Using Naturalistic Driving Study Data to Investigate the Impact of Driver Distraction on Driver’s Reaction Time in Freeway Rear-ending Events

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August 31, 2016

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Overview

• Research Objectives
• Data Collection
• Analysis Methodologies
• Results
• Conclusion
Research Objectives

• Understand the mechanism of *freeway rear-ending* events

• Identify the *driving behavior* associated with freeway rear-ending events

• Mechanism by which *driver distraction* could influence *crash risk* (indicator: *reaction time*) in freeway rear-ending events
Research Objectives

• Important Definition
• **Distraction:**
• A driver is regarded as *distracted* if the driver “has chosen to engage in a *secondary task* that is not necessary to perform the primary driving task (Klauer, et al., 2006)”.


Research Objectives

- Important Definition
- **Reaction Time:**

![Event Timeline (sec)]

- Leader's brake light first went on
- Follower's reaction time
- Follower's first brake
Data Collection

1. Included Cases

Filter built to extract subject events

(Source: SHRP 2 Insight Website)
Data Collection

• 2. Data Coding

_data availability:_
Data available for viewing on the Insight website (front-facing video, non-PII, etc.).
Data Collection

- 2. Data Coding

1. Response Variable: *Reaction Time*

2. Explanatory Variable
   - (i) Endogenous Variable
     *Driver-related, Distraction-related* variables
   - (ii) Exogenous Variable
     *Environment-related* variables
Data Collection

2. Data Coding

Driver-related Variables:
Age, Gender

Distraction-related Variables:
Distraction Duration*, Distraction Scenario, Secondary Task Type

Environment-related Variables:
Visual Obstruction, Weather, Lighting

* : Continuous variable
A : Categorical variable
Data Collection

2. Data Coding

Distraction Scenario:

- **S1**: normal driving;
- **S2**: follower’s distraction ended before leader braked;
- **S3**: follower’s distraction began after leader braked;
- **S4**: follower driver was distracted when leader braked.
1. Driving Feature Estimation

$t_1 =$ the time point when the leader’s brake first went on,
$t_2 =$ the time point when the follower’s brake first went on,
$t_3 =$ the time point when the follower’s distraction began,
$t_4 =$ the time point when the follower’s distraction ended.

**Reaction Time:** $r = t_2 - t_1$

**Distraction Duration:** $d = t_4 - t_3$

(Source: SHRP 2 Insight Website)
Analysis Methodologies

2. Model Validation

Basic model: Linear Model
2. Model Validation

(1) *Tetrad* exploration

*Causal model search* based on

*Conditional Independence*
Analysis Methodologies

Existence of Reaction Time independent of Driver Age/Secondary Task Type given Distraction Duration?
Analysis Methodologies

• *Tetrad* exploration

Attempt was not pursued because limitation in:
(i) software usage: continuous/discrete set only
(ii) sample size: issue with continuous data discretization
Analysis Methodologies

2. Model Validation
(2) Linear regression
 (testing proposed model structure)
Analysis Methodologies

- Distraction-related
  - Distraction Scenario (S2, S3, S4)
  - Secondary Task Type (Non-visual, Visual)

- Environment-related
  - Normal Driving
  - Distracted Driving
  - Reaction Time
  - Gender
  - Age
  - Weather
  - Visual Obstruction
  - Lighting

A is assumed to be a contributing factor of B
Analysis Methodologies

• Step 1 of 3:

Association between Reaction Time and 1st-layer predictors?

- Distraction Scenario (S2, S3, S4)
- Secondary Task Type (Non-visual, Visual)
- Normal Driving
- Distracted Driving
- Gender
- Age
- Visual Obstruction
- Weather
- Lighting

A → B: A is assumed to be a contributing factor of B
Analysis Methodologies

• Step 2 of 3:

*Reaction Time* and *2nd-layer predictors* are d-separated by *1st-layer predictors*?

Diagram:
- Distraction Scenario (S2, S3, S4)
- Secondary Task Type (Non-visual, Visual)
- Normal Driving
- Distracted Driving
- Reaction Time
- Gender
- Age
- Weather
- Visual Obstruction
- Lighting

A is assumed to be a contributing factor of B
Analysis Methodologies

- **Step 3 of 3:**

Association between 1\textsuperscript{st}-layer predictors and 2\textsuperscript{nd}-layer predictors?

Diagram:

- Distraction Scenario (S2, S3, S4)
- Secondary Task Type (Non-visual, Visual)
- Normal Driving
- Distracted Driving
- Reaction Time
- Gender
- Age
- Weather
- Visual Obstruction
- Lighting

A \rightarrow B: A is assumed to be a contributing factor of B
Results

- Final sample size: 108 events
  (from 108 different drivers)

- 62 female, 46 male drivers
- 45 normal driving, 63 distracted driving
### Results

**Statics of Reaction Time** in different driving groups:

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>M</th>
<th>Mdn</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal Driving</td>
<td>45</td>
<td>1.669</td>
<td>1.290</td>
<td>1.254</td>
</tr>
<tr>
<td>Distracted</td>
<td>63</td>
<td>2.192</td>
<td>1.956</td>
<td>1.317</td>
</tr>
</tbody>
</table>

N=Number of events, M=Mean, Mdn=Median, SD=Standard deviation

T-test of Reaction Time in different driving groups:

**Two Sample t-test**

<table>
<thead>
<tr>
<th>t</th>
<th>df</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.075</td>
<td>106</td>
<td>0.020</td>
</tr>
</tbody>
</table>

95 percent confidence interval: (0.104232744, 0.941767255)
Results

• Linear regression
• Step 1:

  • M1:
  • Reaction Time = $\beta_0 + \beta_1 \times \text{Distraction Duration} + \beta_2 \times \text{Gender} + \beta_3 \times \text{Age} + \beta_4 \times \text{Weather} + \beta_5 \times \text{Lighting}$
**Results**

```
lm(formula = ReactionTime ~ factor(Gender) + factor(Age) + DistractionDuration + Weather + Lighting, data = data)

Residuals:
       Min        1Q  Median         3Q        Max
-2.3480465 -0.8582740 -0.2691908  0.5050057  5.3121602

Coefficients:
                          Estimate Std. Error  t value   Pr(>|t|)
(Intercept)                    1.44920    0.39537    3.6657    0.000397 ***
factor(Gender)M          0.14696    0.26190    0.5619    0.575948
factor(Age)Old            0.40695    0.48722    0.8352    0.405597
factor(Age)Teen           0.04204    0.43847    0.0962    0.923806
factor(Age)Young          0.09372    0.38637    0.2433    0.808840
DistractionDuration     0.12890    0.04315    2.9873    0.003540 **
Weather                     -0.21928    0.41441   -0.5290    0.597879
Lighting                    0.09328    0.31231    0.2991    0.765815

---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 1.294 on 100 degrees of freedom
Multiple R-squared:  0.09005,   Adjusted R-squared:  0.02636
F-statistic: 1.414 on 7 and 100 DF,  p-value: 0.2081
```

*Distraction Duration* is the only factor associated with *Reaction Time.*
Results

• Linear regression

• Step 2:

  • $M2$:  
  • Residuals of $M1 = \beta_0 + \beta_1 \times \text{Distraction Scenario} + \beta_2 \times \text{Secondary Task Type}$
### Results

\[
\text{lm(formula = Residuals ~ factor(DistractionScenario) + factor(SecondaryTaskType), data = datad)}
\]

Residuals:

<table>
<thead>
<tr>
<th></th>
<th>Min</th>
<th>1Q</th>
<th>Median</th>
<th>3Q</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>-1.3575</td>
<td>-0.6502</td>
<td>-0.1905</td>
<td>0.4490</td>
<td>3.8944</td>
</tr>
</tbody>
</table>

Coefficients:

|                          | Estimate | Std. Error | t value | Pr(>|t|) |
|--------------------------|----------|------------|---------|---------|
| (Intercept)              | 0.38730  | 0.34557    | 1.121   | 0.267   |
| factor(DistractionScenario)S3 | 0.09531  | 0.49935    | 0.191   | 0.849   |
| factor(DistractionScenario)S4 | -0.56486 | 0.36537    | -1.546  | 0.127   |
| factor(SecondaryTaskType)Visual | 0.01316  | 0.26576    | 0.050   | 0.961   |

Residual standard error: 1.002 on 59 degrees of freedom
Multiple R-squared: 0.07338, Adjusted R-squared: 0.02626
F-statistic: 1.557 on 3 and 59 DF, p-value: 0.2093

Neither *Distraction Scenario* nor *Secondary Task Type* has direct impact on *Reaction Time*. 
Results

- Linear regression
- Step 3:

  - \( M3: \)
  - \( \text{Distraction Duration} = \beta_0 + \beta_1 \times \text{Distraction Scenario} + \beta_2 \times \text{Secondary Task Type} \)
Results

```
lm(formula = DistractionDuration ~ factor(DistractionScenario) + factor(SecondaryTaskType), data = datad)

Residuals:
    Min     1Q  Median     3Q    Max
-4.9840 -0.7934  0.2074  1.1762  3.6440

Coefficients:
                      Estimate Std. Error  t value Pr(>|t|)
(Intercept)               2.0217      0.6589     3.068   0.0032 **
factor(DistractionScenario)S3 -0.4735      0.9522    -0.497   0.62084
factor(DistractionScenario)S4  4.0403      0.6967     5.799   2.78e-07 ***
factor(SecondaryTaskType)Visual -0.4201      0.5068     0.829   0.41043

---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

Only Distraction Scenario has significant effect on Distraction Duration.
Results

- Final model structure validated:

```
Distraction Scenario (S2, S3, S4)  Secondary Task Type (Non-visual, Visual)
```

```
Normal Driving  Distracted Driving
```

```
Reaction Time
```

```
Gender  Lighting
Age  Weather
```

```
A  B : A is assumed to be a contributing factor of B
```
Conclusion

• Driver distraction could affect reaction time
  • In the studied events, driver distraction duration is the primary direct cause of reaction time, with other factors having indirect effects mediated by distraction.
  • Longer distraction duration and the distracted status when a leader braked tended to result in longer reaction times.

• Limitations in this study
  • Limited access to NDS data, e.g. situation kinematics
  • Small sample size
Acknowledgement

• SHRP 2 Safety Data Program, Transportation Research Board (TRB) Oversight Committee for Use and Oversight of SHRP 2 Safety Data, Phase 1

• Virginia Tech Transportation Institute (VTTI)

• University of Minnesota
  Professor Gary A. Davis
  Dr. Indrajit Chatterjee
  Minnesota Traffic Observatory (MTO)
• Questions?

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