Examining the Role of Driving Volatility on Intensity of Crashes: Insights from Naturalistic Driving Study Data

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Introduction

• Each year, near $1 Trillion crash cost in the U.S.

• Tennessee (2018):
  • 24,612 distracted driving crashes
  • 996 fatalities

• Note: Certain types of crashes are under-reported in such databases.
  • Specifically, a National Highway Traffic Safety Administration report: 50% of no-injury crashes and 25% of minor injury crashes are unreported.

• Availability of high-resolution naturalistic driving study → In depth analysis of crash contributing factors

• Information on driver behavior and vehicle kinematics help us to investigates their contribution on crash severity
Main objectives:

1. Instead of analyzing conventional police-reported crashes that do not contain microscopic vehicle kinematic information, this study analyzes pre-crash kinematic data and extracts a different set of contributing factors.

2. Study the association of driver behavior, roadway/environmental factors on driving stability

3. Analyze correlations of crash severity with speed and stability
Conceptual framework

Associated factors, $X$

**Driver Behavior:**
- Distracted driving
- Aggressive driving
- Seatbelt use
- Both hands on wheel

**Roadway and environmental factors:**
- Location of crash
- Relation to junction
- Intersection influence
- Traffic density
- Road alignment
- Traffic flow
- Light condition
- Weather condition
- Surface condition

**Vehicle-specific factors**
- Vehicle type
- Vehicle age
- Safety features

Driving instability, $Y_1$

- Speed volatility
- Acceleration volatility
- Deceleration volatility

Crash intensity, $Y_2$

- Low-risk Tire Strike
- Minor crash
- Police-reportable crash
- Most severe

Driving speed ($\nu$)
Path analysis

- **Model 1 ($f_{volatility}$):** Estimates the impact of driving behavior and surrounding environment factors on the driving volatility prior to crash:

  \[ Y_1 = f_{volatility}(\alpha_1 + \beta_1 X_1) \]

- **Model 2 ($f_{severity}$):** Estimates the severity outcome of the crash using the direct association of driving volatility, speed, driver behavior, and roadway factors to the crash severity

  \[ Y_2 = f_{severity}(\alpha_2 + \beta_2 X_2 + \gamma Y_1 + \beta_3 V) \]
Data

- Second Strategic Highway Research Program (SHRP 2) is used
- Biggest naturalistic driving study - High-quality data on more than 3500 drivers
- 617 crashes containing the information on 30 seconds of vehicle kinematic data
- 20 seconds of data is used for each crash

**Level 1 Severe Crash:** includes any injury, airbag deployment, vehicle rollover, or high-delta V.

**Level 2 Crash Moderate Severity:** Not a level 1 crash. Crashes that are minimum $1500 damage worth. Also, the crashes that acceleration reaches ±1.3 g.

**Level 3 Crash Minor Severity:** Not a level 1 or 2 crash. The crashes that the vehicle contacts other objects, or crashes that vehicle depart from the road and sustain minimal damage.

**Level 4 Crash Tire Strike:** Not a level 1, 2 or 3 crash. Crashes that the tire is struck with little risk element.
Instability in driving

Driving volatility: Quantifies variations in instantaneous driving behavior

<table>
<thead>
<tr>
<th>Measures of volatility</th>
<th>Formulation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time-varying stochastic volatility</td>
<td>$V_f = \sqrt{\frac{1}{n-1} \sum_{i=1}^{n} (r_i - \bar{r})}$</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>$S_{dev} = \sqrt{\frac{1}{n-1} \sum_{i=1}^{n} (x_i - \bar{x})^2}$</td>
</tr>
<tr>
<td>Coefficient of Variation</td>
<td>$C_v = \frac{SD}{\bar{x}} \times 100$</td>
</tr>
<tr>
<td>Quartile Coefficient of Variation</td>
<td>$Q_{cv} = \frac{Q_3 - Q_1}{Q_3 + Q_1} \times 100$</td>
</tr>
</tbody>
</table>
Exclusion of evasive maneuver

Figure 2 – Speed and acceleration profile of a randomly chosen crash
## Descriptive Statistics

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
<th>Mean/Percent</th>
<th>S.D./frequency</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crash intensity</td>
<td>Low-risk Tire Strike</td>
<td>40.19%</td>
<td>248</td>
<td>0</td>
<td>1</td>
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<tr>
<td></td>
<td>Minor Crash</td>
<td>36.79%</td>
<td>227</td>
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<tr>
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<td>Moderate Crash</td>
<td>13.61%</td>
<td>84</td>
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<tr>
<td></td>
<td>Severe Crash</td>
<td>9.4%</td>
<td>58</td>
<td>0</td>
<td>1</td>
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<tr>
<td>Driving behavior</td>
<td>Hand on wheel</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Two hands on wheel</td>
<td>46.52%</td>
<td>287</td>
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<td>1</td>
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<tr>
<td></td>
<td>Other</td>
<td>53.48%</td>
<td>330</td>
<td>0</td>
<td>1</td>
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<tr>
<td></td>
<td>Aggressive</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Aggressive driving</td>
<td>9.72%</td>
<td>60</td>
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<tr>
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<td>None</td>
<td>90.28%</td>
<td>557</td>
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<td>1</td>
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<tr>
<td></td>
<td>Distracted</td>
<td></td>
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<td>64.67%</td>
<td>399</td>
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<tr>
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<td>None</td>
<td>35.33%</td>
<td>218</td>
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<td></td>
<td>Seatbelt</td>
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<td>Seatbelt used</td>
<td>90.6%</td>
<td>559</td>
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<td>1</td>
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<tr>
<td></td>
<td>No</td>
<td>9.4%</td>
<td>58</td>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>
Pathway diagram

Distracted Driving
Aggressive Driving
Intersection Influence
Locality
Traffic Density
Relation to Junction
Weather
Airbag Deployment

Speed Mean
Speed Volatility
Deceleration Volatility

Crash Severity:
- Low-risk tire strike (base)
- Minor crash
- Police-reportable Crash
- Most severe

Legend
- Driver Behavior Factors
- Driving Stability Factors
- Roadway/Environmental Factors
Results

- Driving stability in terms of speed and deceleration volatility are highly correlated with the crash severity

- Distracted driving directly and indirectly increase the probability of severe crash

- Higher driving speed increases the likelihood of severe crash
Thank you!