Symposium on Traffic Safety

Drivers’ Responses – Getting a Better Number to Use and How to Apply It.

Jeff Muttart, Ph.D.
Crash Safety Solutions, LLC
DRIVERS' RESPONSES: GETTING A BETTER NUMBER TO USE AND HW TO APPLY IT

Jeffrey W. Muttart, Ph.D.

2018
Symposium on Traffic Safety
DISCLAIMER

- The information contained in this presentation is, to the best of our knowledge, authentic and reliable; the author gives no guarantee that he has exactly paraphrased prior research. The author acknowledges that other factors and procedures not discussed in this class may affect your conclusions and interpretation of these results.

- We cannot teach you in one week what it took years to learn – this presentation is a very small sample and should be treated as a starter.

ACKNOWLEDGMENTS

I would like to thank all those who have assisted in my research. This includes all co-authors, colleagues, and professors at the Universities of Hartford and Massachusetts. I would also like to give credit to my colleagues at Crash Safety Research Center, LLC including Lisa Ton, Erin Strout, Lynn Carangelo and Swaroop Dinakar.
Copyright

- These materials may be used by only the person who paid for attendance, or purchased the materials.
- Thus, the materials are for a single user only.
- Use of any part of this course material for any purpose other than reconstructing and investigating motor vehicle crashes by the single user is prohibited. No derivative works are allowed.
- Therefore, do not use this material to...
  - teach a class,
  - write a study or article,
  - for any other purpose without the written permission of the author.
- No materials herein may be shared without written permission. These materials are the intellectual property of CSS, LLC. If someone wishes to purchase these materials, please contact info@crashsafetysolutions.com
- The cost for these materials is $100 per user unless provided as part of an authorized course of study provided by, or sponsored by CSS, LLC.
Correct application of perception-response times

FOCUSING OUR ATTENTION ON THE RESEARCH OF DRIVERS RESPONSES TO EASILY IDENTIFIED IMMEDIATE HAZARDS (EMERGENCY RESPONSES)
Problem

- Problems
  - “blanket” or “abstract” 1.5 seconds – not associated with THIS case
  - Unknown starting point (road edge, stop line, when 1st seen)?
  - Unknown end – 1st reaction? Brake reaction? Up to 0.4 g, up to 0.7 g?

- In 2017, there were several Daubert hearings related to PRT
  - “…a blanket PRT of 1.5 seconds – such as was used by # in his analysis – was overly simplistic and inappropriate under the circumstances because PRT is a discipline that is very dependent on the specific environment and hazard presented to a particular driver.”
  - Must used accepted research
  - Must apply the research properly to the facts of the case
Musical Scale
Good information versus bad information
DIFFERENCE BETWEEN EXPECTED AND UNEXPECTED IS BASED UPON INFORMATION!!!
More information is good until...

- Information... more is better
- Until we get too much

Capabilities

Minimum Threshold

BAD!

BAD!
Example of too much information

Text messaging and responding to an unexpected hazard

Minimum necessary information for recognition

Ped dart out when negotiating a curve or intersection when involved in a hands free argument

Average PRT $0 \to \infty$
Normal range (Standard deviation)
Texting
Add 0.7 s
(If they respond at all)
Example of too little information

Minimum necessary Information for recognition

Also, Pedestrian dressed in black at night

Vehicle or pedestrian more than 8 feet from road edge

Vehicle stopped facing forward in travel lane on high speed highway

CANNOT apply PRT...

Cannot respond to something That is unrecognizable
Problem – so you know?

1. What is PRT and what phases are included?
2. When does PRT start?
3. When does PRT end?
4. How each of the above might change for different crash types?
5. Otherwise... you are
6. Making up!
Each crash type should be addressed separately

Path Intrusions:

CSRC, LLC Added Crash Types

Lead vehicle:
- Lead vehicle stopped < 2 seconds
- Lead vehicle stopped > 2 seconds
- Lead vehicle traveling slower
- Lead vehicle decelerating

?? Human limitation??
?? Human error??

National Motor Vehicle Crash Causation Study Crash Types
Response to a vehicle ahead

<table>
<thead>
<tr>
<th>Classification</th>
<th>Scenario</th>
<th>Weighted Frequency</th>
<th>% of Category</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rear-end</td>
<td>Lead Vehicle - Stopped</td>
<td>254,316</td>
<td>72%</td>
</tr>
<tr>
<td></td>
<td>Lead Vehicle - Decelerating</td>
<td>55,326</td>
<td>16%</td>
</tr>
<tr>
<td></td>
<td>Lead Vehicle - Moving</td>
<td>42,522</td>
<td>12%</td>
</tr>
<tr>
<td></td>
<td>TOTAL</td>
<td>352,163</td>
<td>100%</td>
</tr>
<tr>
<td>All Other Frontal</td>
<td>LTAP/OD</td>
<td>379,774</td>
<td>24%</td>
</tr>
<tr>
<td></td>
<td>Road Departure - no maneuver</td>
<td>265,943</td>
<td>16%</td>
</tr>
<tr>
<td></td>
<td>SCP</td>
<td>260,653</td>
<td>16%</td>
</tr>
<tr>
<td></td>
<td>Vehicle Turning at Junction</td>
<td>260,164</td>
<td>16%</td>
</tr>
<tr>
<td></td>
<td>Lane Departure - no maneuver</td>
<td>96,606</td>
<td>6%</td>
</tr>
<tr>
<td></td>
<td>All Others</td>
<td>352,077</td>
<td>22%</td>
</tr>
<tr>
<td></td>
<td>TOTAL</td>
<td>1,615,217</td>
<td>100%</td>
</tr>
</tbody>
</table>

| ALL                  |                            | 1,967,380          |               |
driver error - slips or errors of execution or mistakes

Information? – Sudden change in following distance
Brake lights, traffic slowing, = BRAKE STUPID!
### Low Speed Rear End & Close Following Perception-Response Times (Day & Night)

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>PRT (AVG)</th>
<th>PRT (Median)</th>
<th>85th Percentile</th>
<th>Crashes</th>
<th>Nighttime</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Routine Rear-end</strong> (not looming)</td>
<td>13</td>
<td>1.1 s</td>
<td>1.0 s</td>
<td>1.3 s</td>
<td>7</td>
<td>2</td>
</tr>
</tbody>
</table>

Naturalistic data from Muttart, 2003, 2005
Closing Speed is not at issue at intersections

Muttart, Messerschmidt & Gillen, 2005
Human error - (Inability to detect or diagnose closing speed)
Looming: > 40 mph Closing on Straight Multi-lane Road

Average driver starts maneuver ~ 120 ft (36.6 m)
This driver was better than that
Path Intrusion Information factors to consider

Which scenarios offer drivers the least information?

<table>
<thead>
<tr>
<th>Information Factor</th>
<th>A</th>
<th>B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Where was hazard</td>
<td>Directly ahead</td>
<td>Right or left or ahead</td>
</tr>
<tr>
<td>Natural lighting</td>
<td>Day</td>
<td>Night</td>
</tr>
<tr>
<td>Movement</td>
<td>Target was always moving</td>
<td>Target was stationary</td>
</tr>
<tr>
<td>Topography</td>
<td>Intersection, or area</td>
<td>Straight road or highway</td>
</tr>
<tr>
<td></td>
<td>where there was a greater conflict</td>
<td></td>
</tr>
</tbody>
</table>
Previously obstructed Hazard 1st seen in the road

START: APPROXIMATELY ½ THE OBJECT IS RECOGNIZABLE (3 FT OF FRONT)
END: BRT – BRAKING; PRT - ~0.4 G

AVERAGE PRT (PERCEPTION-RESPONSE TIME = 1.0 SEC +/- 0.36 SEC
85% OF DRIVERS RESPOND FASTER THAN 1.4 SEC
95% OF DRIVERS RESPOND FASTER THAN 1.7 SEC
What if the Principle Other Unit is Already In the Road When First Seen?
When to Start the PRT Clock
Pre-recognition
Recognition
From between cars - day
Steers Left / Brakes 1.0 s later
Average = 1.0 s +/- 0.36 s
References: Sudden appearing path intrusion


# Rule of Thumb PRTs

<table>
<thead>
<tr>
<th>Crash type</th>
<th>Start</th>
<th>End</th>
<th>PRT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sudden slowing LV</td>
<td>Brake lights of LV or 0.006 r/s</td>
<td>0.4 g</td>
<td>1.0 +/- .32 s</td>
</tr>
<tr>
<td>High speed closing</td>
<td>Looming threshold</td>
<td>0.4 g</td>
<td>Expect ~ 120 ft of hard braking or steering</td>
</tr>
<tr>
<td>Sudden appearance</td>
<td>3 ft. / 1 m of target in sightline</td>
<td>0.4 g</td>
<td>1.0 +/- .36 s</td>
</tr>
</tbody>
</table>

When were brakes applied?
Subtract 0.25 s

- EASILY identifiable
  - Know what it is
  - Know where it is
  - know that it is headed directly toward path
- Requires an emergency response

Requirements with all PRTs

- Ising, et al., 2012
- Mazzea et al., 1999
- Muttart, 2003, 2005
- Goudie et al. (SAE)
**Left turn or through movement intruder**

**START:** VEHICLE: STOP LINE OR SIMILAR LOCATION
PEDESTRIAN: .5 M (1.5 FT) FROM ROAD EDGE (I.E., CURB)

**END:** BRT – BRAKE; PRT - ~0.4 G
Path Intrusion

An object that is traveling or facing a different direction than the subject driver and enters the driver’s path

Primary Factors
1. Intersection vs. straight road
2. Eccentricity
   1. How many lanes
   2. How fast is the intruder
3. PRT, BRT, pRT???
4. Manual secondary task

NOT Factors
1. Headway
2. Lanes
Side intrusion starting from a near road edge/stop line

<table>
<thead>
<tr>
<th></th>
<th>Day</th>
<th>Night</th>
</tr>
</thead>
<tbody>
<tr>
<td>Straight</td>
<td>1.34 sec</td>
<td>1.80 sec</td>
</tr>
<tr>
<td>Curve, cued, intersection</td>
<td>1.55 sec</td>
<td>2.05 sec</td>
</tr>
</tbody>
</table>

Plus or minus 35%
Path Intrusion Intersection
Night – 1.6 seconds works!
1.6 s later – the only common crash type where 1.5 - 1.6 s is correct
Pedestrian Intrusion – Intersection - day
0.8 s – hard braking
0.8 s – hard braking
Expected ~ 1.1 s +/- 0.4 s
Straight road – day
Average PRT – 1.8 sec
85% respond faster than 2.4 sec
95% respond faster than 3.0 sec
This driver’s PRT ~ 3.2 sec
(much slower than average)
Path Intrusion

PEDESTRIANS
Barrett et al 1968
- Started response time when pedestrian emerged from a roadside shed
Started at the last landing foot before entering road
One study started the clock at the wall

When PRT was measured as described earlier, Lubbe = IDRR

Lubbe et al, 2015 Intersection – day – expect BRT = 1.1 s – he reported 1.4 s can you explain why he was higher?
Naturalistic data from Muttart, 2003, 2005
(Other unit started from stop: Day 19; Night 7)
References: Vehicle path Intrusions


References: Pedestrian path Intrusions


# Rule of Thumb PRTs

<table>
<thead>
<tr>
<th>Crash type</th>
<th>Start</th>
<th>End</th>
<th>PRT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sudden slowing LV</td>
<td>Brake lights of LV or 0.006 r/s</td>
<td>0.4 g</td>
<td>1.0 +/- .32 s</td>
</tr>
<tr>
<td>High speed closing</td>
<td>Looming threshold</td>
<td>0.4 g</td>
<td>Expect ~ 120 ft of hard braking or steering</td>
</tr>
<tr>
<td>Sudden appearance</td>
<td>3 ft. / 1 m of target in sightline</td>
<td>0.4 g</td>
<td>1.0 +/- .36 s</td>
</tr>
<tr>
<td>Straight – day *(lane side)</td>
<td></td>
<td>0.4 g</td>
<td>1.8 +/- .63</td>
</tr>
<tr>
<td>Straight – night*</td>
<td>Ped – 1.5 ft (0.5 m) before curb</td>
<td>0.4 g</td>
<td>2.1 +/- .71</td>
</tr>
<tr>
<td>Intersection/cued – day*</td>
<td>Vehicle – stop line or 6.5 ft (2 m) from curb (edge of road)</td>
<td>0.4 g</td>
<td>1.3 +/- .51</td>
</tr>
<tr>
<td>Intersection/cued – night*</td>
<td></td>
<td>0.4 g</td>
<td>1.6 +/- .73</td>
</tr>
</tbody>
</table>

When were brakes applied?
Subtract 0.25 s

- Ising, et al., 2012
- Mazzae et al., 1999
- Muttart, 2003, 2005
- Goudie et al. (SAE)
Where to start PRT

WHAT IS STARTING FROM STOP... INTRUDER INITIALLY SLOW

WHAT IF INTRUDER IS COMING IN HOT! – SHOULD DRIVER RECOGNIZE THIS BEFORE INTRUDER REACHES STOP LINE?
If I wanted to measure the time to fill a cup, would it matter where I start?

Study A

Start

2.5 sec

End

Study B

Start

1.3 sec

End
Study: Time to fill cup
Which study (A or B) best applies?

Estimate the time it would take to fill each cup

~ stop line
~ sudden appearance in road
All Response Times are Not The Same

Start at one of three locations

Experimenter C starts the clock here
Experimenter B starts the clock here
Experimenter A starts the clock here

Start at one of three locations when brake lights go on

DO NOT use a PRT that started at B to a starting point at A or C
Two phase stop – Consistent with Harwood et al.
CDL Driver - Two phase stop – secondary glance
High speed intrusion

BOTH VEHICLES ENTER THE INTERSECTION AT SPEED

EXPECT 0.4 TO 0.7 SECONDS OF PRE-IMPACT BRAKING AND MOST WILL CRASH
What if a car comes in without slowing? Do we recognize it earlier?... NO! We assume drivers will obey the law.
Anticipation (hope?) – that side road drivers will stop
Braking 0.3 s before impact
Anticipation (hope?) – that side road drivers will stop
Braking 0.3 s before impact
### AT SPEED INTRUSIONS –


**Greater eccentricity**  
Accounts for Expectation that Other driver will obey the law  
PRTs are fast, but not fast enough

<table>
<thead>
<tr>
<th></th>
<th>Marshall</th>
<th>Perron</th>
</tr>
</thead>
<tbody>
<tr>
<td>POU Speed</td>
<td>45 mph</td>
<td>60 km/h – 37.3 mph</td>
</tr>
<tr>
<td>Visible</td>
<td>2.49 s</td>
<td>6.1 s</td>
</tr>
<tr>
<td></td>
<td>Warning at 1.2 s before visible</td>
<td></td>
</tr>
<tr>
<td>Speed reduction (median)</td>
<td>Not mentioned</td>
<td>5 km/h (3 mph)</td>
</tr>
<tr>
<td>Median response before impact</td>
<td>0.4 s</td>
<td>0.7 s</td>
</tr>
<tr>
<td>Crashed</td>
<td>91%</td>
<td>89%</td>
</tr>
</tbody>
</table>

- [Image of car and road with speed and time indicators: 2.5 sec, 6.1 sec]
References: High speed path Intrusion


# Rule of Thumb PRTs

<table>
<thead>
<tr>
<th>Crash type</th>
<th>Start</th>
<th>End</th>
<th>PRT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sudden slowing LV</td>
<td>Brake lights of LV or 0.006 r/s</td>
<td>0.4 g</td>
<td>1.0 +/- .32 s</td>
</tr>
<tr>
<td>Sudden appearance</td>
<td>3 ft. / 1 m of target in sightline</td>
<td>0.4 g</td>
<td>1.0 +/- .36 s</td>
</tr>
<tr>
<td>Straight – day <em>(lane side)</em></td>
<td>Ped – 1.5 ft (0.5 m) before curb</td>
<td>0.4 g</td>
<td>1.8 +/- .63</td>
</tr>
<tr>
<td>Straight – night*</td>
<td>Vehicle – stop line or 6.5 ft (2 m) from curb (edge of road)</td>
<td>0.4 g</td>
<td>2.1 +/- .71</td>
</tr>
<tr>
<td>Intersection/cued – day*</td>
<td></td>
<td>0.4 g</td>
<td>1.3 +/- .51</td>
</tr>
<tr>
<td>Intersection/cued – night*</td>
<td></td>
<td>0.4 g</td>
<td>1.6 +/- .73</td>
</tr>
<tr>
<td>High speed Intrusion</td>
<td>Stop line or 6.5 ft (2 m) from curb (edge of road)</td>
<td>0.4 g</td>
<td>0.8 +/- .7 s Speed/Accuracy</td>
</tr>
</tbody>
</table>

When were brakes applied? Subtract 0.25 s

*See previously stated requirements For PRT

Ising, et al., 2012
Mazzae et al., 1999
Muttart, 2003, 2005
Goudie et al. (SAE)
Path Intrusion from same direction

VEHICLE CHANGING LANES OR CUT-OFF

START: 1st LATERAL MOVEMENT OF THE INTRUDER

END: BRT-BRAKING; PRT – 0.4 G
Sideswipe - same

A VEHICLE that is traveling the same direction as the subject driver and enters the driver’s path

**Primary Factors**
1. No. Lanes changed
2. Eccentricity
   1. How many lanes
   2. How fast is the intruder traveling
3. Day versus night

**NOT Factors**
1. Headway
2. Intersection vs. straight road
Path Intrusion from same direction vehicle (Cut-off)
Noticeable deceleration
1.2 seconds –
how did he compare?
Path Intrusion from Same Direction: Cut-off

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>PRT</th>
<th>SD</th>
<th>CV</th>
<th>Crashes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Day - Next lane</td>
<td>24</td>
<td>0.93</td>
<td>0.34</td>
<td>0.37</td>
<td>10</td>
</tr>
<tr>
<td>Day - &gt;1 lane</td>
<td>28</td>
<td>1.13</td>
<td>0.41</td>
<td>0.37</td>
<td>20</td>
</tr>
<tr>
<td>Night - Next lane</td>
<td>6</td>
<td>1.32</td>
<td>0.49</td>
<td>0.37</td>
<td>1</td>
</tr>
<tr>
<td>Night - &gt; 1 lane</td>
<td>22</td>
<td>1.40</td>
<td>0.45</td>
<td>0.32</td>
<td>11</td>
</tr>
</tbody>
</table>

MeanCV = 0.35

Naturalistic data from Muttart, 2003, 2005
References: Path Intrusion from same direction (cut-off)


## Rule of Thumb PRTs

<table>
<thead>
<tr>
<th>Crash type</th>
<th>Start</th>
<th>End</th>
<th>PRT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sudden slowing LV</td>
<td>Brake lights of LV or 0.006 r/s</td>
<td>0.4 g</td>
<td>1.0 +/- .32 s</td>
</tr>
<tr>
<td>Sudden appearance</td>
<td>3 ft. / 1 m of target in sightline</td>
<td>0.4 g</td>
<td>1.0 +/- .36 s</td>
</tr>
<tr>
<td>Straight – day *(lane side)</td>
<td>Ped – 1.5 ft (0.5 m) before curb</td>
<td>0.4 g</td>
<td>1.8 +/- .63</td>
</tr>
<tr>
<td>Straight – night*</td>
<td>Vehicle – stop line or 6.5 ft (2 m) from curb</td>
<td>0.4 g</td>
<td>2.1 +/- .71</td>
</tr>
<tr>
<td>Intersection/cued – day*</td>
<td>Vehicle – stop line or 6.5 ft (2 m) from curb (edge of road)</td>
<td>0.4 g</td>
<td>1.3 +/- .51</td>
</tr>
<tr>
<td>Intersection/cued – night*</td>
<td></td>
<td>0.4 g</td>
<td>1.6 +/- .73</td>
</tr>
<tr>
<td>High speed Intrusion</td>
<td>Stop line or 6.5 ft (2 m) from curb (edge of road)</td>
<td>0.4 g</td>
<td>0.8 +/- .7 s</td>
</tr>
<tr>
<td>Same direction day - next lane</td>
<td></td>
<td>0.4 g</td>
<td>0.9 +/- .34</td>
</tr>
<tr>
<td>Same direction day - 2 lanes</td>
<td>First lateral movement that lead directly to the intrusion</td>
<td>0.4 g</td>
<td>1.1 +/- .41</td>
</tr>
<tr>
<td>Same direction night - next lane</td>
<td></td>
<td>0.4 g</td>
<td>1.3 +/- .49</td>
</tr>
<tr>
<td>Same direction night – 2 lanes</td>
<td></td>
<td>0.4 g</td>
<td>1.4 +/- .45</td>
</tr>
</tbody>
</table>

When were brakes applied? Subtract 0.25 s

• See previously stated requirements For PRT
<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>69</td>
<td>68</td>
<td>70u</td>
</tr>
<tr>
<td>71u</td>
<td>72u</td>
<td></td>
</tr>
</tbody>
</table>

| 68: Turn Across Path: Initial Opposite Directions (Left/Right) | 70u: Turn Across Path: Initial Same Directions (Turning Right) | 72u: Turn Across Path: Initial Same Directions (Turning Left) |
| 69: Turn Across Path: Initial Opposite Directions (Going Straight) | 71u: Turn Across Path: Initial Same Directions (Going Straight) | 73u: Turn Across Path: Initial Same Directions (Going Straight) |

**Left turn across path-opposite direction / head-on / U-turn**

**START:** 1\(^{st}\) LATERAL MOVEMENT THAT LEADS TO THE INTRUSION

**END:** BRT – BRAKE; PRT - ~0.4 G
D’Addario, 2014
Brake Resp Time = 2.05 s

LTAP-OD Day – No Intervening vehicle
LTAP-OD – Day – No Intervening vehicle 2.2 s
Average 1.8 s +/- 0.5 s (See D’Addario, 2015)
1st lateral movement to start of steering = 1.8 s
Head-on
Start- 1$^{st}$ lateral movement OR when it is clear the vehicle is in lane – whichever is last
U-Turn

Unbeknownst to each driver, another live subject driver was approaching head-on in daylight at an average closing speed of near 72.1 mph.

From 1st visible over crest, steer response times were an average of 1.65 +/- 0.17 second.

Steering time was approximately 0.38 second.

# Rule of Thumb PRTs

<table>
<thead>
<tr>
<th>Crash type</th>
<th>Start</th>
<th>End</th>
<th>PRT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sudden slowing LV</td>
<td>Brake lights of LV or 0.006 r/s</td>
<td>0.4 g</td>
<td>1.0 +/- .32 s</td>
</tr>
<tr>
<td>Sudden appearance</td>
<td>3 ft. / 1 m of target in sightline</td>
<td>0.4 g</td>
<td>1.0 +/- .36 s</td>
</tr>
<tr>
<td>Sudden appearance</td>
<td>3 ft. / 1 m of target in sightline</td>
<td>0.4 g</td>
<td>1.0 +/- .36 s</td>
</tr>
<tr>
<td>Sudden appearance</td>
<td>3 ft. / 1 m of target in sightline</td>
<td>0.4 g</td>
<td>1.0 +/- .36 s</td>
</tr>
<tr>
<td>Straight – day *(lane side)</td>
<td>Ped – 1.5 ft (0.5 m) before curb</td>
<td>0.4 g</td>
<td>1.8 +/- .63 s</td>
</tr>
<tr>
<td>Straight – night*</td>
<td>Vehicle – stop line or 6.5 ft (2 m) from curb (edge of road)</td>
<td>0.4 g</td>
<td>2.1 +/- .71 s</td>
</tr>
<tr>
<td>Intersection/cued – day*</td>
<td>Vehicle – stop line or 6.5 ft (2 m) from curb (edge of road)</td>
<td>0.4 g</td>
<td>1.3 +/- .51 s</td>
</tr>
<tr>
<td>Intersection/cued – night*</td>
<td>Vehicle – stop line or 6.5 ft (2 m) from curb (edge of road)</td>
<td>0.4 g</td>
<td>1.6 +/- .73 s</td>
</tr>
<tr>
<td>High speed Intrusion</td>
<td>Stop line or 6.5 ft (2 m) from curb (edge of road)</td>
<td>0.4 g</td>
<td>0.8 +/- .7 s</td>
</tr>
<tr>
<td>Same direction day - next lane</td>
<td>First lateral movement that lead directly to the intrusion</td>
<td>0.4 g</td>
<td>0.9 +/- .34 s</td>
</tr>
<tr>
<td>Same direction day - 2 lanes</td>
<td>First lateral movement that lead directly to the intrusion</td>
<td>0.4 g</td>
<td>1.1 +/- .41 s</td>
</tr>
<tr>
<td>Same direction night - next lane</td>
<td>First lateral movement that lead directly to the intrusion</td>
<td>0.4 g</td>
<td>1.3 +/- .49 s</td>
</tr>
<tr>
<td>Same direction night – 2 lanes</td>
<td>First lateral movement that lead directly to the intrusion</td>
<td>0.4 g</td>
<td>1.4 +/- .45 s</td>
</tr>
<tr>
<td>Left turn from opposite direction / Head-on / U-turns</td>
<td>First lateral movement that lead directly to the intrusion</td>
<td>0.4 g</td>
<td>Use straight road PRT</td>
</tr>
<tr>
<td>High speed closing</td>
<td>Looming threshold</td>
<td>0.4 g</td>
<td>Expect ~ 120 ft of hard braking or steering</td>
</tr>
</tbody>
</table>

- See previously stated requirements For PRT
- When were brakes applied? Subtract 0.25 s

© Jeffrey W Muttart 2018
Want to be more precise than rule-of-thumb?

- Learn when PRT cannot be used
  - Night recognition
  - CAPLETs
    - Contrast
    - Anticipation (relevance, experience, shape of object, ...)
- Account for more variables
  - Rules of thumb are very general
  - PRT will vary from Rules of thumb
    - Driver attention
    - Visual angle of the target
    - Speed of intruder
    - When the driver’s foot already rests on the brake
    - When not driving
    - When the driver knows what is coming (almost never in real-life)
Nighttime Recognition

- CONTRAST
- ANTICIPATION
- PATTERN
- LIGHTING
- ECCENTRICITY
- TIME OF EXPOSURE
- SIZE

CAPLETS

Information necessary for recognition
High & Low Beam Headlight aim (SAE J599)
Nighttime Recognition Distance Unlit Open Roads
(test track tests result in much greater distances)

Assumptions:

- The object is a recognizable shape (not a pedestrian on the ground, a pile of dirt, the underside of a vehicle, or some object with a definite shape)

- The object is not a self-illuminated pattern (entire outside edge is not lighted, like the Eiffel Tower)

- If an upright vehicle, add 52 ft / 15.8 m

- If unfamiliar shape (pedestrian on the ground, underside of a vehicle, etc.) subtract 108 ft / 33 m

SAE Paper 2015-01-0787

Figure 2. Nighttime recognition distance on unlit roads for recognizable shaped, non-reflective objects (pedestrians, animals)
Pattern / Size

More information – A well marked trailer ahead– or the underside of a trailer across the road.

Deceleration started 1.62 sec before impact.
On June 12, 2007 at approx. 11:14 p.m., Vehicle #1, a 2000 Nissan flatbed tow truck from Henry's Wrecker Service, being driven by D, was traveling southbound on the Beltway, just south of Route 50. Flatbed was empty, he was not towing a vehicle. He was attempting to make an illegal u-turn in the crossover designated for emergency vehicles only. There is a sign on the left shoulder near jersey barrier that clearly states, "FOR USE OF AUTHORIZED AND EMERGENCY VEHICLES ONLY."
Family with Flashlight
Generally, age has made a difference. But what about **THIS** driver?

Theoretical distribution of responses for young versus old driver participants.
Summary of PRT / Night Recognition

Drivers’ responses varied due to actionable information to the driver.
# Rule of Thumb PRTs

<table>
<thead>
<tr>
<th>Crash type</th>
<th>Start</th>
<th>End</th>
<th>PRT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sudden slowing LV</td>
<td>Brake lights of LV or 0.006 r/s</td>
<td>0.4 g</td>
<td>1.0 +/- .32 s</td>
</tr>
<tr>
<td>Sudden appearance</td>
<td>3 ft. / 1 m of target in sightline</td>
<td>0.4 g</td>
<td>1.0 +/- .36 s</td>
</tr>
<tr>
<td>Straight – day *(lane side)</td>
<td>Ped – 1.5 ft (0.5 m) before curb</td>
<td>0.4 g</td>
<td><strong>1.8 +/- .63 s</strong></td>
</tr>
<tr>
<td>Straight – night*</td>
<td>Vehicle – stop line or 6.5 ft (2 m) from curb (edge of road)</td>
<td>0.4 g</td>
<td><strong>2.1 +/- .71 s</strong></td>
</tr>
<tr>
<td>Intersection/cued – day*</td>
<td>Vehicle – stop line or 6.5 ft (2 m) from curb (edge of road)</td>
<td>0.4 g</td>
<td>1.3 +/- .51 s</td>
</tr>
<tr>
<td>Intersection/cued – night*</td>
<td>Vehicle – stop line or 6.5 ft (2 m) from curb (edge of road)</td>
<td>0.4 g</td>
<td>1.6 +/- .73 s</td>
</tr>
<tr>
<td>High speed Intrusion</td>
<td>Stop line or 6.5 ft (2 m) from curb (edge of road)</td>
<td>0.4 g</td>
<td>0.8 +/- .7 s</td>
</tr>
<tr>
<td>Same direction day - next lane</td>
<td>First lateral movement that lead directly to the intrusion</td>
<td>0.4 g</td>
<td>0.9 +/- .34 s</td>
</tr>
<tr>
<td>Same direction day - 2 lanes</td>
<td>First lateral movement that lead directly to the intrusion</td>
<td>0.4 g</td>
<td>1.1 +/- .41 s</td>
</tr>
<tr>
<td>Same direction night - next lane</td>
<td>First lateral movement that lead directly to the intrusion</td>
<td>0.4 g</td>
<td>1.3 +/- .49 s</td>
</tr>
<tr>
<td>Same direction night – 2 lanes</td>
<td>First lateral movement that lead directly to the intrusion</td>
<td>0.4 g</td>
<td>1.4 +/- .45 s</td>
</tr>
<tr>
<td>Left turn from opposite direction / Head-on / U-turns</td>
<td>First lateral movement that lead directly to the intrusion</td>
<td>0.4 g</td>
<td>Use straight road PRT</td>
</tr>
<tr>
<td>High speed closing</td>
<td>Looming threshold</td>
<td>0.4 g</td>
<td>Expect ~ 120 ft of hard braking or steering</td>
</tr>
</tbody>
</table>

When were brakes applied? Subtract 0.25 s

- See previously stated requirements For PRT
Nighttime Recognition Distance Unlit Open Roads
(test track tests result in much greater distances)

Assumptions:

- The object is a recognizable shape (not a pedestrian on the ground, a pile of dirt, the underside of a vehicle, or some object with a definite shape)
- The object is not a self-illuminated pattern (entire outside edge is not lighted, like the Eiffel Tower)
- If an upright vehicle, add 52 ft / 15.8 m
- If unfamiliar shape (pedestrian on the ground, underside of a vehicle, etc.) subtract 108 ft 33 m

SAE Paper 2015-01-0787

Figure 2. Nighttime recognition distance on unlit roads for recognizable shaped, non-reflective objects (pedestrians, animals)