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 Σ Centered with baseline mean $\bar{X}_B$

Factor Loading Calculation $U_k = (X - \bar{X}_B)a_k$

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

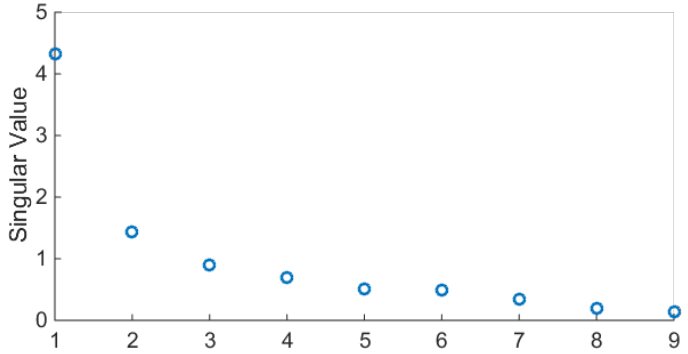
$$a_k = \frac{\mathrm{cov}(X_B, U_k)}{\sigma_{X_B}\sigma_{U_k}} = \frac{E[(X_B - \bar{X}_B)^T(U_k - \bar{U}_k)]}{\sigma_{X_B}\sigma_{U_k}}$$

Methods: Aggressive Behavior Measure Cont.

Define Following Behavior based on selected variables through principle component analysis

Factor Loading for First Principle Components

Varaibles	U(1)
Short Time Headway Ratio	0.396
Long Time Headway Ratio	-0.394
Short Range Rate Ratio	0.307
Long Range Rate Ratio	-0.332
Short TTC Ratio	0.385
High Speed Ratio	0.354
Low Speed Ratio	-0.166
Extreme Acceleration Ratio	0.309
Brake Frequency	0.296



Define Longitudinal Aggressiveness with U(1)

$\lambda = (X - \bar{X}_B)a$ $\bar{X}_B$ Baseline Mean

λ Longitudinal Aggressiveness

a Factor Loading of U(1)

Methods: Data on Crash Warning System

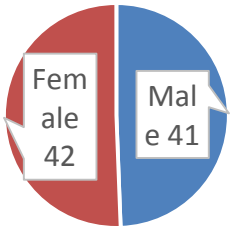
IVBSS Car Following Data Description

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

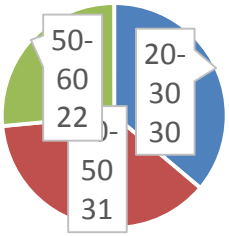
Steady state highway car following
- Average Vehicle Speed > 55mph (24.59 m/s)
- Range rate <+-2 m/s
- Event length larger than 20s
- At least 30 events for baseline and 30 for treatment

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

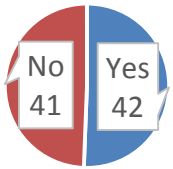
Gender

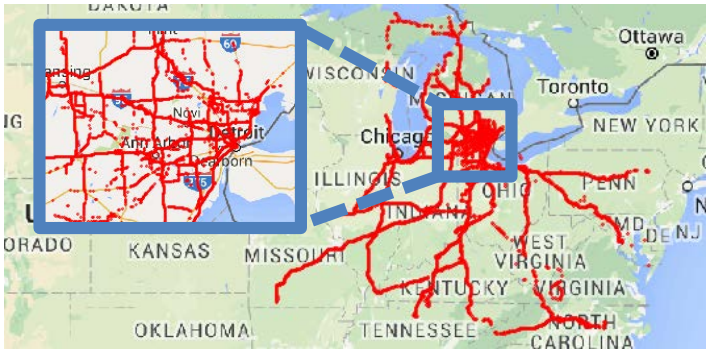


Age

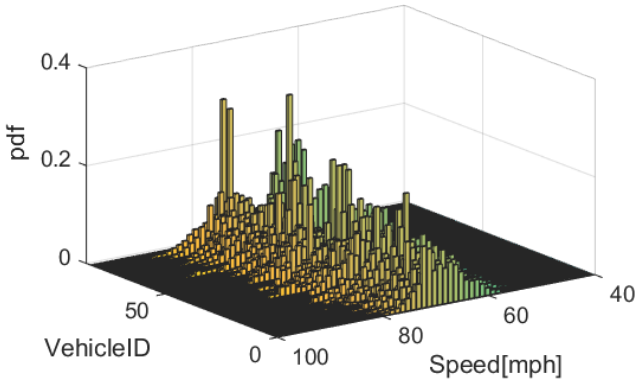


Corrective Lens





Highway Car Following Position Per Minute



Speed Distribution of Highway Car Following

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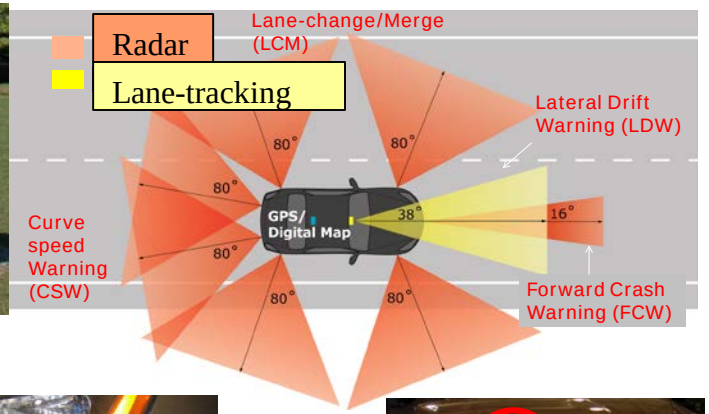
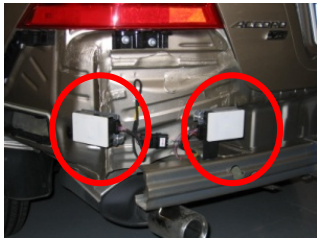
IVBSS Light Vehicles

- 16 vehicles each with an four prototype crash warning systems
- 7 radars, 5 video streams, GPS, >500 other signals at 10 to 50 Hz





Radars behind fascias

Data Viewer Tool – Highly Reconfigurable

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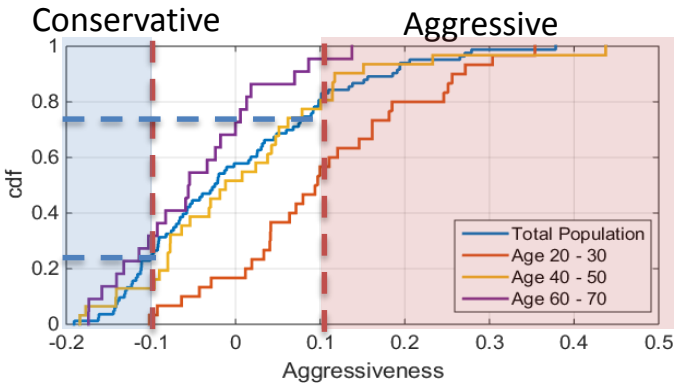
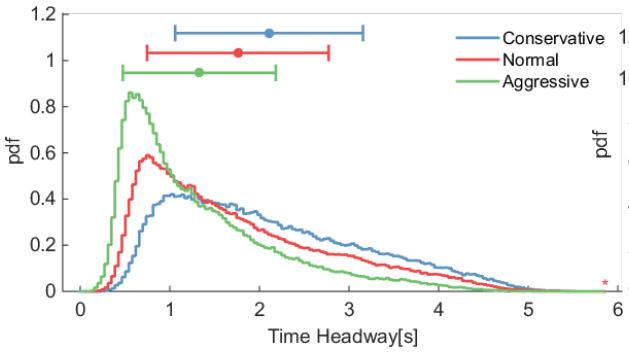
Results: Following Style Classification

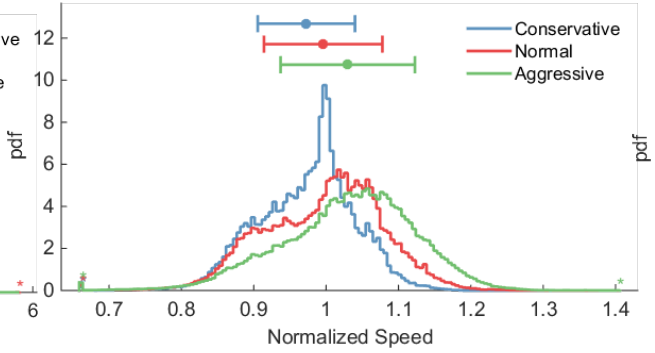
Baseline Behavior

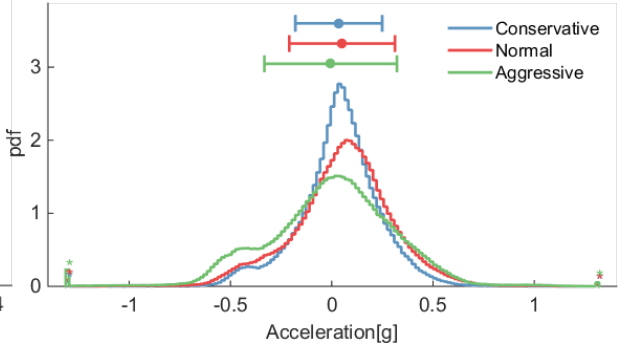
Type	Count
Aggressive	21
Normal	42
Conservative	20



	P	Max Diff.
Young v.s. Middle	0.00039	0.5097
Young v.s. Old	0.00003	0.6394
Middle v.s. Old	0.3793	0.2434







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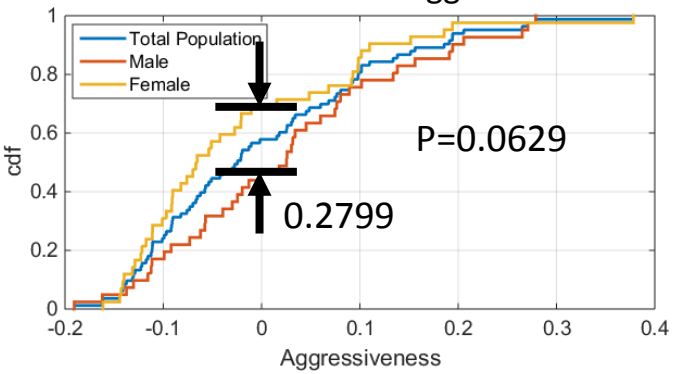
Results: Driver Characteristics

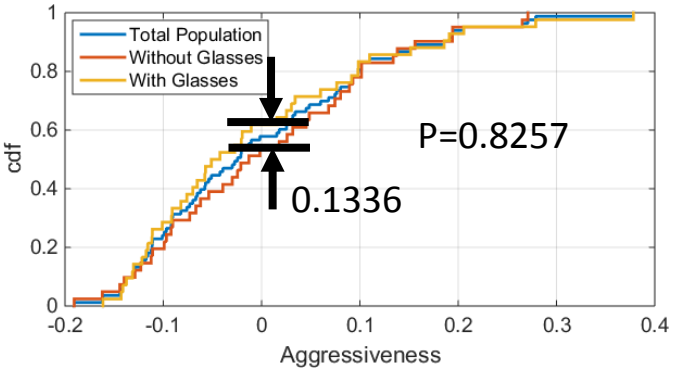
Driver Variable
Gender
Age
Driving years
Annual mileage
Corrective Lens

Influence of **Gender** on Aggressiveness



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

Influence of **Glasses** on Aggressiveness



Null hypothesis cannot be rejected
Influence of glasses is not significant

Pearson's Linear Correlation Coefficients

Aggressiveness	Age	Driving Years	Annual Mileage
1	-0.5359	-0.5356	0.1682

- Age and driving year are negative related with aggressiveness
- Annual mileage is positive related with aggressiveness

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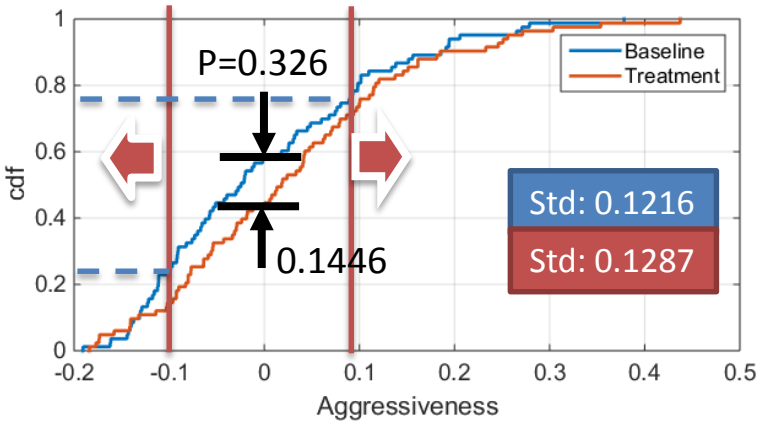
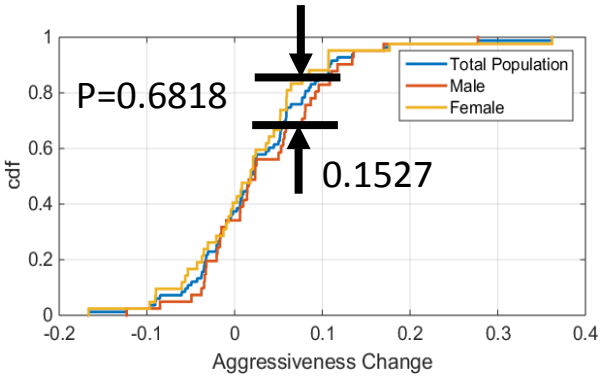
Results: Crash Warning Effects

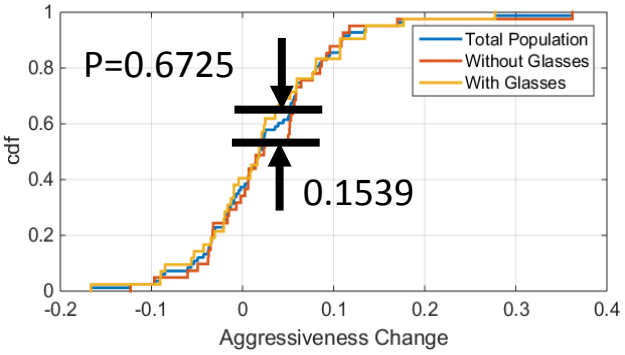
Driving Style Analysis

Type	Baseline	Treatment
Aggressive	21	24
Normal	42	47
Conservative	20	12





Influence of **Gender**



Influence of **Glasses**

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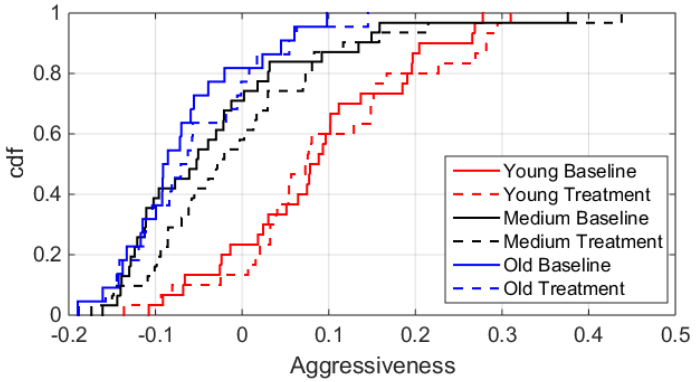
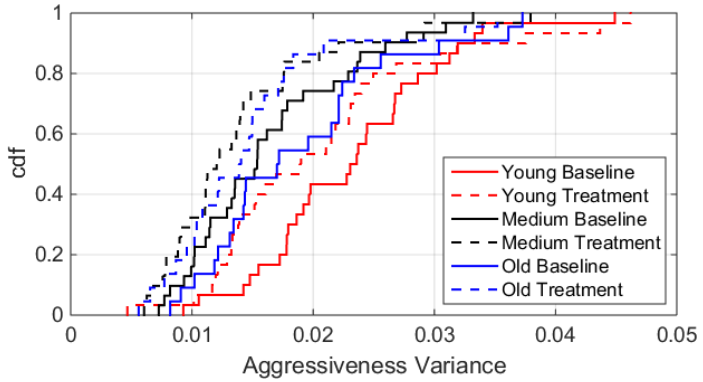
Results: Crash Warning Effects Cont.

Warning condition analysis



Interaction between age and driving condition



	Mean		Variance	
Group	$Mean_{Base}$	$Mean_{Treat}$	$Mean_{Base}$	$Mean_{Treat}$
20 – 30	0.0847	0.1037	0.0232	0.0206
40 – 50	-0.0322	0.0086	0.0164	0.0140
60 – 70	-0.0702	-0.0492	0.0189	0.0147

	Mean		Variance	
Group	P	Max Diff.	P	Max Diff.
20 – 30	0.9360	0.1333	0.1088	0.3000
40 – 50	0.2164	0.2581	0.1200	0.2903
60 – 70	0.8210	0.1818	0.1746	0.3182

- Mean value shows aggressiveness slightly increase, variance decrease

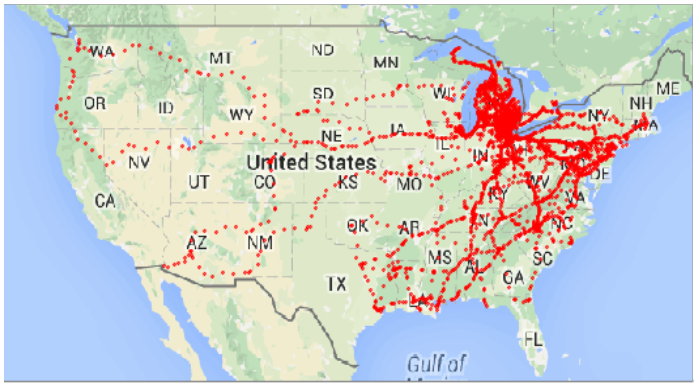
Methods: Data on Connected Vehicle Technology

Safety Pilot Model Deployment

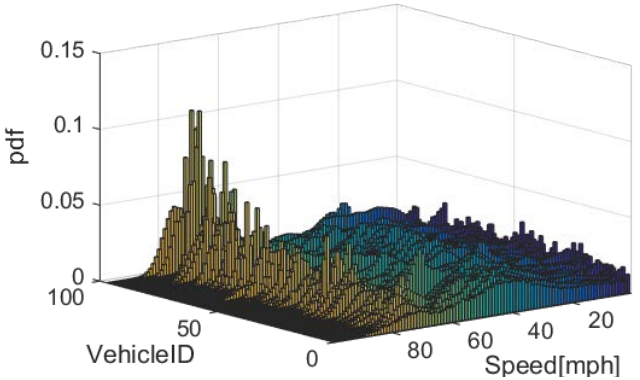
Largest Connected Vehicle FOT led by UMTRI

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



Hourly Position of DAS Equipped Vehicle



Speed Distribution of DAS Equipped Vehicle

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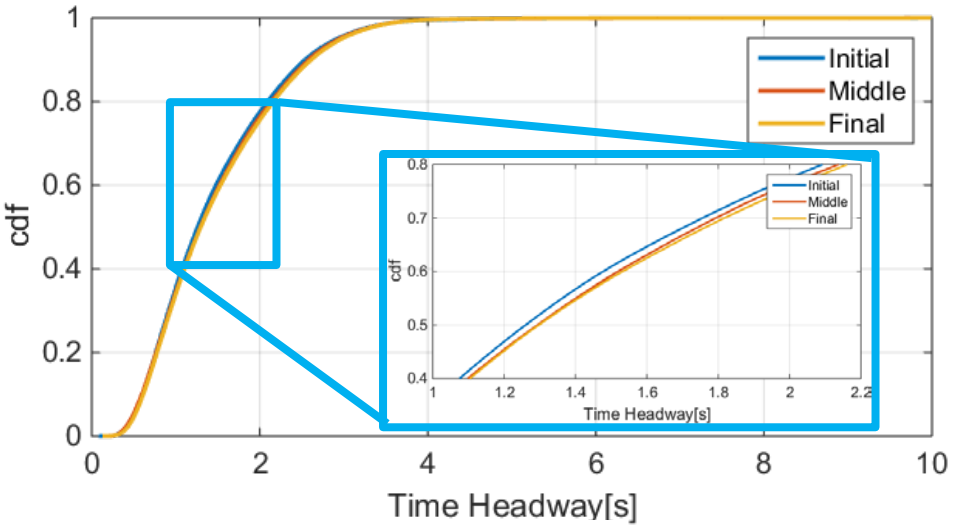
Results: Driving Style Classification

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



Data Group	Mean[s]	Std.Dev
Initial	1.44	0.79
Middle	1.47	0.79
Final	1.48	0.79

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Video Redacted

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Summary and Acknowledgement

- 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.

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Thank you!

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