

<table>
<thead>
<tr>
<th></th>
<th>Predicted</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Stop</td>
<td>Go</td>
<td>% Correct</td>
<td>Total</td>
</tr>
<tr>
<td><strong>Position-Based Model</strong> (Observed)</td>
<td>Stop 145  11 93% 98%</td>
<td>Go 27 137 84% 88%</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Speed/Position-Based Model</strong> (Observed)</td>
<td>Stop 132  24 85% 89%</td>
<td>Go 12 152 93% 89%</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>TTSL-Based Model</strong> (Observed)</td>
<td>Stop 149 7 96% 90%</td>
<td>Go 25 139 85% 90%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### An Oregon Example: Visual Attention during Permitted LTs (Hurwitz et al., 2014)

<table>
<thead>
<tr>
<th>Signal Display</th>
<th>Indication Sequence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Four Section FYA Display</td>
<td><img src="image1" alt="Signal Display" /></td>
</tr>
<tr>
<td>Three Section FYA with a Bimodal Lens</td>
<td><img src="image3" alt="Signal Display" /> AND</td>
</tr>
</tbody>
</table>
**Simulated Experiment**

- 1 pedestrian walking away
- 4 pedestrians, two walking in each direction
- No pedestrians
- 1 pedestrian walking towards

**Eye Tracking**

- Eye movement consists of fixations and saccades
  - Fixations are points that are focused on during a short period of time
  - Saccades are the quick eye movements between fixations
  - The majority of visual data is acquired from fixations
- The Mobile Eye-XG system records a fixation when the subject’s eyes have paused in a certain position for more than 100 milliseconds
Simulated Permitted LT with conflicting vehs & peds

Fixations on FYA by Signal Configuration
An Oregon Example: Driver Comprehension of Right Turn Indications (Hurwitz et al., 2018)

What Does Your State Say?
This table shows comparison of states that permit or prohibit right turns on red arrow. For the majority of the states that allow a left turn on red from a one-way street to another one-way street, the same ruling would apply for a left red arrow.

Randomly Distributed Postcard Survey

- 399 responses
- 4% response rate
- Overall, survey demographic
  - Older
  - Whiter
  - More educated
- 98% Oregon licensed drivers
- 50% drive 10+ times a week
- 95% 10+ years driving
- 2.5% color blind
### Error Coding of Open Ended Survey Responses

<table>
<thead>
<tr>
<th>If respondents indicated that they would...</th>
<th>Correct</th>
<th>Partially Incorrect</th>
<th>Incorrect</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Steady Circular Green</strong></td>
<td>Turn right with caution after yielding to pedestrians in the crosswalk</td>
<td>Turn right without stopping but failed to state that they would yield to pedestrians if present in the crosswalk</td>
<td>Stop before turning</td>
</tr>
<tr>
<td><strong>Steady Green Arrow</strong></td>
<td>Turn right without stopping recognizing that the steady green arrow indication means a protected movement (or) Indicated that they would watch for pedestrians who may cross against the pedestrian Don't Walk signal</td>
<td>Check for pedestrians and turn right (or) slow down and check for pedestrians and other cross traffic but did not recognize the protected movement in either case</td>
<td>Stop before turning</td>
</tr>
<tr>
<td><strong>Steady Circular Red and Steady Red Arrow</strong></td>
<td>Come to a complete stop and complete the turn when they found a safe gap or remained stopped if they failed to find a gap</td>
<td>Stop or turn right, without providing additional details</td>
<td>Stop and remained stopped until the green indication</td>
</tr>
<tr>
<td><strong>Flashing Yellow Arrow</strong></td>
<td>Turn right with caution after yielding to pedestrians in crosswalk</td>
<td>Turn right without stopping or failed to state that they would yield to pedestrians if present in the crosswalk</td>
<td>Stop before turning</td>
</tr>
</tbody>
</table>

### Survey Open Ended

Imagine that you are approaching the intersection in **the lane farthest to the right and planning to TURN RIGHT**. What action would you take based on the current signal display? Please type your response in the box below and be as descriptive as possible.
Overall, n=399

- **Green Arrow**: 63.5% Did not recognize exclusive
- **Circular Green**: 73.1% Did not state check for peds
- **Flashing Yellow Arrow**: 76.6% Stop before turning
- **Red Arrow**: 52.1% Stop and stay stopped
- **Circular Red**: 83.2%

Steady Red and Flashing Yellow Arrow Multiple Choice

- **Stop and wait for a green indication before turning**: 1% Flashing Yellow Arrow, 47% Steady Red Arrow
- **Complete stop and find a gap before turning**: 23% Flashing Yellow Arrow, 53% Steady Red Arrow
- **Turn right cautiously without stopping**: 76% Flashing Yellow Arrow, 0% Steady Red Arrow
Steady Red and Flashing Yellow Arrow Multiple Choice

- Not at all Confident: 3% Flashing Yellow Arrow, 2% Steady Red Arrow
- Somewhat Confident: 6% Flashing Yellow Arrow, 7% Steady Red Arrow
- Neutral: 5% Flashing Yellow Arrow, 5% Steady Red Arrow
- Confident: 36% Flashing Yellow Arrow, 30% Steady Red Arrow
- Very Confident: 50% Flashing Yellow Arrow, 56% Steady Red Arrow

Red Ball and Red Arrow Comparison

- Overall (n = 395)
  - Different: 0% to 60%
  - Similar: 0% to 60%
Green Ball and Flashing Yellow Arrow Comparison

<table>
<thead>
<tr>
<th></th>
<th>Overall (n = 395)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Similar</td>
<td></td>
</tr>
<tr>
<td>Different</td>
<td></td>
</tr>
</tbody>
</table>

Primary Findings

- Good geographic coverage and number of responses
- Older drivers over-sampled
- Expected driver behavior with Steady Red Arrow not well understood
- FYA and CG
  - Both have good comprehension
  - FYA more incorrect, but fail safe (STOP)
  - CG more partially correct (fail to mention pedestrian)
  - CG and FYA strongly recognized “as different”
An Oregon Example: Right-Hooks and Situational Awareness (Hurwitz et al., 2015; 2017)

Types of Right-Hook Crashes

onset of the green indication
at a stop sign

cyclist passing motorist
motorist passing cyclist
Latter portion of green indication
Exp. 1: Right-Hook Crash Causality

- 67 Participated
- 16 Simulator Sickness
- 51 Usable
- 1,071 total-right turn scenarios

- Visual attention
- SAGAT responses
- Observed crashes
- Position and speed of vehicles, bicycles, and pedestrians

Crash Avoidance: Crashes

From 1,071 right turns, 26 collisions observed:
- 66% did not check mirror before turning
- 16% looked but didn’t see
- 18% assumed bike would yield or there was enough time
Crash Avoidance: Crashes

From 408 right turns, 28 near-collisions observed:
- 58% did not check mirror before turning
- 23% looked but didn't see
- 19% assumed bike would yield or there was enough time

Field Validation

- November 5, 2014 to February 12, 2015
- All days of week
- 144 hours
- Extraction of 43 events with measured TTC < 5 seconds
Comparison of All Field and Simulator PET/TTCs

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