What NDSs Tell Us About Driver Behavior

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VTTI has conducted 100s of NDS analyses assessing driver behavior and performance. Examples:

- Research (NHTSA): Naturalistic study dedicated to distraction relative to cell phone and portable mobile device use
- Research (Various sponsors): Analyzed existing naturalistic data for trucks and light-vehicle age cohorts to determine secondary task prevalence and risk
- Research (AAAFTS): Drowsiness prevalence and risk
- Modeling and Simulation (Various sponsors): Differences in driver demographics; driver reaction to near-crash events

Research Methods

Naturalistic

Experimental

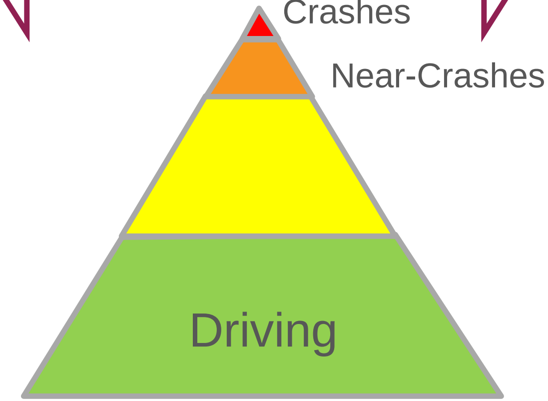
Controlled and safe experiments
Lab, Test Track, Simulator
Manipulate an independent variable
Measure a dependent variable

Epidemiological

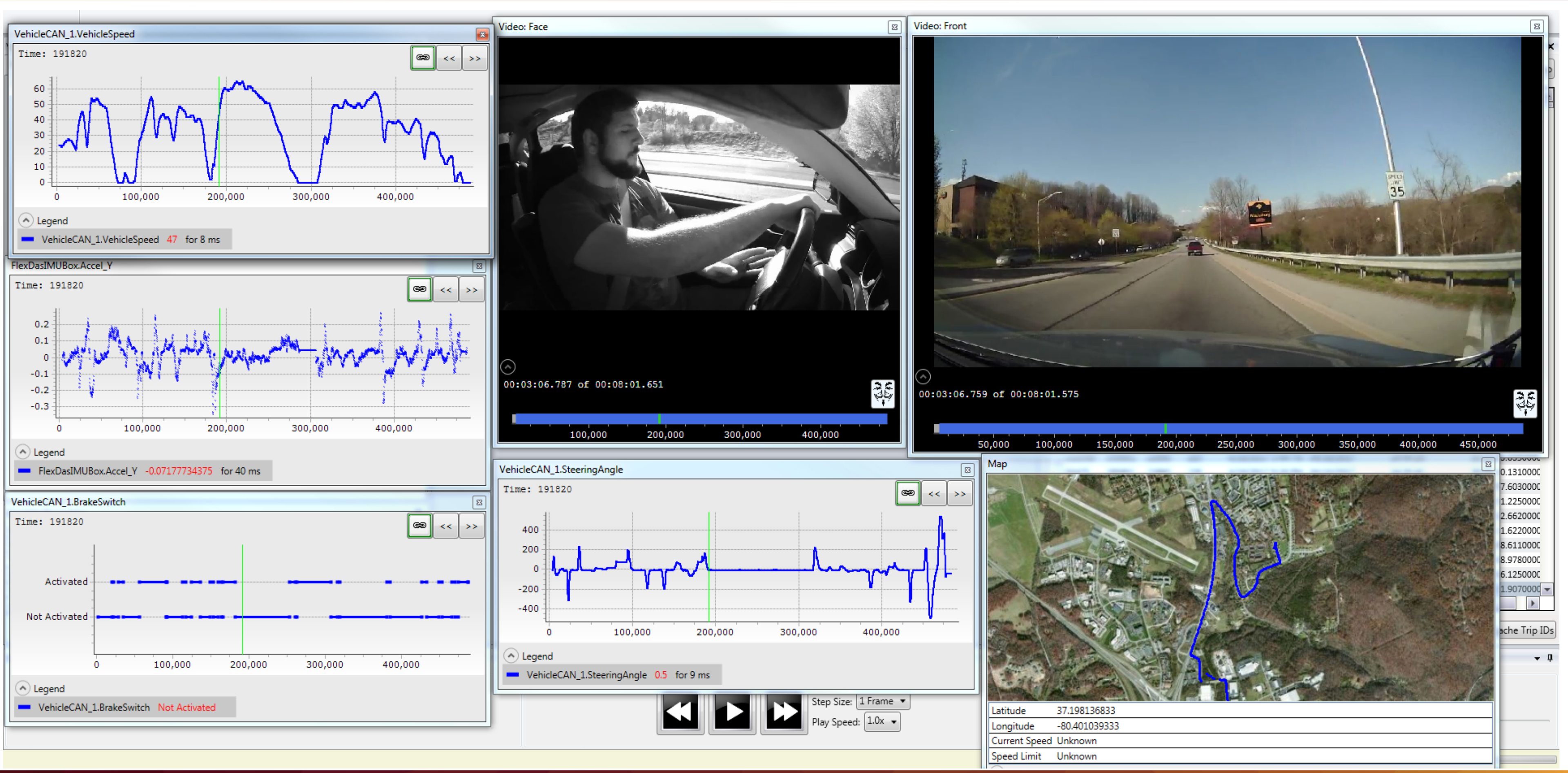
Passive collection
Naturally occurring events
Sampling strategies
Health sciences

TRANSPORTATION INSTITUTE
VIRGINIA TECH.

- Use this vehicle as you normally would
- Long duration

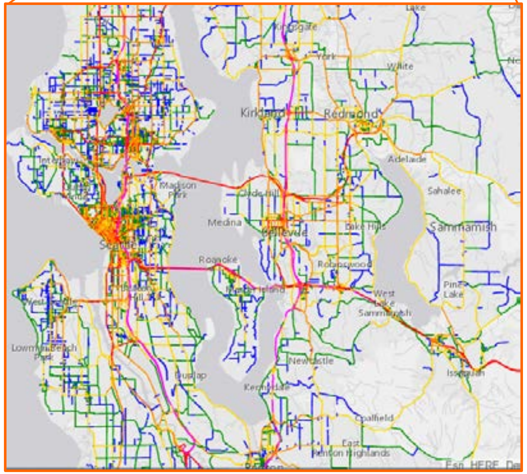


~70M miles of data
Cars, Trucks, Motorcycles


VehicleCAN_1.VehicleSpeed
Time: 191820
Legend
VehicleCAN_1.VehicleSpeed 47 for 8 ms
FlexDasIMUBox.Accel_Y
Time: 191820
Legend
FlexDasIMUBox.Accel_Y -0.07177734375 for 40 ms
VehicleCAN_1.BrakeSwitch
Time: 191820
Activated
Not Activated
Legend
VehicleCAN_1.BrakeSwitch Not Activated
Video: Face
00:03:06.787 of 00:08:01.651
Video: Front
00:03:06.759 of 00:08:01.575
VehicleCAN_1.SteeringAngle
Time: 191820
Legend
VehicleCAN_1.SteeringAngle 0.5 for 9 ms
Step Size: 1 Frame
Play Speed: 1.0x
Map
Latitude 37.198136833
Longitude -80.401039333
Current Speed Unknown
Speed Limit Unknown

SHRP 2 Naturalistic Study

- 3,542 drivers
- Cars, trucks, SUVs
- 6 locations
- ~1 yr. per participant
- ~6M trips
- 32M miles
- ~1M hours
- Continuous video



VTTI Naturalistic Studies

- U.S.
- Canada
- China
- Australia

Driver crash risk factors and prevalence evaluation using naturalistic driving data

- *Proceedings of the National Academy of Sciences* (January 2016)
- First analysis to use 905 property-damage and injurious crashes collected as part of a NAS five-year study (SHRP 2 NDS)
- Looked at observable impairment, driver performance error, driver judgment error, and observable driver distraction (e.g., not "voice-only")
- Comparison baselines included *only* alert, attentive, and non-impaired driving ("model driving")
  - ~45% of baseline cases qualified as "model"
  - Provides a comparison to assess crash risk relative to "just driving" to detect crash-causing performance decrements
  - These odds ratios (ORs) will generally be higher than an "all-driving" comparison

Driver crash risk factors and prevalence evaluation using naturalistic driving data

- Results definitively show a distraction “epidemic,” with HH electronic devices having high use rates and risk
  - 52% of baseline cases: Drivers were doing something other than “just driving”
  - Just prior to 68% of crashes: Drivers were doing something other than “just driving”
  - 6.8% of baseline cases: HH cell phone use occurred
- Results have important implications for distraction interactions
  - 9.8 OR = Driving in observable emotional state (anger, sadness, crying, and/or emotional agitation)
  - ~10% of baseline cases: Some kind of driving performance or judgment error occurred (includes common factors like speeding, failure to signal, rolling stops)
    - Some of the distraction crashes also had an error
    - Whether or not the error was independent of the distraction or the distraction led to the error was not analyzed

Driver crash risk factors and prevalence evaluation using naturalistic driving data

- Results only shown for those tasks associated with at least one crash event
  - Missing items: Applying makeup, donning clothing, several “no-hands” combined tasks that have been alluded to as issues over the years
  - Essentially includes anything (even very low prevalence cases) where an OR could be computed
- Results tend to show that tasks requiring visual glances away from the roadway have higher ORs

	O.R. (95% CI)	Baseline Prevalence
*Observable Impairment**		
Overall	5.2 (3.8 - 7.1)	1.92%
Drug/alcohol	35.9 (17.0 – 75.8)	0.08%
Drowsiness/fatigue	3.4 (2.3 - 5.1)	1.57%
Emotion (anger, sadness, crying, and/or emotional agitation)	9.8 (5.0 – 19.0)	0.22%
Driver Performance Error		
Overall	18.2 (14.8 – 22.3)	4.81%
Major error sub-categories (observed in crash and baseline events)		
Apparent inexperience with vehicle/roadway	204.5 (111.1 – 376.6)	0.07%
Blind spot error	55.1 (21.6 – 140.6)	0.05%
Improper turn	92.1 (68.8 – 123.4)	0.51%
Right-of-way error	936.1 (123.8 – 7078.3)	0.01%
Signal violation	28.3 (15.9 – 50.2)	0.19%
Stop/yield sign violation	7.4 (4.9 – 11.4)	1.05%
Wrong side of road	22.3 (12.0 - 41.5)	0.19%
Driving too slowly	2.3 (1.1 – 4.8)	0.97%
Sudden or improper braking/stopping	247.8 (53.1 - 1156.2)	0.01%
Failed to signal	2.5 (1.5 - 4.0)	2.27%
Driver Momentary Judgment Error (Speeding/Aggressive Driving)		
Overall	11.1 (9.0 - 13.8)	4.22%
Aggressive driving (general observed behavior)	34.8 (17.2 – 70.5)	0.10%
Speeding (over limit and too fast for conditions)	12.8 (10.1 - 16.2)	2.77%
Speeding/unsafe in work zone	14.2 (3.9 – 52.0)	0.05%
Illegal/unsafe passing	14.4 (7.2 - 28.8)	0.18%
Following too closely	13.5 (4.4 - 41.4)	0.07%
Intentional signal violation	15.3 (7.9 – 29.9)	0.19%
Intentional stop/yield sign violation	5.3 (3.4 – 8.4)	1.04%

*Observable from 20-second pre-crash and baseline sample video segments

	O.R. (95% CI)	**Baseline Prevalence**
*Observable Distraction***		
Overall	2.0 (1.8 - 2.4)	51.93%
Major distraction sub-categories (observed in crash and baseline events)		
In-vehicle radio	1.9 (1.2 – 3.0)	2.21%
In-vehicle climate control	2.3 (1.1 – 5.0)	0.56%
In-vehicle device (other)	4.6 (2.9 – 7.4)	0.83%
Total in-vehicle device	2.5 (1.8 - 3.4)	3.53%
Cell browse	2.7 (1.5 – 5.1)	0.73%
Cell dial (handheld)	12.2 (5.6 - 26.4)	0.14%
Cell reach	4.8 (2.7 - 8.4)	0.58%
Cell text (handheld)	6.1 (4.5 - 8.2)	1.91%
Cell talk (handheld)	2.2 (1.6 - 3.1)	3.24%
Total cell (handheld)	3.6 (2.9 - 4.5)	6.40%
Child rear seat	0.5 (0.1 – 1.9)	0.80%
Interaction with adult/teen passenger	1.4 (1.1 – 1.8)	14.58%
Reading/writing (includes tablet)	9.9 (3.6 - 26.9)	0.09%
Eating	1.8 (1.1 - 2.9)	1.90%
Drinking (non-alcohol)	1.8 (1.0 - 3.3)	1.22%
Personal hygiene	1.4 (0.8 - 2.5)	1.69%
Reaching for object (non-cell phone)	9.1 (6.5 - 12.6)	1.08%
Dancing in seat to music	1.0 (0.4 - 2.3)	1.10%
Extended glance duration to external object	7.1 (4.8 - 10.4)	0.93%

The baseline prevalence of a factor represents the percentage of time the factor was present during the normal driving condition.

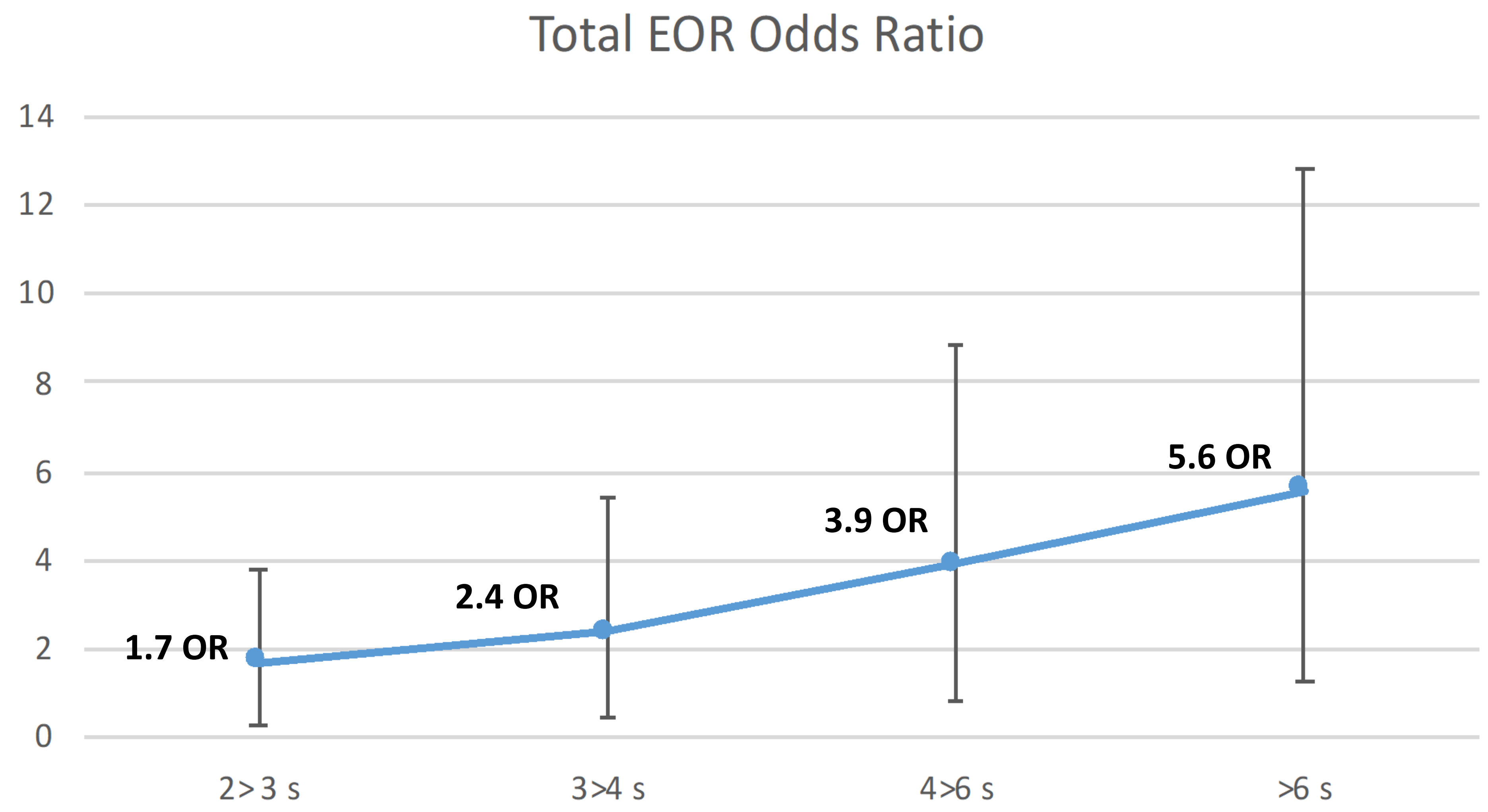
**Observable from 6-second pre-crash and baseline sample video segments

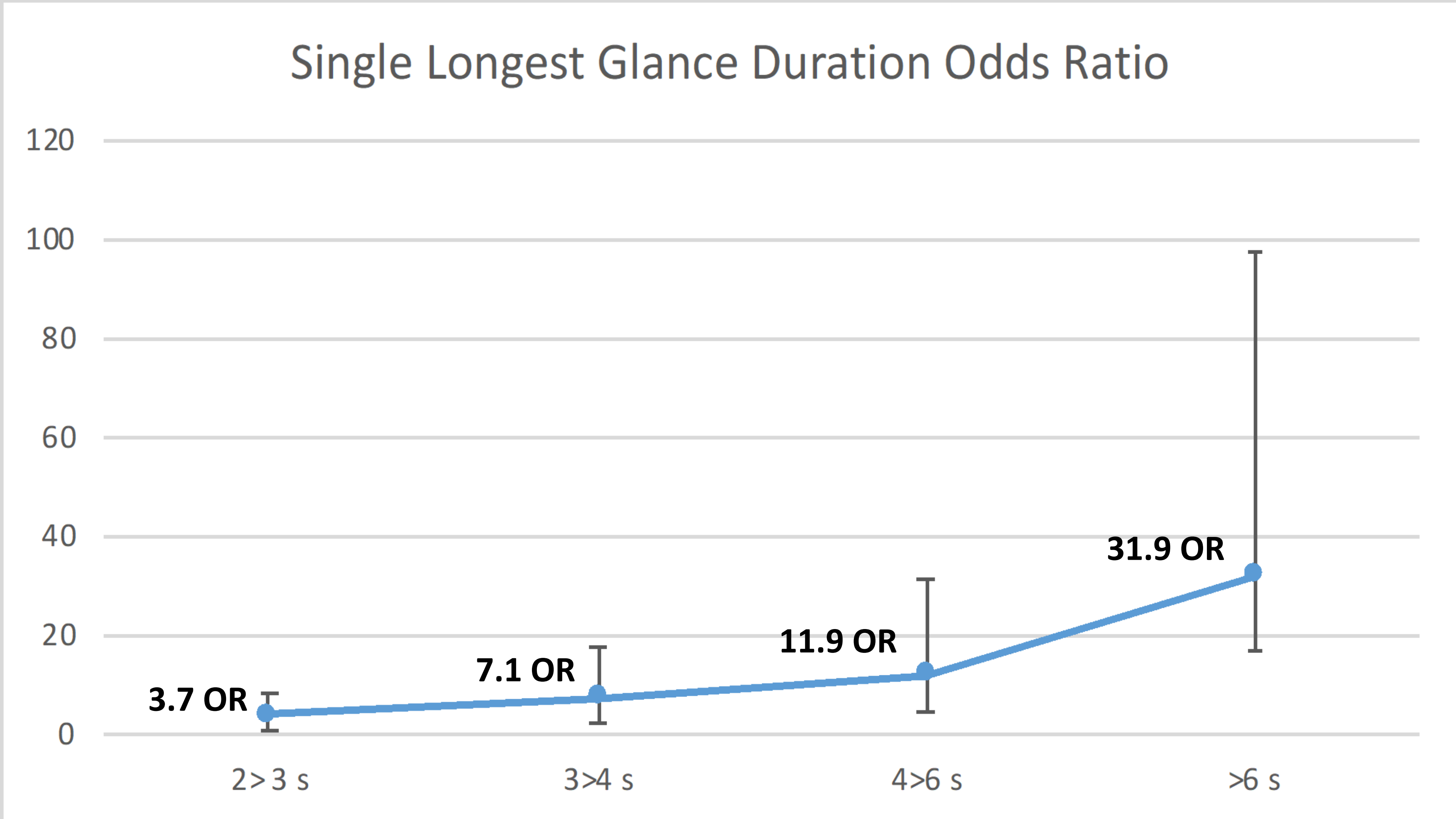
Driver Distraction: Crash Risk Factors for Visual, Manual, and Cognitive Tasks Based on NDS Data

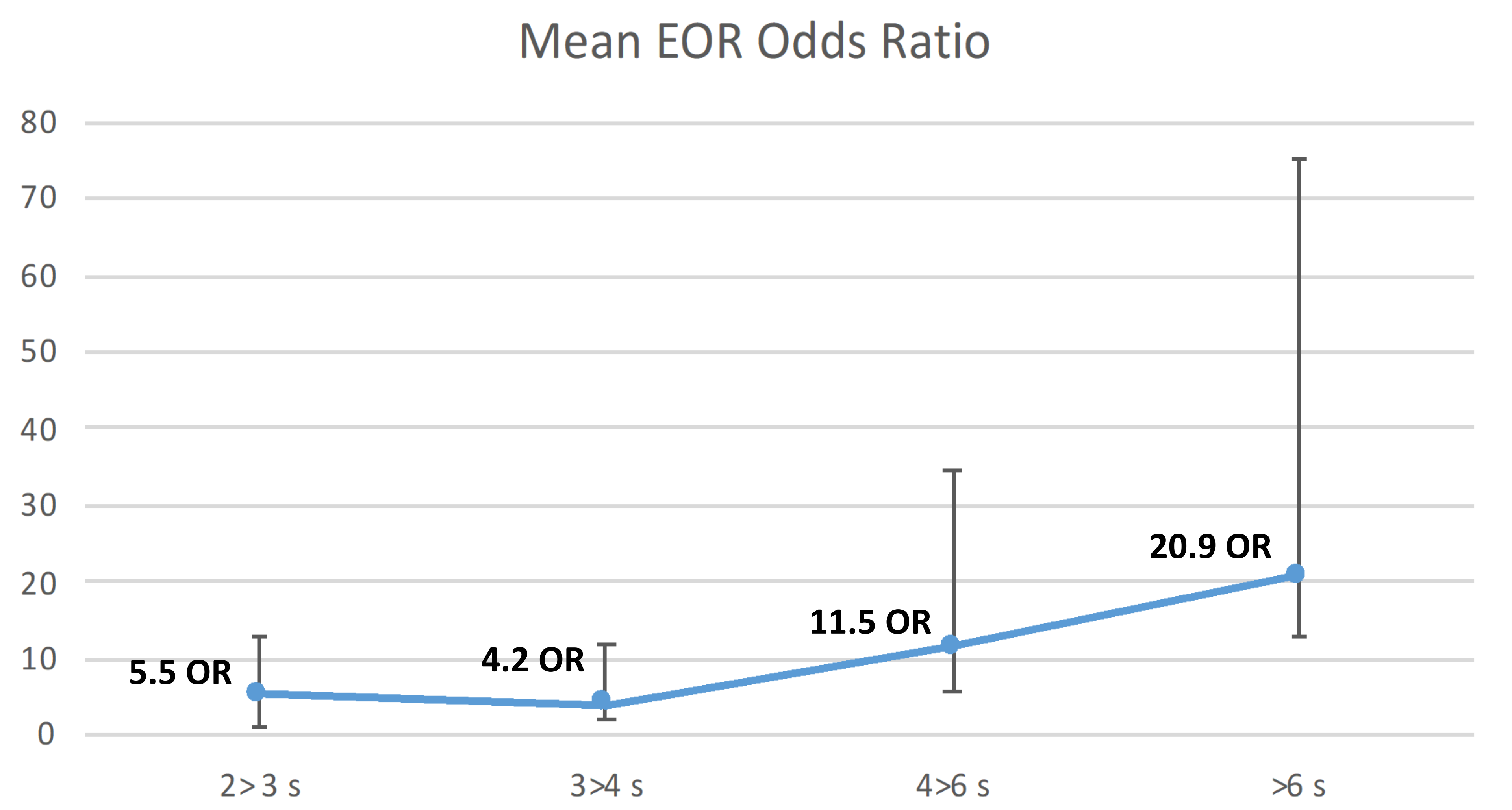
Driver distraction is a primary cause of crashes

Studies of the crash risk associated with visual demand

- VTTI has performed several additional studies specifically analyzing the effects of eyes-off-road on crash risk
- Several results are provided below; they have not yet been published but are in preparation
- The comparisons for the results shown are model driving (alert, attentive, non-impaired)
- Studies included several glance measures:
  - Total EOR = The total glance time away from the roadway during a secondary task (limited to a 10-s window)
  - Single longest glance duration = The longest glance away from the roadway during a secondary task
  - Mean EOR = The average of the single glances away from the roadway during a secondary task


Total EOR Odds Ratio
14
12
10
8
6
4
2
0
1.7 OR
2.4 OR
3.9 OR
5.6 OR
2>3 s
3>4 s
4>6 s
>6 s


Single Longest Glance Duration Odds Ratio
120
100
80
60
40
20
0
3.7 OR
7.1 OR
11.9 OR
31.9 OR
2>3 s
3>4 s
4>6 s
>6 s



Mean EOR Odds Ratio
80
70
60
50
40
30
20
10
0
5.5 OR
4.2 OR
11.5 OR
20.9 OR
2>3 s
3>4 s
4>6 s
>6 s

The prevalence of and crash risk associated with primarily cognitive secondary tasks

- *Safety Science* (January 2019)
- Assess the risk associated with engaging in primarily cognitive tasks while driving, using data from SHRP 2 NDS
- Parse out tasks drivers perform that are primarily cognitive in nature (i.e., tasks that do not place overt visual/manual demands on the driver)
  - Still includes cases where the driver voluntarily looked away from the roadway

The prevalence of and crash risk associated with primarily cognitive secondary tasks

- Analyzed data using two different crash severity levels:
    1. SHRP 2 NDS crash types 1-2: Airbag injury and significant property damage
    2. SHRP 2 NDS crash types 1-3: Above + minor collisions
- Analyzed the data using two different comparison groups:
    1. “All driving baseline”: All non-cognitive distraction baseline cases included in the comparison
    2. “Model driving”: Only cases where the driver was alert, attentive, and non-impaired included in the baseline comparison

Results

Primarily cognitive secondary tasks were observed in 20% of driving references

- Interacting with passenger: 12.2%
- Talking/singing alone: 4.2%
- Talking/listening on HH phone: 2.7%
- Talking/listening on HF phone: 0.9%

Prevalence of comparison tasks

- Adjust radio: 1.3%
- HH texting/browsing/dialing: 1.8%
- Cell phone holding: 1.1% (manual-only task)

Impact of primarily cognitive secondary tasks on crash risk relative to *all driving*

	Crash Levels 1-2					Crash Levels 1-3				
	OR	**95% LCL**	**95% UCL**	**p-value**	**# Crash with Cognitive Secondary Task**	**OR**	**95% LCL**	**95% UCL**	**p-value**	**# Crash with Cognitive Secondary Task**
Cognitive Secondary Tasks										
Grouped Cognitive Secondary Tasks	0.74	0.53	1.03	0.074	43	**0.71***	0.58	0.85	<0.001	138
Talking/Singing Alone Before Crash	0.68	0.34	1.39	0.291	8	0.83	0.58	1.20	0.325	33
Interacting with Passenger	0.85	0.58	1.25	0.410	29	**0.74***	0.58	0.93	0.010	85
Talking/Listening on a Handheld Cell Phone	0.94	0.44	1.99	0.862	7	0.75	0.47	1.19	0.221	19
Talking/Listening on a Hands-free Cell Phone	**	**	**	**	0	0.25	0.06	1.02	0.054	2
Comparison Tasks										
Adjust Radio	0.85	0.27	2.69	0.786	3	0.95	0.51	1.77	0.876	11
HH Cell Texting/ Browsing/ Dialing	**2.19***	1.18	4.05	0.013	11	1.48	0.98	2.23	0.065	26
Cell Phone Holding	1.70	0.69	4.17	0.249	5	1.15	0.63	2.10	0.640	12

* Indicates significant effect at the 0.05 level of significance
** Indicates effects not calculated due to no crashes identified

	Crash Levels 1-2					Crash Levels 1-3				
	OR	**95% LCL**	**95% UCL**	**p-value**	**# Crash with cognitive secondary task**	**OR**	**95% LCL**	**95% UCL**	**p-value**	**# Crash with cognitive secondary task**
Cognitive Secondary Tasks										
Grouped Cognitive Secondary Tasks	1.25	0.86	1.81	0.240	43	**1.25***	1.01	1.54	0.042	138
Talking/Singing Alone Before Crash	1.12	0.54	2.31	0.770	8	1.44	0.99	2.08	0.056	33
Interacting with Passenger	1.38	0.90	2.12	0.138	29	1.26	0.98	1.62	0.073	85
Talking/Listening on a Handheld Cell Phone	1.49	0.69	3.25	0.312	7	1.27	0.79	2.04	0.330	19
Talking/Listening on a Hands-free Cell Phone	**	**	**	**	0	0.40	0.10	1.63	0.202	2
Comparison Tasks										
Adjust Radio	1.37	0.43	4.37	0.594	3	1.57	0.85	2.91	0.152	11
Cell Texting/Browsing/HH Dialing	**3.47***	1.83	6.57	<0.001	11	**2.56***	1.68	3.88	<0.001	26
Cell Phone Holding	**2.76***	1.11	6.88	0.030	5	**2.05***	1.13	3.73	0.019	12

Impact of primarily cognitive secondary tasks on crash risk relative to *model driving*

* Indicates significant effect at the 0.05 level of significance
** Indicates effects not calculated due to no crashes identified

Key Results

- Conversing on HF phone was *not* found to be associated with an overall increased crash risk (OR >1.0)
- When considering Level 1-3 crashes relative to all driving, a significant risk reduction (OR = 0.25, 95% CI [0.08, 0.78]) was found for primarily cognitive tasks overall
- This analysis provides evidence that HF cell phone use does not increase crash risk
- This analysis shows that primarily cognitive tasks in general do not impact driving to nearly the same degree as visual and/or manual tasks

The prevalence of cognitive disengagement in automobile crashes

- Submitted to *Applied Cognitive Psychology* (under review)
- The current study is the first of its kind using the SHRP 2 NDS data to attempt to determine the role that cognitive disengagement (i.e., purely cognitive distraction [PCD] and mind-wandering/micro-sleep [MW/MS]) plays in driver crash risk
- Builds upon Dingus et al. (2019) and Owens et al. (2018) studies of prevalence/crash risk associated with cognitive distraction
  - However, cases where the driver voluntarily looked away from the road during a primarily cognitive task, or for other reasons, were excluded
  - Goal was to assess the impact of cognitive disengagement on crash risk in and of itself

The prevalence of cognitive disengagement in automobile crashes

- Uses 905 SHRP 2 NDS Level 1-3 crashes
- Primary non-cognitive disengagement contributing factors were identified for each crash, including:
  - Eyes not on the road during the 3s prior to the crash due to distraction or moderate to severe fatigue
  - Presence of environmental circumstances that were a primary cause (traction, visual obstruction)
  - Unavoidable crashes caused by the actions of another driver
- Elimination of these causes left 172 crashes that were candidates for other causes
- Each remaining case was analyzed, frame-by-frame, to assess if cognitive disengagement could be a causal factor
  - Achieved through assessment of factors such as delayed driver reaction time or response error

Crash Level	Frequency (%)
1	2 (20.0%)
2	1 (10.0%)
3	7 (70.0%)
Total	**10**

Resulting frequency of crashes where *MW/MS* was a potential contributing factor (out of 172 filtered L1-3 crashes; 905 total crashes)

Crash Level	Frequency (%)
1	0 (0.0%)
2	2 (12.5%)
3	14 (87.5%)
Total	**16**

Resulting frequency of crashes where *PCD* was a potential contributing factor (out of 172 filtered L1-3 crashes; 905 total crashes)

Key Results

- The prevalence of cognitive disengagement was small relative to other causal factors
  - <1% of Level 1-3 crashes had MW/MS as a potential contributing factor (95% CI: 0.45% - 1.66%)
  - ~1.5% of Level 1-3 crashes had a potential contributing factor of PCD (95% CI: 0.83% - 2.32%)
  - Versus 72% of L1-3 crashes in SHRP 2 NDS due to eyes-off forward roadway or visual/manual secondary task
- No Level 1-2 crashes in the SHRP 2 NDS data set had a contributing factor of cognitive distraction related to HF cell phone conversation

Questions?