Driver Adaptation Behavior and Driving Style Classification

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Introduction

- Driver Adaptation Behavior: Drivers change their behavior adaptively as they integrate these new support systems into their driving routine (Sullivan, Flannagan, Pradhan & Bao, 2016);

- Identify risky driving style measures;
  - Fancher et al. (1998) studied driver’s behavior change with ACC (Adaptive Cruise Control) and drivers are classified based on range rate and speed in car following scenario;
  - Guo et al (2013) defined driver class with the NEO five-factor inventory and used crash and near-crash as a measurement of aggressiveness;
  - Murphey et al (2009) defined driving behavior based on jerk and classified the drivers for online power management purposes;
Study Objectives and Tasks

• Objectives
  – To assess and quantify negative safety consequences associated with drivers’ adaptively interact with different active in-vehicle safety technologies;

• Main tasks
  – Define driving style measures;
  – Evaluate and model driving style changes with crash warning systems;
  – Evaluate and model driving style changes with connected vehicle technologies;
Methods: Aggressive Behavior Measure

Principle Component Analysis

Statistical procedure that uses an orthogonal transformation to convert a set of observations of possibly correlated variables into a set of values of linearly uncorrelated variables

\[ X - \bar{X}_B = U \Sigma V \]

Principle Components \( U \)

Corresponding Singular values \( \Sigma \)

Centered with baseline mean \( \bar{X}_B \)

Factor Loading Calculation

\[ U_k = (X - \bar{X}_B)a_k \]

Factor loading: Correlation coefficients between the variables and factors

Key to understanding the underlying nature of a particular factor

Obtained through Pearson product-moment correlation coefficient

\[ a_k = \frac{\text{cov}(X_B, U_k)}{\sigma_{X_B} \sigma_{U_k}} = E[(X_B - \bar{X}_B)^T (U_k - \bar{U}_k)] \]
Define Following Behavior based on selected variables through principle component analysis

**Factor Loading for First Principle Components**

<table>
<thead>
<tr>
<th>Variables</th>
<th>U(1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Short Time Headway Ratio</td>
<td>0.396</td>
</tr>
<tr>
<td>Long Time Headway Ratio</td>
<td>-0.394</td>
</tr>
<tr>
<td>Short Range Rate Ratio</td>
<td>0.307</td>
</tr>
<tr>
<td>Long Range Rate Ratio</td>
<td>-0.332</td>
</tr>
<tr>
<td>Short TTC Ratio</td>
<td>0.385</td>
</tr>
<tr>
<td>High Speed Ratio</td>
<td>0.354</td>
</tr>
<tr>
<td>Low Speed Ratio</td>
<td>-0.166</td>
</tr>
<tr>
<td>Extreme Acceleration Ratio</td>
<td>0.309</td>
</tr>
<tr>
<td>Brake Frequency</td>
<td>0.296</td>
</tr>
</tbody>
</table>

Define Longitudinal Aggressiveness with U(1)

\[
\lambda = (X - \bar{X}_B) a \quad \bar{X}_B \quad \text{Baseline Mean}
\]

\[\lambda \quad \text{Longitudinal Aggressiveness}
\]

\[a \quad \text{Factor Loading of U(1)}\]
Methods: Data on Crash Warning System

**IVBSS Car Following Data Description**

- **IVBSS:** 108 Light Vehicle Drivers, 6 weeks each, 213,000 miles

Steady state highway car following
- Average Vehicle Speed > 55mph (24.59 m/s)
- Range rate <±2 m/s
- Event length larger than 20s
- At least 30 events for baseline and 30 for treatment

**83** Drivers, **15,050** Baseline Events, **14,636** Treatment Events

**Gender:**
- Female 42
- Male 41

**Age:**
- 20-30: 30
- 30-40: 31
- 40-50: 22
- 50-60: 22
- 60-70: 5

**Corrective Lens:**
- No 41
- Yes 42

**Speed Distribution of Highway Car Following**

**Highway Car Following Position Per Minute**
IVBSS Light Vehicles

- 16 vehicles each with an four prototype crash warning systems
- 7 radars, 5 video streams, GPS, >500 other signals at 10 to 50 Hz
Data Viewer Tool – Highly Reconfigurable
Results: Following Style Classification

<table>
<thead>
<tr>
<th>Baseline Behavior</th>
<th>Type</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Aggressive</td>
<td>21</td>
</tr>
<tr>
<td></td>
<td>Normal</td>
<td>42</td>
</tr>
<tr>
<td></td>
<td>Conservative</td>
<td>20</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>P</th>
<th>Max Diff.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Young v.s. Middle</td>
<td>0.00039</td>
<td>0.5097</td>
</tr>
<tr>
<td>Young v.s. Old</td>
<td>0.00003</td>
<td>0.6394</td>
</tr>
<tr>
<td>Middle v.s. Old</td>
<td>0.3793</td>
<td>0.2434</td>
</tr>
</tbody>
</table>
Results: Driver Characteristics

Driver Variable:
- Gender
- Age
- Driving years
- Annual mileage
- Corrective Lens

Pearson's Linear Correlation Coefficients:

<table>
<thead>
<tr>
<th>Aggressiveness</th>
<th>Age</th>
<th>Driving Years</th>
<th>Annual Mileage</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>-0.5359</td>
<td>-0.5356</td>
<td>0.1682</td>
</tr>
</tbody>
</table>

Influence of Gender on Aggressiveness:
- Total Population
- Male
- Female

Null hypothesis rejected at a=0.1
Male drivers are more aggressive

P=0.0629
0.2799

Influence of Glasses on Aggressiveness:
- Total Population
- Without Glasses
- With Glasses

Null hypothesis cannot be rejected
Influence of glasses is not significant

P=0.8257
0.1336

- Age and driving year are negative related with aggressiveness
- Annual mileage is positive related with aggressiveness
Results: Crash Warning Effects

Driving Style Analysis

<table>
<thead>
<tr>
<th>Type</th>
<th>Baseline</th>
<th>Treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aggressive</td>
<td>21</td>
<td>24</td>
</tr>
<tr>
<td>Normal</td>
<td>42</td>
<td>47</td>
</tr>
<tr>
<td>Conservative</td>
<td>20</td>
<td>12</td>
</tr>
</tbody>
</table>

P = 0.326

Influence of Gender

P = 0.6818

Influence of Glasses

P = 0.6725
Results: Crash Warning Effects Cont.

Warning condition analysis

Interaction between age and driving condition

- Mean value shows aggressiveness slightly increase, variance decrease
Methods: Data on Connected Vehicle Technology

Safety Pilot Model Deployment

Largest Connected Vehicle FOT led by UMTRI

Over 2,800 personal vehicles, truck fleets, and transit buses;
About 35 million miles or 1.2 million hours of driving;
About 140 vehicles equipped with Mobileye and DAS;
Over 3,200 events of bicyclists interacting with vehicles;

Aug. 19th, 2012 - Apr 20th, 2015
Results: Driving Style Classification

Steady state highway car following
- Vehicle Speed > 55mph (24.59 m/s)
- Range rate <±2 m/s
- Event length between 20s and 300s
- Driver with more than 250 events (87)
- 201,045 events identified

Initial: first 50 events
Middle: event from 150 to 200
Final: last 50 events

<table>
<thead>
<tr>
<th>Data Group</th>
<th>Mean[s]</th>
<th>Std.Dev</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial</td>
<td>1.44</td>
<td>0.79</td>
</tr>
<tr>
<td>Middle</td>
<td>1.47</td>
<td>0.79</td>
</tr>
<tr>
<td>Final</td>
<td>1.48</td>
<td>0.79</td>
</tr>
</tbody>
</table>

![CDF Chart]

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UNIVERSITY OF MICHIGAN
Video Redacted
Video Redacted
• Definition of longitudinal aggressiveness provides one behavior quantification solution;

• With driver assistance functions, no evidence shows that drivers follow more aggressively;

• Male drivers were relatively following more aggressively than female drivers;

• Younger drivers had a higher value of aggressiveness when following other vehicles among the three age groups;

• More factors should be considered in evaluating individual driver/trip level;

• Sponsored by UM Mobility Transformation Center.
Thank you!
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