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ANALYSIS OF NATURALISTIC DRIVING DATA TO ASSESS DISTRACTION AND DROWSINESS IN DRIVERS OF COMMERCIAL MOTOR TRUCKS AND BUSES

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BACKGROUND

RESEARCH QUESTIONS

1) What are the **types and frequency of tasks in which drivers engage prior to involvement in Safety-Critical Events (SCEs)**? What are the odds ratios (OR) and the Population Attributable Risk (PAR) percentage for each task type?
2) What are the **prevalence and characteristics of hands-free and handheld cell phone use**? What are the odds and the PAR of being involved in an SCE while talking on a handheld or hands-free cell phone?
3) What are the **environmental conditions associated with driver choice of engagement in tasks**? What are the odds and PAR of being in an SCE while engaging in tasks while encountering these conditions?
4) What are the **ORs of eyes off forward roadway**? Does eyes off forward roadway significantly affect safety and/or driving performance?
5) What is the **prevalence of driver drowsiness**? What are the odds and PAR of being in an SCE while drowsy?
6) How does **driver drowsiness vary when drivers are involved in a secondary task** and/or driving-related task?
7) What is the impact of **time on task on the risk of SCEs as a function of driving hour**? Is there a significant increase in risk associated with increasing hour of driving?
8) What is the prevalence of **drowsy driving by hour of driving**? Is there a significant increase in drowsy driving by hour of driving for both SCEs and normal driving segments?

DRIVER SAMPLE

Fleet	Location	Operation	Vehicles	Drivers	Participation
A	Baton Rouge, LA	Grocery—Reefer	65	58	1 year
B	Escanaba, MI	Dry goods – long-haul, regional; company and owner-operator drivers	8	9	3 months
C	Selma, NC	Fuel-tanker	35	47	3 weeks
D	Tampa, FL	Fuel-tanker	42	23	6 months
D	Taft, FL	Fuel-tanker			6 months
E	Los Angeles, CA	Motorcoach	22	38	1 year
F	San Antonio, TX	Motorcoach	21	35	2 years
G	Coraopolis, PA	Oil Field	14	17	1 month
G	Williamsport, PA	Oil Field			3 weeks
H	Pembroke, NH	Grocery—Reefer	18	18	1 year

METHODS OVERVIEW

- The study included reduction for:
  - Driver behaviors, including secondary task behaviors & cell phone use behaviors
  - Eye glance
  - Observer Rating of Drowsiness (ORD)
  - Manual Percentage of Eye Closure (PERCLOS)
  - Event sampling and reduction, baseline sampling and reduction, and additional sampling from shifts with 11 hours of driving
- Analysis methods included:
  - Mixed-effect logistic regression models with OR and confidence interval (CI) output
  - Poisson regression models
  - Analysis of variance (ANOVA)
  - Calculation of Population Attributable Risk (PAR)

EVENTS COLLECTED BY VEHICLE TYPE

Event Type	Motorcoach		Truck	
	Frequency of All SCEs	Frequency of At-Fault Only SCEs	Frequency of SCEs	Frequency of At-Fault Only SCEs
All SCEs	**1,739**	**876**	**2,363**	**1,736**
Crash	10	3	25	22
Near Crash	538	233	328	184
Crash Relevant Conflict	927	376	1,055	575
Unintentional Lane Deviation	264	264	955	955
Baseline Epochs	6,318	6,318	7,880	7,880

RESULTS

RESEARCH QUESTIONS 2, 5, AND 8

RESEARCH QUESTION 2

WHAT ARE THE **PREVALENCE AND CHARACTERISTICS OF HANDS-FREE AND HANDHELD CELL PHONE USE**? WHAT ARE THE ODDS AND THE PAR OF BEING INVOLVED IN AN SCE WHILE TALKING ON A HANDHELD OR HANDS-FREE CELL PHONE?

Cell Phone Task	MOTORCOACH		TRUCK	
	ALL SCEs	Baselines	ALL SCEs	Baselines
Hand-held locate/reach/answer	8	20	13	27
Hand-held dial	1	2	3	5
Hand-held talk/listen	7	13	7	46
Hand-held holding	7	5	16	26
Hand-held browsing	14	22	92	73
Hand-held texting	3	4	6	10
Hands-free call via headset/earpiece	9	65	66	403
Hands-free call via speakerphone	0	6	4	15
Hands-free talk/listen	9	71	70	418

RESEARCH QUESTION 2

Motorcoach

Cell Phone Task	ALL OR	ALL CI	At-Fault Only OR	At-Fault Only CI
All cell phone tasks	1.41*	(1.00, 2.00)	2.14*	(1.46, 3.12)
Hand-held cell phone tasks	2.42*	(1.61, 3.62)	3.89*	(2.52, 5.99)
Hands-free cell phone tasks	0.45*	(0.22, 0.92)	0.47	(0.19, 1.20)

** Indicates statistical significance at alpha = 0.05*

Truck

Cell Phone Task	ALL OR	ALL CI	At-Fault Only OR	At-Fault Only CI
All cell phone tasks	1.14	(0.93, 1.39)	1.40*	(1.13, 1.75)
Hand-held cell phone tasks	2.81*	(2.16, 3.66)	4.00*	(3.03, 5.27)
Hands-free cell phone tasks	0.51*	(0.38, 0.69)	0.46*	(0.33, 0.66)

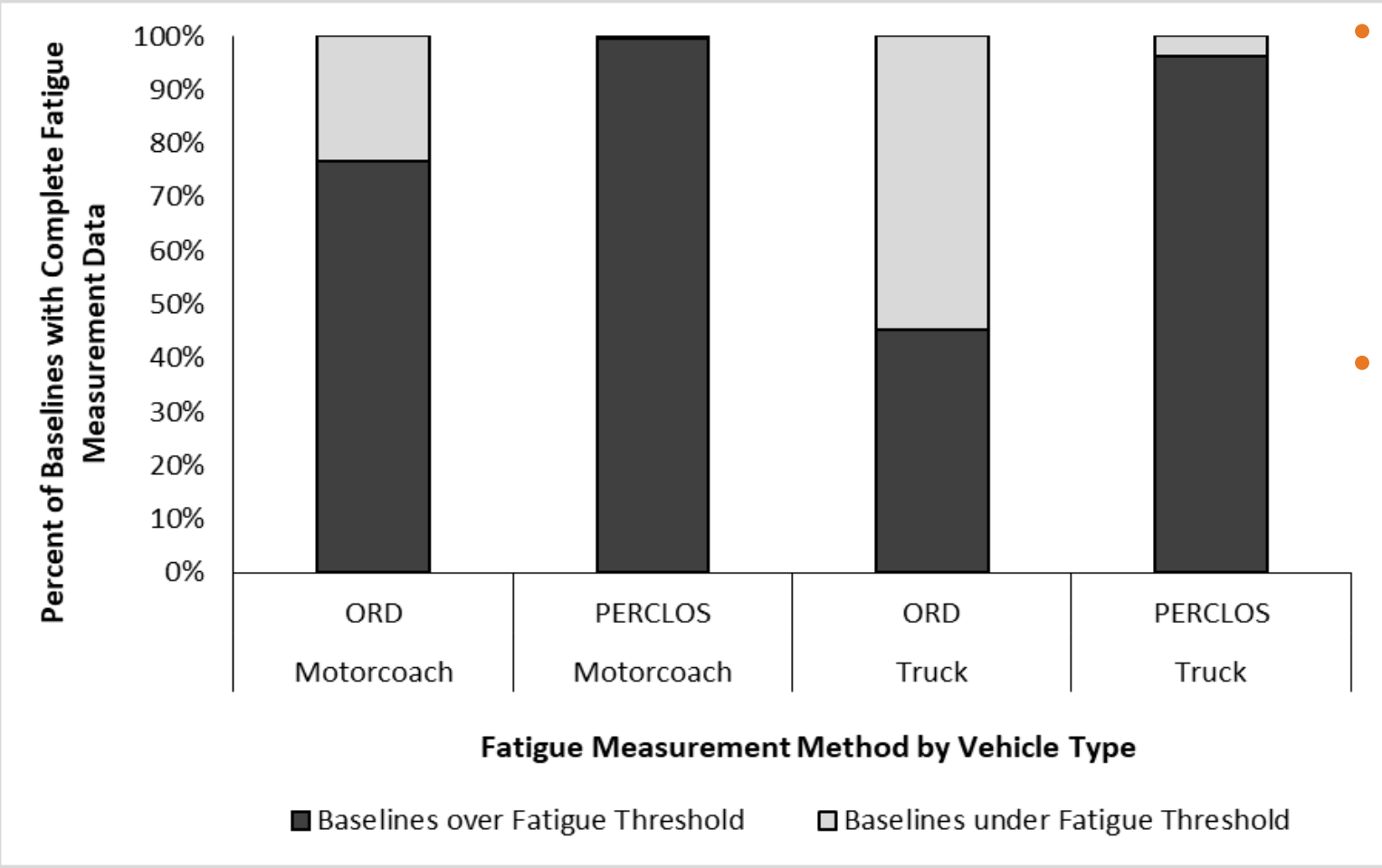
** Indicates statistical significance at alpha = 0.05*

Findings:

- Talking and/or listening to a phone call continues to show no risk or reduced risk in naturalistic driving studies
- Cell phone use lower overall in motorcoach data than in truck data
- Visual-manual intensive tasks on a hand-held phone showed increased risk
- Texting occurred infrequently in the data

RESEARCH QUESTION 5

What is the **prevalence of driver drowsiness**? What are the odds and PAR of being in an SCE while drowsy?



- Motorcoach Baselines:
  - 26.56% (1,409) ORD "very"/"extreme" drowsiness
  - 0.39% (9) PERCLOS drowsiness
- Truck Baselines:
  - 10.91% (214) ORD "very"/"extreme" drowsiness
  - 2.89% (74) PERCLOS drowsiness

RESEARCH QUESTION 5

Odds of SCE Involvement while Drowsy

Findings:

- Drowsiness observed more frequently in truck data than in motorcoach data
- ORD drowsiness and PERCLOS drowsiness observed more frequently in SCEs than baselines for motorcoach and truck drivers

Motorcoach

Fatigue Measurement Method	ALL OR	ALL CI	At-Fault Only OR	At-Fault Only CI
ORD	1.01	(0.69, 1.48)	1.58*	(1.05, 2.39)
PERCLOS	2.68*	(1.14, 6.31)	3.48*	(1.39, 8.73)

** Indicates statistical significance at alpha = 0.05*

Truck

Fatigue Measurement Method	ALL OR	ALL CI	At-Fault Only OR	At-Fault Only CI
ORD	1.31*	(1.07, 1.63)	1.74*	(1.39, 2.18)
PERCLOS	2.88*	(2.10, 3.94)	3.70*	(2.67, 5.12)

** Indicates statistical significance at alpha = 0.05*

RESEARCH QUESTION 8

What is the prevalence of **drowsy driving by hour of driving**? Is there a significant increase in drowsy driving by hour of driving for both SCEs and normal driving segments?

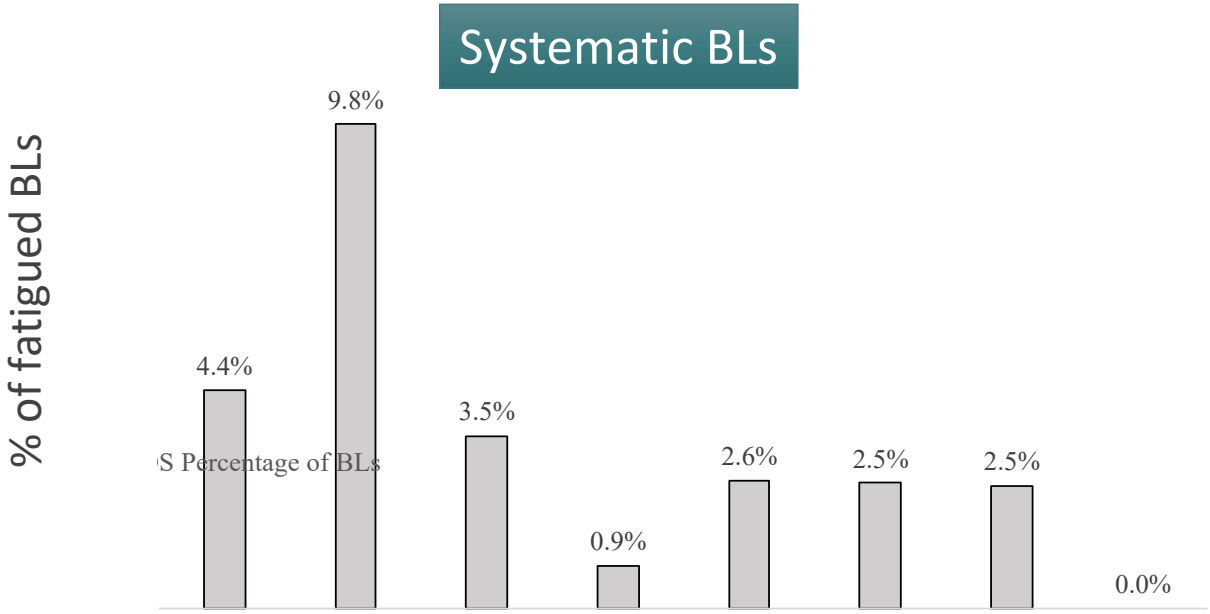
- Method:
  - Evaluate temporal profile for both SCEs and systematically sampled baselines (BLs)
  - Systematic Samples for BLs
    - Selected 200 shifts with driving time longer than 10 hours
    - Samples taken at 1, 3, 5, 7, 8, 9, 10, 11 hours
  - Use PERCLOS score to determine drowsiness status
    - Valid criteria: the percentage of unknown eye status < 20%;
    - Fatigue criteria: PERCLOS percentage > 12%.
  - 2,325 valid SCEs and 929 valid systematic BLs

RESEARCH QUESTION 8

Percentage of SCEs or BLs identified as fatigued by driving hours since shift start

Findings:

- **NO** clear pattern of drowsiness by driving hours;
- Mixed-effect Logistic models confirm no significant results



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Thank you!

Questions?

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Link to report:
https://rosap.ntl.bts.gov/view/dot/57153/dot_57153_DS1.pdf

APPENDIX

RESEARCH QUESTION 1

Motorcoach Event Type – Frequency and percentage of any secondary task

Event Type	All SCEs	Frequency of All SCEs	At-Fault Only SCEs	Frequency of At-Fault Only SCEs
All SCEs	40.5%	704	49.9%	437
Crash	60.0%	6	66.7%	2
Near-crash	36.8%	198	46.8%	109
Crash-relevant conflict	34.0%	315	37.5%	141
Unintentional lane deviation	70.1%	185	70.1%	185
Baseline epochs	31.0%	1,961	31.0%	1,961

RESEARCH QUESTION 1

Truck Event Type – Frequency and percentage of any secondary task

Event Type	All SCEs	Frequency of All SCEs	At-Fault Only SCEs	Frequency of At-Fault Only SCEs
All SCEs	53.5%	1265	62.2%	1080
Crash	48.0%	12	50.0%	11
Near-crash	43.6%	143	53.3%	98
Crash-relevant conflict	39.4%	416	48.2%	277
Unintentional lane deviation	72.7%	694	72.7%	694
Baseline epochs	47.3%	3729	47.3%	3729

RESEARCH QUESTION 1

Motorcoach Secondary Tasks with Significant Odds Ratios

Secondary Task	ALL OR	ALL CI	At-Fault Only OR	At-Fault Only CI
Dancing	0.37*	(0.16, 0.83)	-	-
Reaching for object	2.46*	(1.57, 3.86)	3.07*	(1.83, 5.15)
Intercom use	2.74*	(1.49, 5.03)	1.56	(0.64, 3.79)
Adjusting instrument panel	1.34*	(1.03, 1.75)	1.95*	(1.43, 2.65)
Adjusting/monitoring other devices integral to vehicle	1.59*	(1.07, 2.38)	1.93*	(1.21, 3.08)
External distraction	1.57*	(1.29, 1.93)	2.07*	(1.63, 2.64)
Personal grooming	1.41	(0.96, 2.07)	2.04*	(1.33, 3.15)
Removing/adjusting clothing	2.29*	(1.27, 4.13)	2.79*	(1.41, 5.54)
Other personal hygiene	2.23*	(1.39, 3.57)	3.27*	(1.95, 5.48)

** Indicates statistical significance at alpha = 0.05*

RESEARCH QUESTION 1

Truck Secondary Tasks with Significant Odds Ratios

Secondary Task	ALL OR	ALL CI	At-Fault Only OR	At-Fault Only CI
Talking/singing	0.60*	(0.47, 0.76)	0.62*	(0.47, 0.81)
Dancing	0.40*	(0.24, 0.67)	0.46*	(0.27, 0.81)
Reading	3.27*	(1.63, 6.59)	4.23*	(2.03, 8.81)
Reaching for object	4.57*	(3.27, 6.39)	5.81*	(4.09, 8.26)
Electronic dispatching device	1.44*	(1.05, 1.98)	1.80*	(1.27, 2.55)
Other electronic device	2.87*	(1.54, 5.36)	3.35*	(1.72, 6.52)
External distraction	1.21*	(1.04, 1.41)	1.45*	(1.23, 1.71)
Reaching for food-related or drink-related object	1.67*	(1.19, 2.33)	2.28*	(1.61,, 3.22)
Removing/adjusting clothing	3.01*	(1.72, 5.27)	3.43*	(1.90, 6.21)

** Indicates statistical significance at alpha = 0.05*

RESEARCH QUESTION 2

Motorcoach Odds Ratios of Cell Phone Tasks

Cell Phone Task	ALL OR	ALL CI	At-Fault Only OR	At-Fault Only CI
Hand-held talk/listen	1.97	(0.76, 5.10)	2.85	(0.98, 8.35)
Hand-held holding	3.96*	(1.18, 13.26)	5.72*	(1.51, 21.64)
Hand-held browsing	2.58*	(1.29, 5.18)	4.45*	(2.15, 9.22)
Hands-free call via headset/earpiece	0.50	(0.24, 1.02)	0.52	(0.20, 1.33)
Hands-free talk/listen	0.45*	(0.22, 0.93)	0.48*	(0.19, 1.22)

** Indicates statistical significance at alpha = 0.05*

RESEARCH QUESTION 2

Truck Odds Ratios of Cell Phone Tasks

Cell Phone Task	ALL OR	ALL CI	At-Fault Only OR	At-Fault Only CI
Hand-held locate/reach/answer	1.90	(0.93, 3.87)	2.71*	(1.31, 5.61)
Hand-held talk/listen	0.71	(0.30, 1.67)	0.95	(0.38, 2.40)
Hand-held holding	2.26*	(1.11, 4.61)	3.04*	(1.43, 6.46)
Hand-held browsing	4.35*	(3.08, 6.17)	6.14*	(4.26, 8.85)
Hand-held texting	3.07*	(1.03, 9.15)	4.33*	(1.42, 13.26)
Hands-free call via headset/earpiece	0.50*	(0.37, 0.68)	0.44*	(0.31, 0.63)
Hands-free talk/listen	0.51*	(0.38, 0.69)	0.46*	(0.33, 0.66)

** Indicates statistical significance at alpha = 0.05*

RESEARCH QUESTION 4

Motorcoach Odds Ratios of Eyes off Forward Roadway

Total Eyes Off Forward Roadway	ALL OR	ALL CI	At-Fault Only OR	At-Fault Only CI
Less than or equal to 0.5 seconds	0.86	(0.54, 1.35)	1.30	(0.74, 2.28)
Greater than 0.5 seconds but less than or equal to 1.0 second	0.75	(0.54, 1.05)	1.07	(0.69, 1.65)
Greater than 1.0 second but less than or equal to 1.5 seconds	0.95	(0.69, 1.31)	1.44	(0.95, 2.19)
Greater than 1.5 seconds but less than or equal to 2.0 seconds	1.24	(0.85, 1.81)	1.69*	(1.04, 2.74)
Greater than 2.0 seconds	1.50*	(1.13, 1.98)	2.77*	(1.94, 3.96)

** Indicates statistical significance at alpha = 0.05*

RESEARCH QUESTION 4

Truck Odds Ratios of Eyes off Forward Roadway

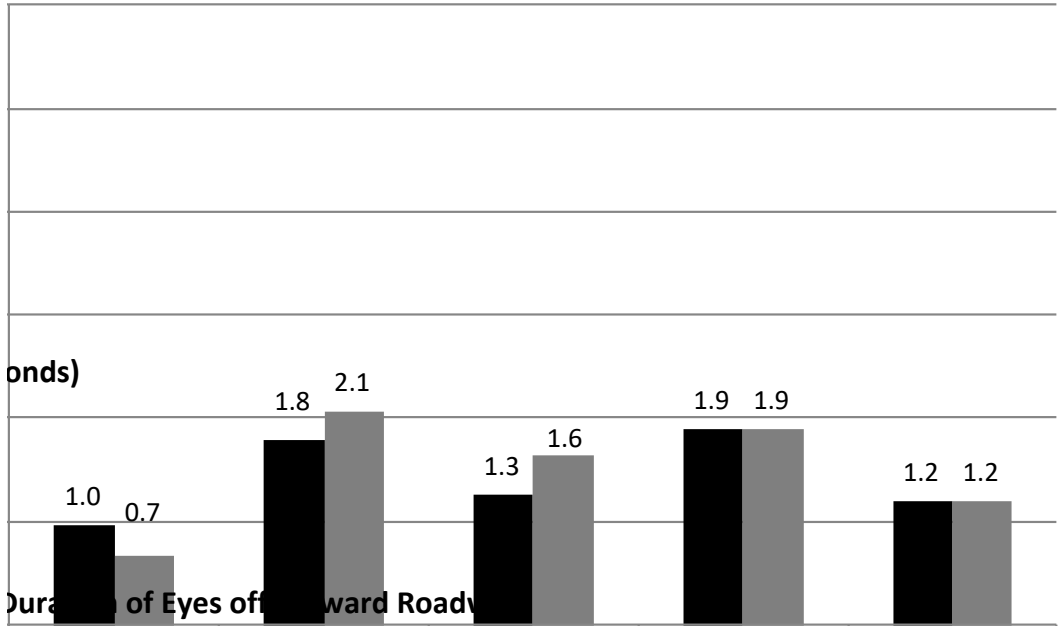
Total Eyes Off Forward Roadway	ALL OR	ALL CI	At-Fault Only OR	At-Fault Only CI
Less than or equal to 0.5 seconds	1.17	(0.82, 1.66)	1.43	(0.95, 2.15)
Greater than 0.5 seconds but less than or equal to 1.0 second	0.99	(0.75, 1.29)	1.10	(0.80, 1.51)
Greater than 1.0 second but less than or equal to 1.5 seconds	1.28	(0.98, 1.67)	1.72*	(1.27, 2.33)
Greater than 1.5 seconds but less than or equal to 2.0 seconds	1.45*	(1.07, 1.95)	1.94*	(1.39, 2.73)
Greater than 2.0 seconds	2.73*	(2.21, 3.37)	4.05*	(3.18, 5.17)

** Indicates statistical significance at alpha = 0.05*

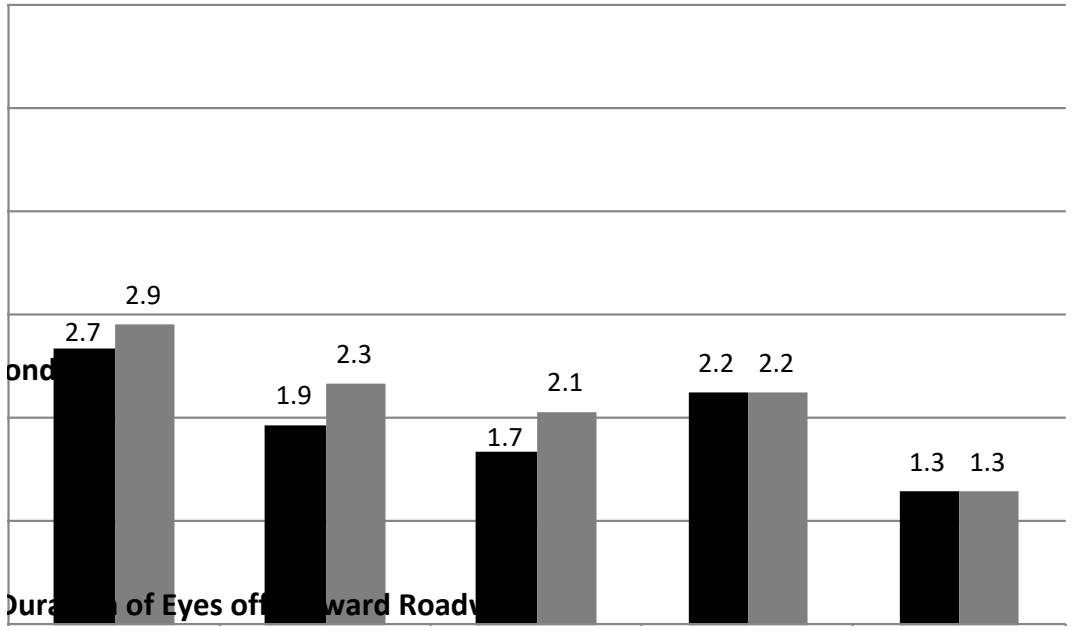
RESEARCH QUESTION 4

Mean Eyes off Forward Roadway

Motorcoach



Truck



RESEARCH QUESTION 6

Motorcoach Driver Drowsiness in Secondary Tasks

Secondary Task	ORD Percent Baselines w/ Drowsiness of All Task Not Present	ORD Percent Baselines w/ Drowsiness of All Task Present	ORD Odds Ratio	ORD 95% CI	ORD Percent SCEs w/ Drowsiness of All Task Not Present	ORD Percent SCEs w/ Drowsiness of All Task Present	ORD Odds Ratio	ORD 95% CI
Secondary Task (Overall)	3.42%	1.72%	**2.22***	**(1.09, 4.50)**	2.18%	1.45%	**1.72***	**(1.07, 2.78)**
Talking/singing	2.05%	0.80%	2.95	(0.92, 9.50)	2.89%	0.81%	3.87	(0.51, 29.30)
Passenger in rear seat	2.82%	0.00%	2.02	(0.44, inf.)	1.99%	0.74%	3.78	(0.52, 27.68)
Reaching for object	1.96%	2.13%	0.85	(0.11, 6.37)	2.65%	6.67%	0.45	(0.10, 2.09)
Intercom use	1.97%	0.00%	0.71	(0.16, inf.)	2.76%	0.00%	0.64	(0.13, inf.)

** Indicates statistical significance at alpha = 0.05*

RESEARCH QUESTION 6

Truck Driver Drowsiness in Secondary Tasks- ORD

Secondary Task	ORD Percent Baselines w/ Drowsiness of All Task Not Present	ORD Percent Baselines w/ Drowsiness of All Task Present	ORD Odds Ratio	ORD 95% CI	ORD Percent SCEs w/ Drowsiness of All Task Not Present	ORD Percent SCEs w/ Drowsiness of All Task Present	ORD Odds Ratio	ORD 95% CI
Secondary Task (Overall)	13.21%	8.40%	1.79*	(1.31, 2.44)	25.84%	13.13%	2.13*	(1.64, 2.78)
Talking/singing	11.14%	7.38%	1.59	(0.77, 3.26)	19.47%	8.89%	2.61*	(1.16, 5.84)
Passenger in adjacent seat	10.97%	0.00%	2.07	(0.43, inf.)	19.13%	0.00%	-	-
Reaching for object	10.96%	5.56%	1.54	(0.19, 12.15)	19.26%	14.58%	1.15	(0.61, 2.19)
External distraction	11.30%	8.27%	1.58	(0.96, 2.58)	20.32%	10.97%	2.02*	(1.31, 3.14)
Eating	11.13%	5.88%	2.16	(0.84, 5.55)	19.58%	9.84%	3.00*	(1.52, 5.89)
Removing/adjusting clothing	10.82%	25.00%	0.37	(0.09, 1.52)	18.69%	46.67%	0.33*	(0.14, 0.81)
Hand-held browsing	10.83%	21.43%	0.46	(0.12, 1.79)	19.58%	6.52%	2.95*	(1.17, 7.42)
Hands-free call via headset/earpiece	11.45%	0.99%	15.14*	(2.05, 111.92)	19.61%	0.00%	22.73*	(5.15, inf.)
Hands-free talk/listen	11.46%	0.96%	15.61*	(2.11, 115.40)	19.65%	0.00%	24.19*	(5.49, inf.)

** Indicates statistical significance at alpha = 0.05*

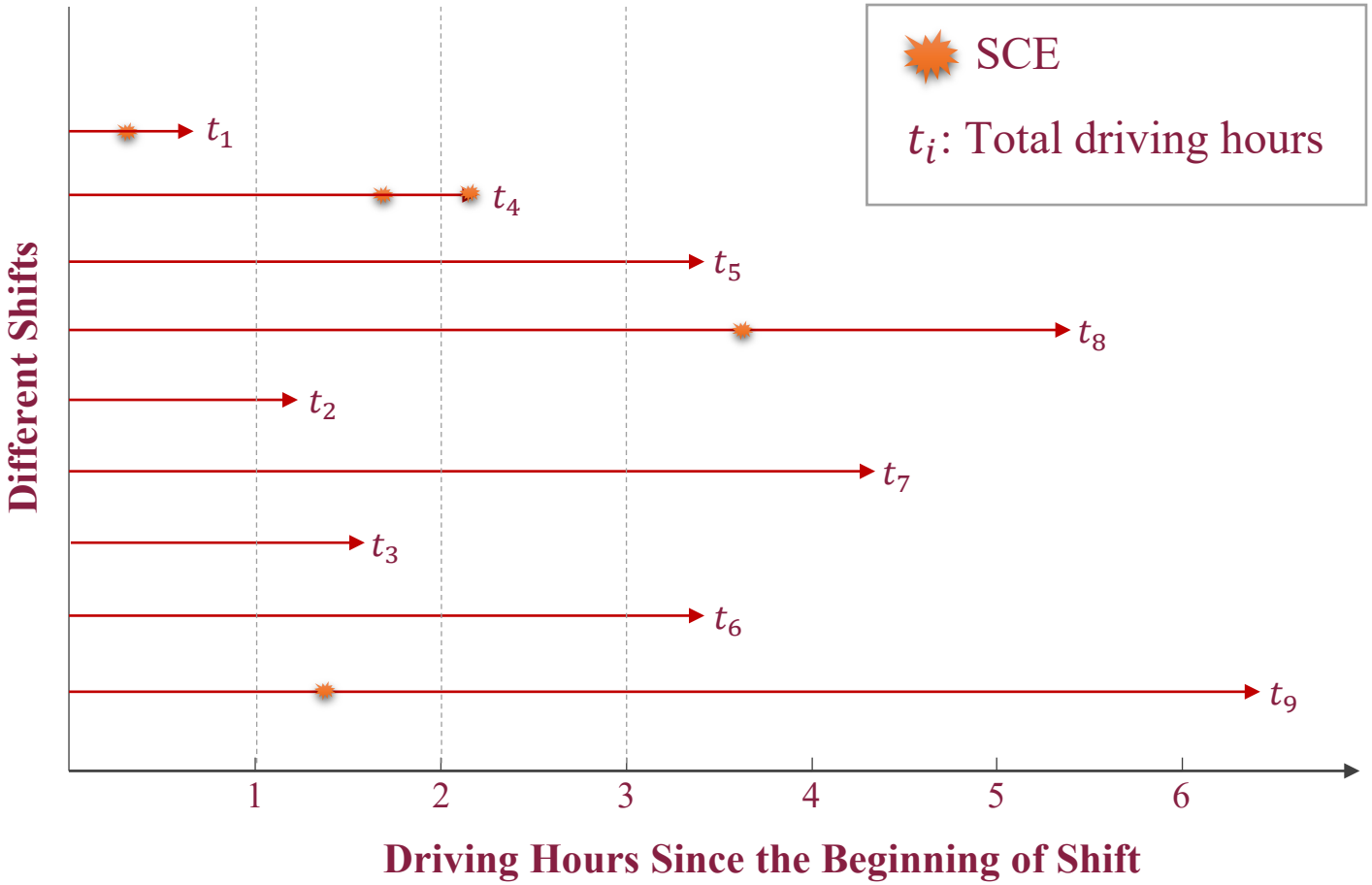
RESEARCH QUESTION 6

Truck Driver Drowsiness in Secondary Tasks- PERCLOS

Secondary Task	PERCLOS Percent Baselines w/ Drowsiness of All Task Not Present	PERCLOS Percent Baselines w/ Drowsiness of All Task Present	PERCLOS Odds Ratio	PERCLOS 95% CI	PERCLOS Percent SCEs w/ Drowsiness of All Task Not Present	PERCLOS Percent SCEs w/ Drowsiness of All Task Present	PERCLOS Odds Ratio	PERCLOS 95% CI
Secondary Task (Overall)	3.65%	3.12%	1.23	(0.78, 1.93)	13.36%	10.52%	1.20	(0.84, 1.71)
Talking/singing	3.25%	5.49%	0.72	(0.34, 1.54)	11.66%	16.00%	1.02	(0.49, 2.10)
Passenger in adjacent seat	3.41%	0.00%	0.80	(0.17, inf.)	11.88%	0.00%	-	-
Reaching for object	3.43%	0.00%	1.26	(0.27, inf.)	11.64%	16.05%	0.63	(0.31, 1.31)
External distraction	3.32%	3.92%	0.86	(0.46, 1.61)	12.89%	4.82%	**2.58***	**(1.31, 5.07)**
Electronic dispatching device	12.16%	0.00%	**9.10***	**(2.04, inf.)**	3.43%	1.75%	1.83	(0.24, 13.88)
Removing/adjusting clothing	3.41%	0.00%	0.69	(0.15, inf.)	11.54%	33.33%	**0.33***	**(0.11, 0.96)**
Hand-held browsing	3.43%	0.00%	1.26	(0.27, inf.)	12.20%	3.95%	2.20	**(0.60, 8.04)**
Hands-free call via headset/earpiece	3.57%	0.00%	**6.57***	**(1.49, inf.)**	12.21%	0.00%	**10.54***	**(2.37, inf.)**
Hands-free talk/listen	3.57%	0.00%	**6.73***	**(1.52, inf.)**	6.68%	0.00%	**10.96***	**(2.47, inf.)**

** Indicates statistical significance at alpha = 0.05*

RQ7 Method



Based on SCE rate by driving hour since beginning of a shift.

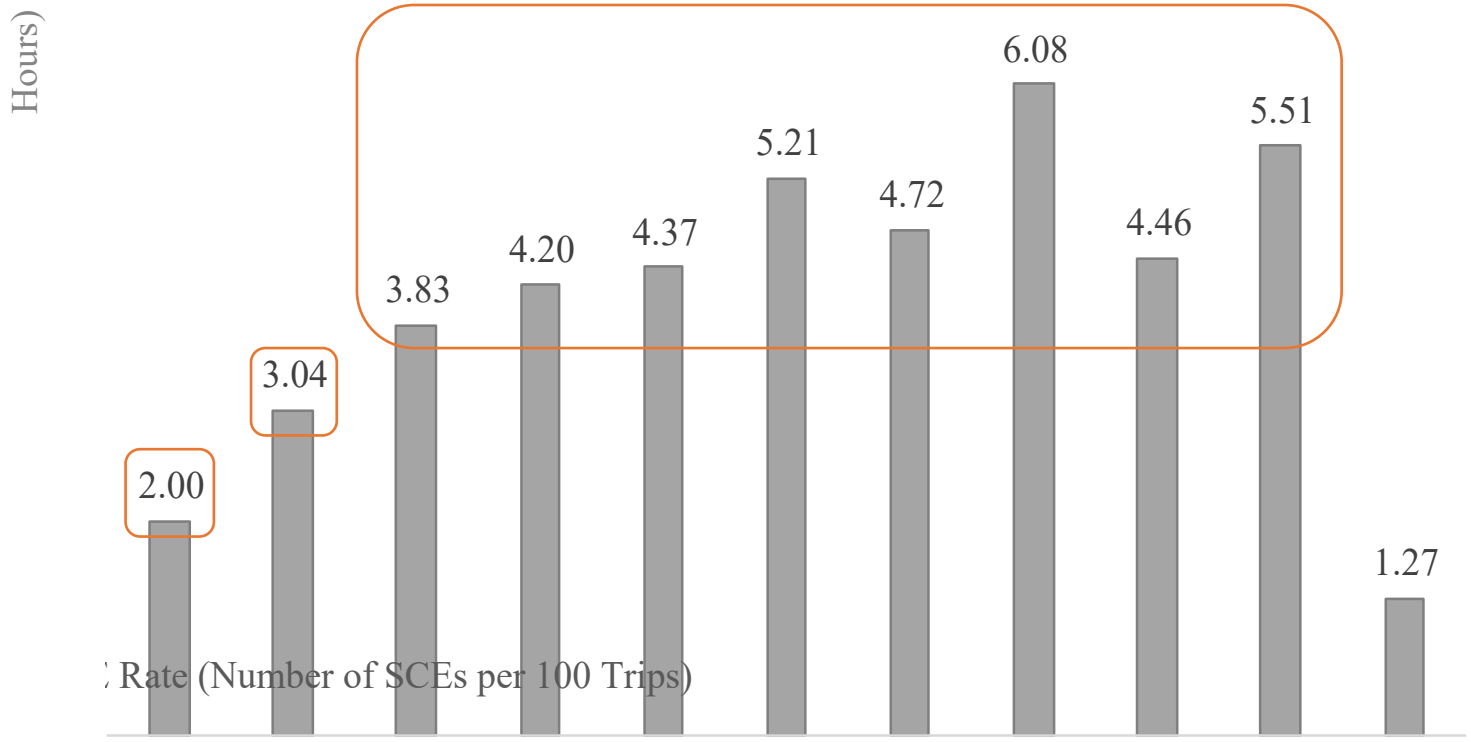
SCE rate for the ith driving hour $= \frac{Number\ of\ SCEs\ in\ the\ i^{th} driving\ hour}{Total\ Driving \text{ time in the i}^{th} \text{driving } hour}$

- **Examples:**
- **1st driving hour:**
- $\frac{1SCE}{(t_1+1+1+1+1+1+1+1+1)hours}$;

- **2nd driving hour:**
- $\frac{2SCEs}{(1+1+1+(t_2-1)+1+(t_3-1)+1+1)hours}$;

RESEARCH QUESTION 7

SCE Rates as a function of Driving Hour since Shift Start



Evaluated by

- Mixed-effect Poisson model
- Tukey multiple comparison

Findings:

- SCE rates show an increase pattern over driving time;
- The first 10 driving hours can be categorized into 3 groups:
  - The 1st hour;
  - The 2nd hour;
  - The 3rd – 10th hour.