



# The Relationship Between Visual Time Sharing Gaze Patterns and Driving Performance in Naturally Occuring Distractions

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<sup>5</sup>Volvo Car Corporation

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# SeMiFOT

A SAFER PROJECT

Late-breaking results

Sweden Michigan Naturalistic Field Operational Test



## Partners

### Industry

AB Volvo  
Autoliv  
Länsförsäkringar  
Saab Automobile  
Scania  
Test Site Sweden/  
Lindholmen Science Park  
Volvia  
Volvo Car Corporation

### Authority

Swedish Road Administration

### Academy

Chalmers University of Technology  
Swedish National Road and Transport Research  
Institute (VTI)  
Technical Research Institute of Sweden (SP)  
University of Michigan Transportation Research  
Institute (UMTRI)

## Safety Systems

Forward Collision Warning  
Adaptive Cruise Control  
Lane Departure Warning  
Electronic Cruise Control  
Impairment Warning

**SAFER**

# Data Acquisition



## VEHICLE NETWORK

- **Vehicle** data (Steering, accel, etc)
- **Environment** data (radar, machine vision, etc)

## SAFER DAS1

- All COTS parts, in-house assembly

## SAFER DAS2

- COTS COM 1.6 GHz CPU module.
- In-house "motherboard" with power supply and all I/Os. Extra CPU for voltage and temperature monitoring.
- 2 PC/104+ slots.
- In-house chassis.

Hard drive

## VIDEO

- Either PC/104+ frame grabber or external video server (Ethernet).
- Up to seven cameras using external multiplexer.

## EXTRA SENSORS

- **Eyetrackers:** 3 types, COTS
- **Forward machine vision:** Lane position, headway, *pedestrian*, *traffic signs*, *oncoming headlights*
- **Accelerometers**
- **GPS**



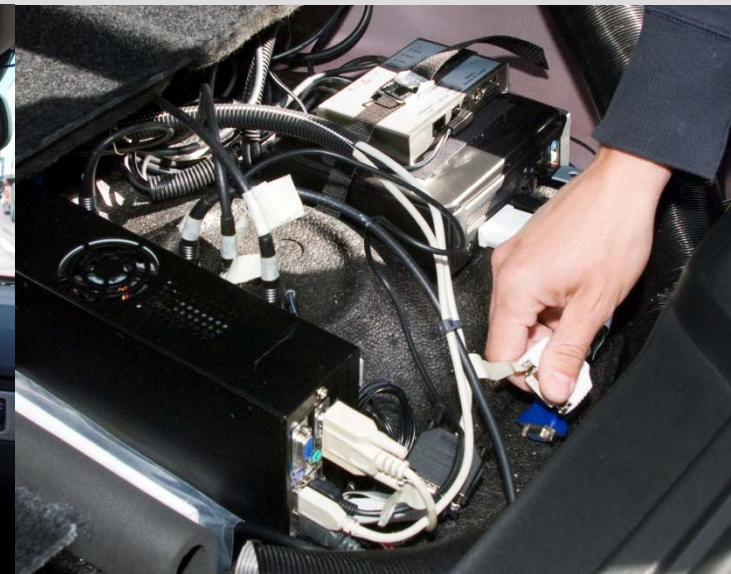
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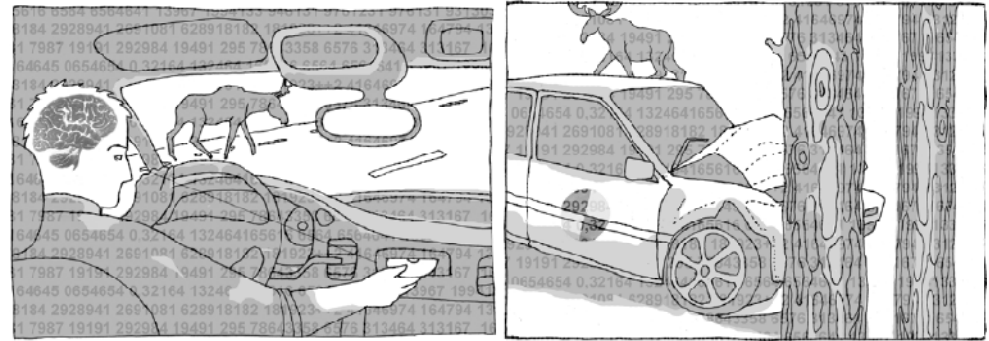
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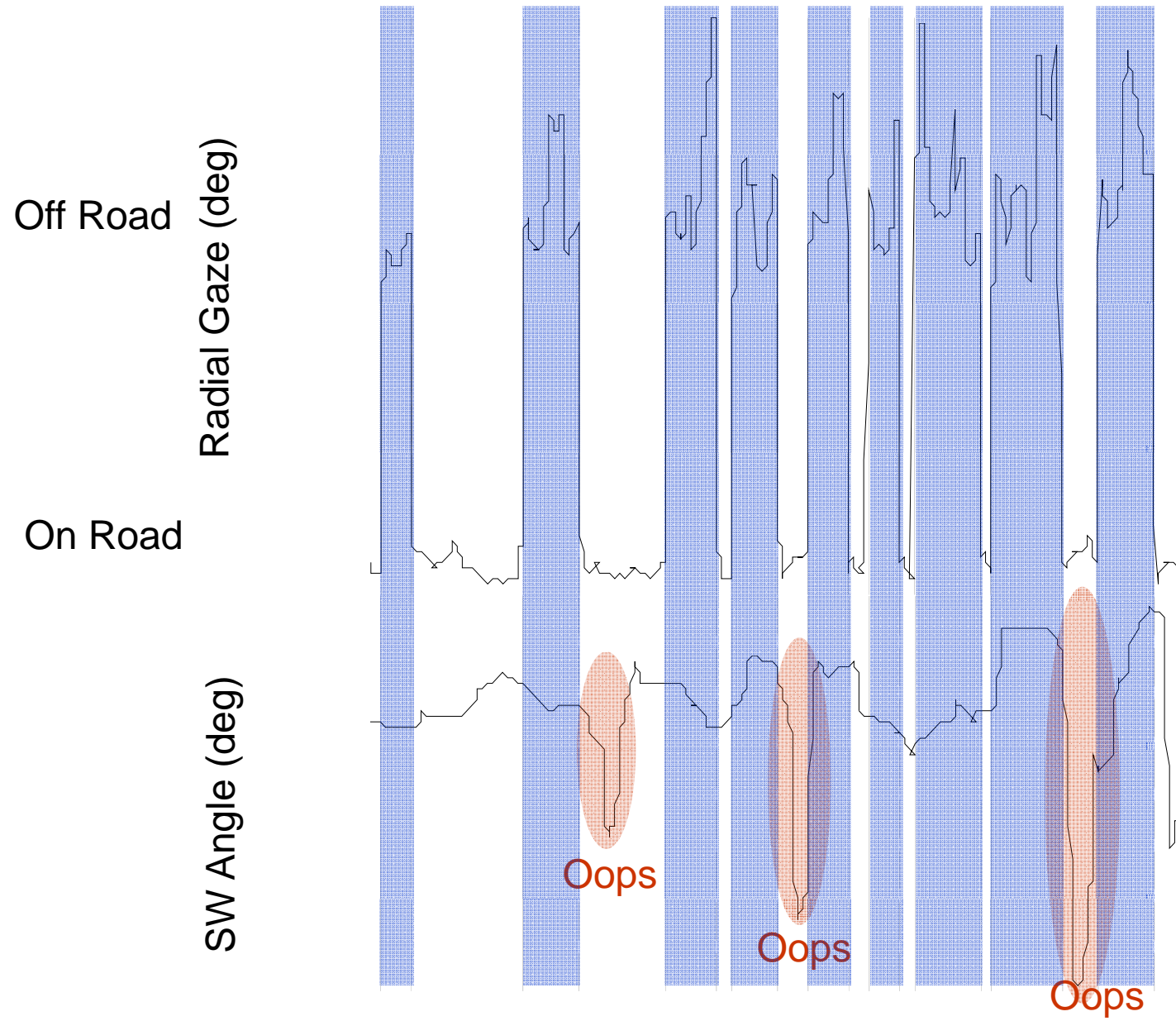
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# Background

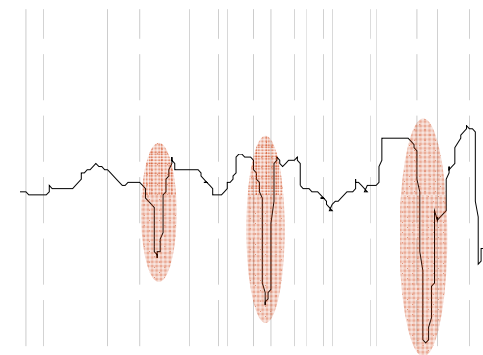
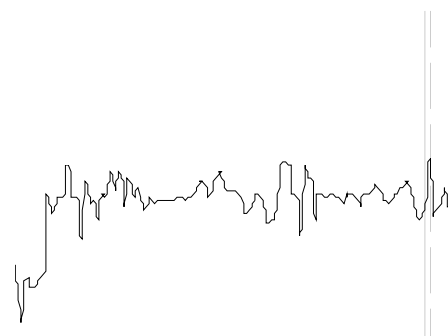
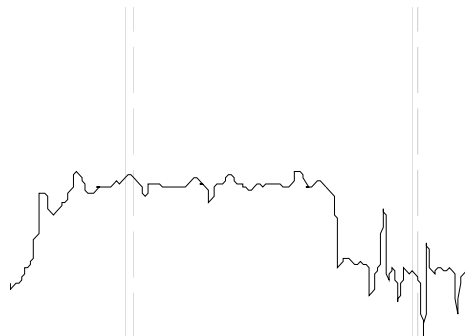
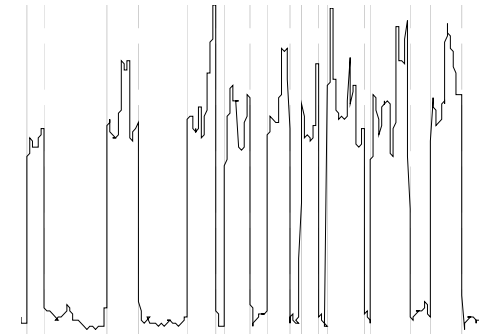
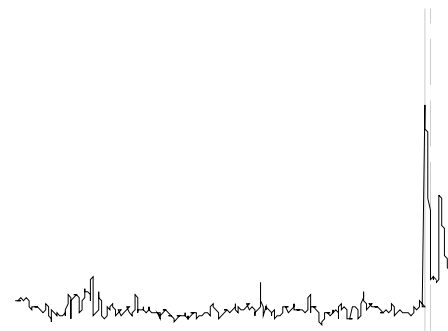
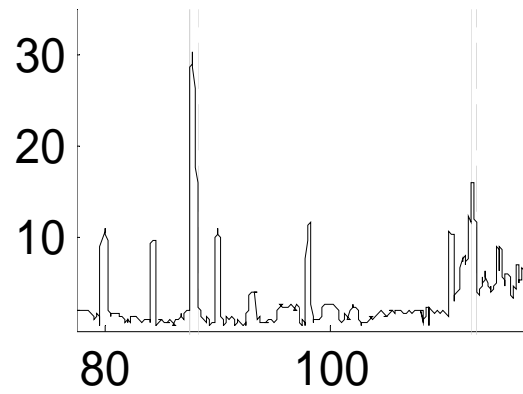
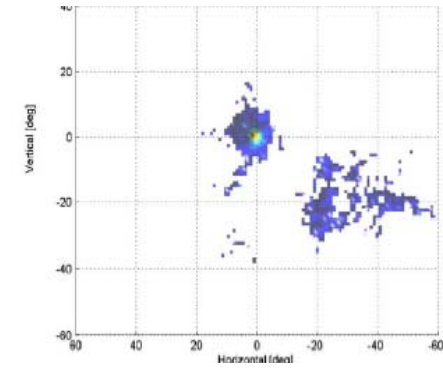
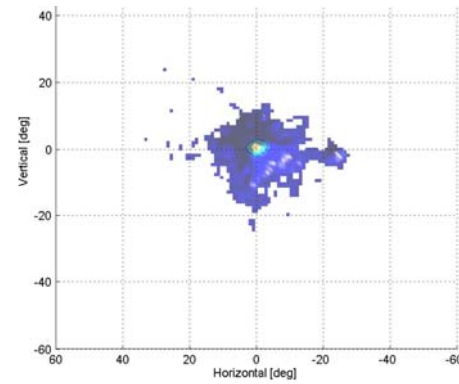
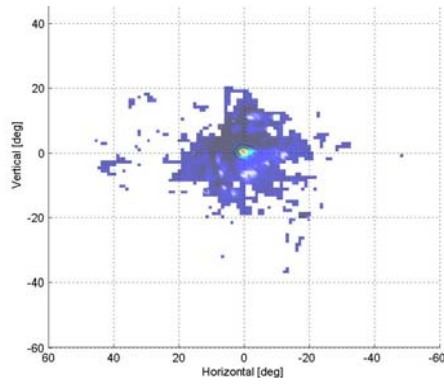


- Relationship between visual time sharing behavior (looking back and forth at the road) and driving performance metrics in naturalistic field data?
  - Particular interest in the “Oops reaction” being caused by preceding poor visual behavior patterns.



(Markkula & Engström, 2006)

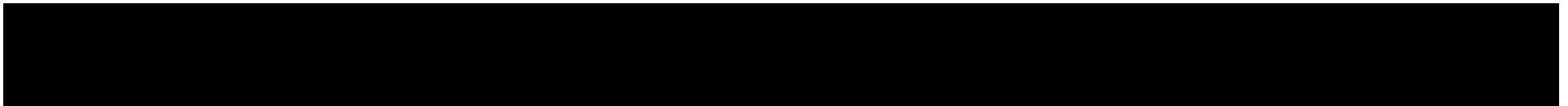




(Markkula & Engström, 2006)

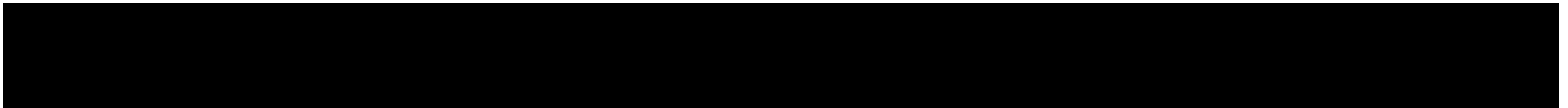
# Background

- Eye movement metrics are considered the most sensitive metrics for measuring distraction and workload (see CAMP Driver Workload Metrics project (Angell et al., 2006; O. M. J. Carsten et al., 2005; Wierwille & Tijerina, 1998b).
- Eye movement metrics are highly sensitive (discriminative, repeatable and have predictive validity) to the demands of visual and auditory in-vehicle tasks as well as driving task demands (Angell et al., 2006; O. M. J. Carsten et al., 2005; Wierwille & Tijerina, 1998b)
- Perhaps the most direct indicator of visual distraction is the visual timesharing revealed in the eye movement.
  - Visual time sharing refers to the stereotypical pattern of glancing back and forth between the road and an object (e.g., a cellphone) during a visual task such as dialing.



# Dependent Variables

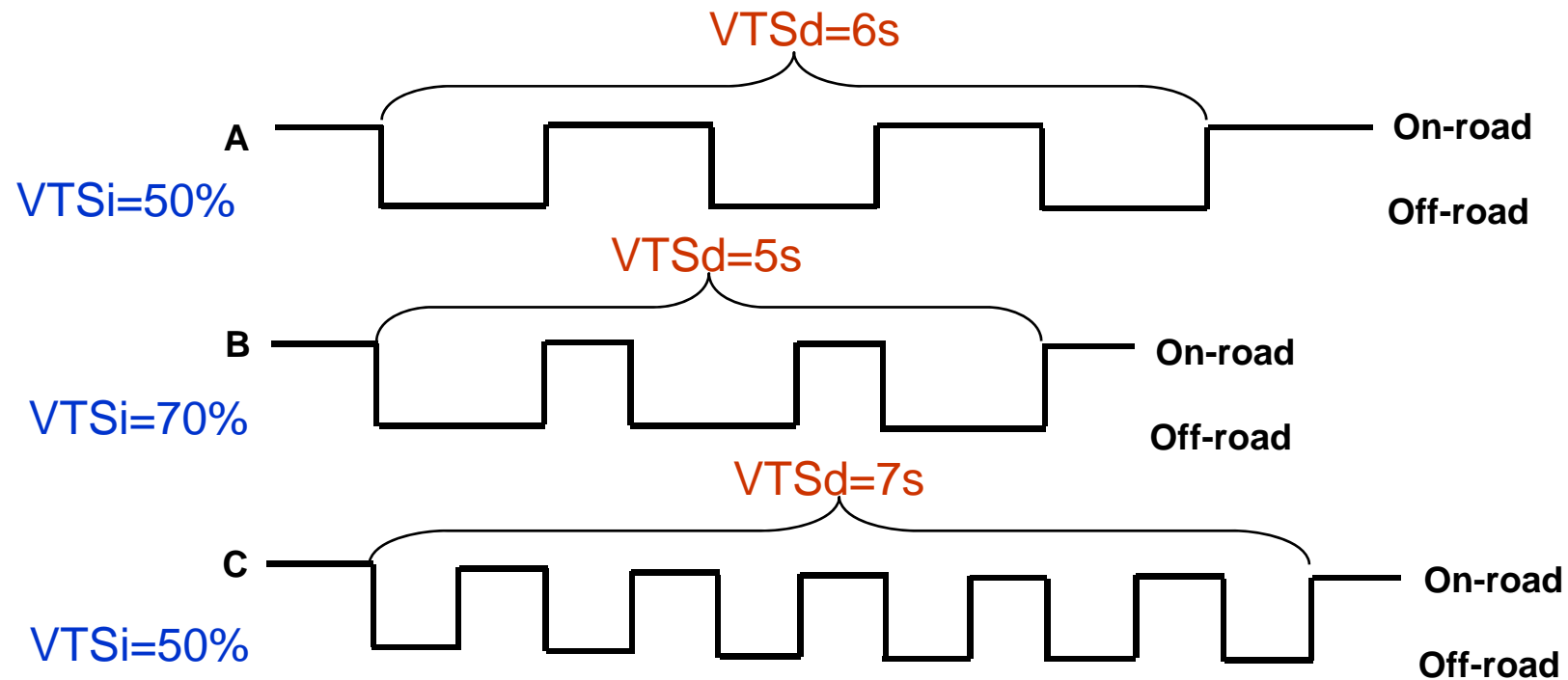
- A key problem with existing metrics is that they are developed for instructed, known segments given in experiments. They are difficult to implement (sometimes unsuitable) in real world settings.
- For example, it may be difficult to determine the starting point of an event or it may be difficult to even detect that an event occurred in naturalistic data.





# Visual Time Sharing Metrics

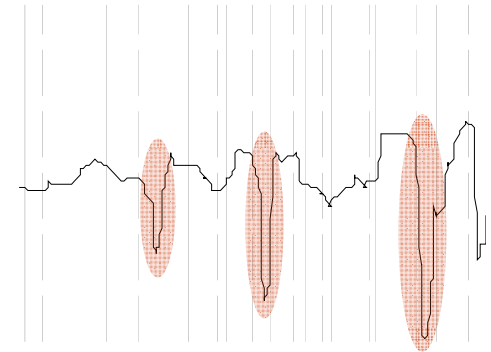
- **VTSDuration** = nr seconds spent in Visual Time Sharing
- **VTIntensity** = Percent of duration spent looking away
- $VTSeor = Duration * Intensity$



# Driving Performance Metrics

## – Quantifying "Oops"

The "Oops" could be expressed through steering or braking  
→ Calculated for the period during VTSd and 3sec after

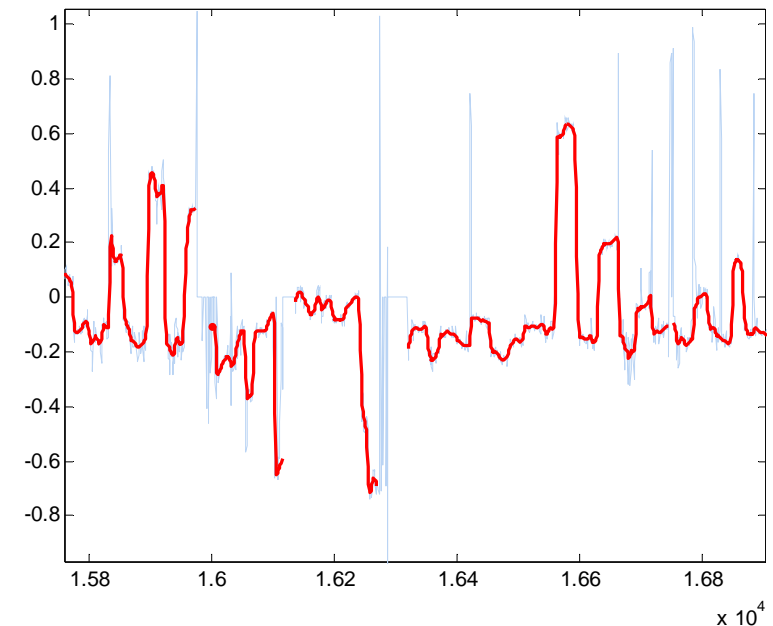
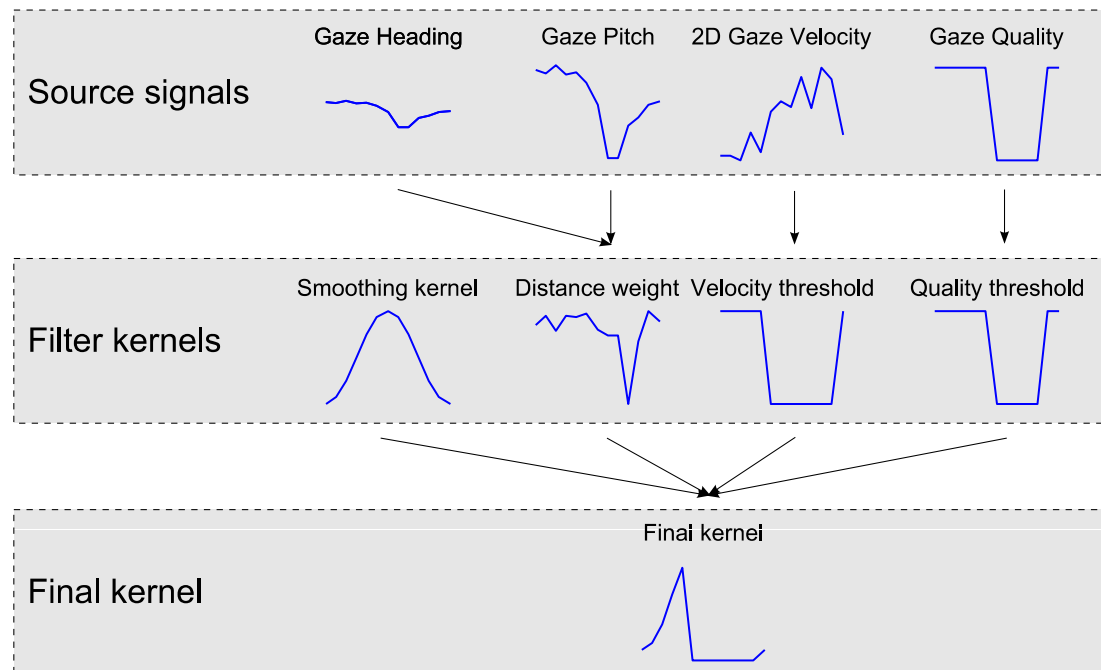


- **MaxReversal** (Steering Wheel) - Steering wheel changes: a visual secondary task leads to increased steering wheel movements in a wide range of amplitudes (i.e., 2-6 degrees) and frequencies, whereas cognitive tasks cause corrective movements with small amplitudes (less than 1 degree) (Östlund, Peters et al., 2006b)
- **ReversalRate** (Steering Wheel) - This metric is intuitive and simple but could be sensitive to environmental and age factors.
- **AbsMaxLatAccel** – Absolute maximum lateral acceleration
- **StdLatAccel** – Standard deviation of lateral acceleration
- **MinLongAccel** – Smallest acceleration value = deceleration (e.g. because of braking)
- **MeanSpeed** – For context

# Visual Behavior

## – New Quality and Smoothing Filter

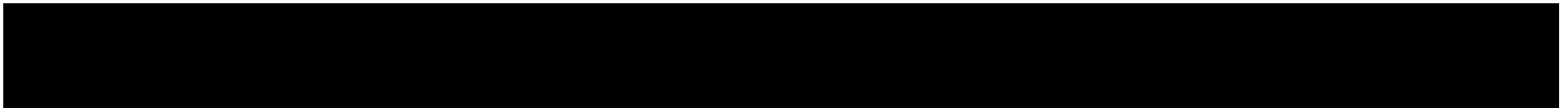
- Bilateral filter with a filter kernel that adapts itself to the properties of the signal



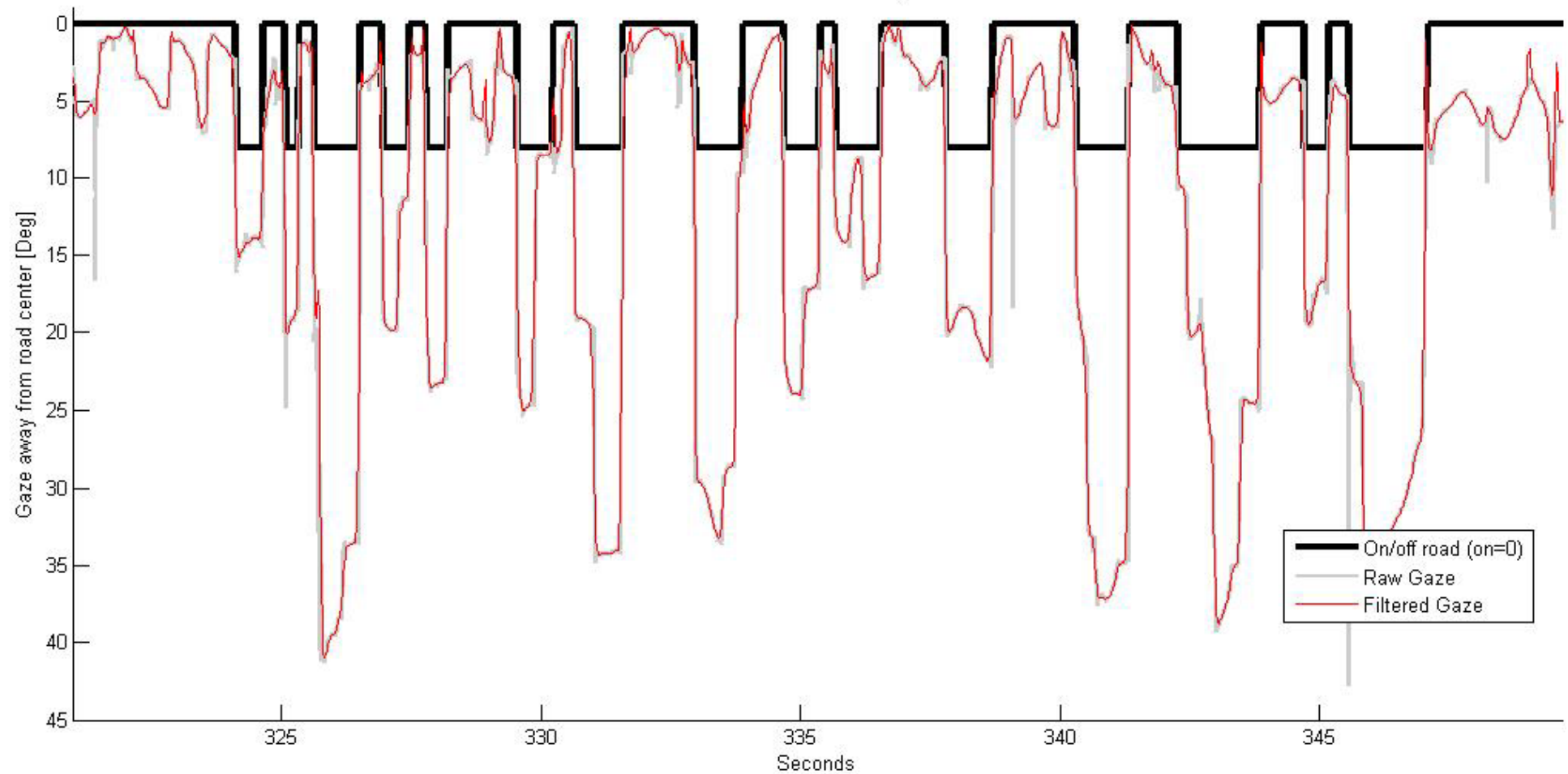
## Visual Behavior

### – New Algorithm Features

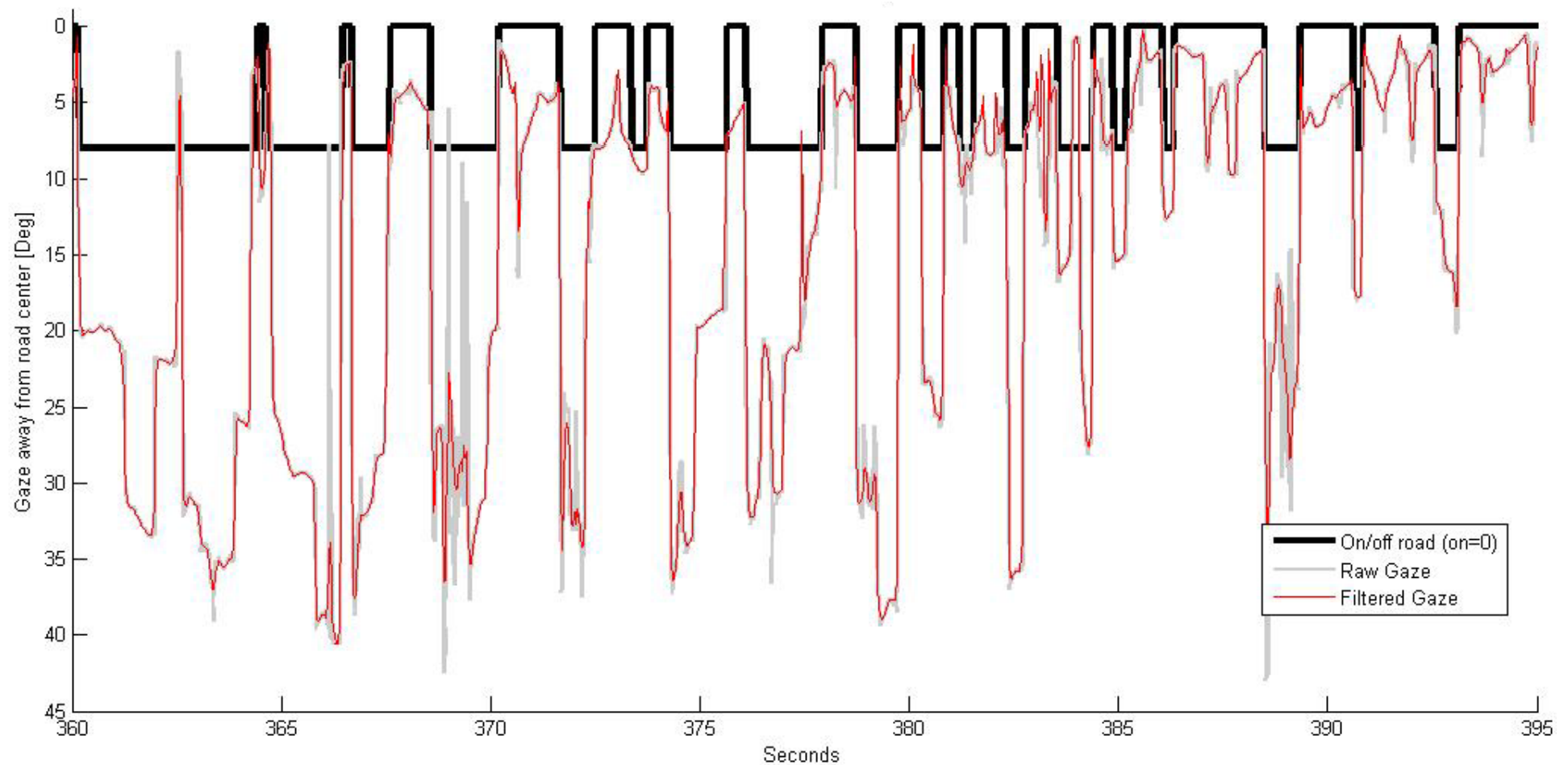
- An adaptive road centre point calculation – running weighted median
- Road center segmentation – 8degree radius from adaptive road centre point
  - Gives on-off road signal
    - Median filter then applied to remove short segments (<180ms)
- Rule-based Visual Time Sharing identifier algo
  - >3 sec min time between VTS events,
  - at least 3 glances away from road



# Automatic Visual Time Sharing Identifier Algorithm

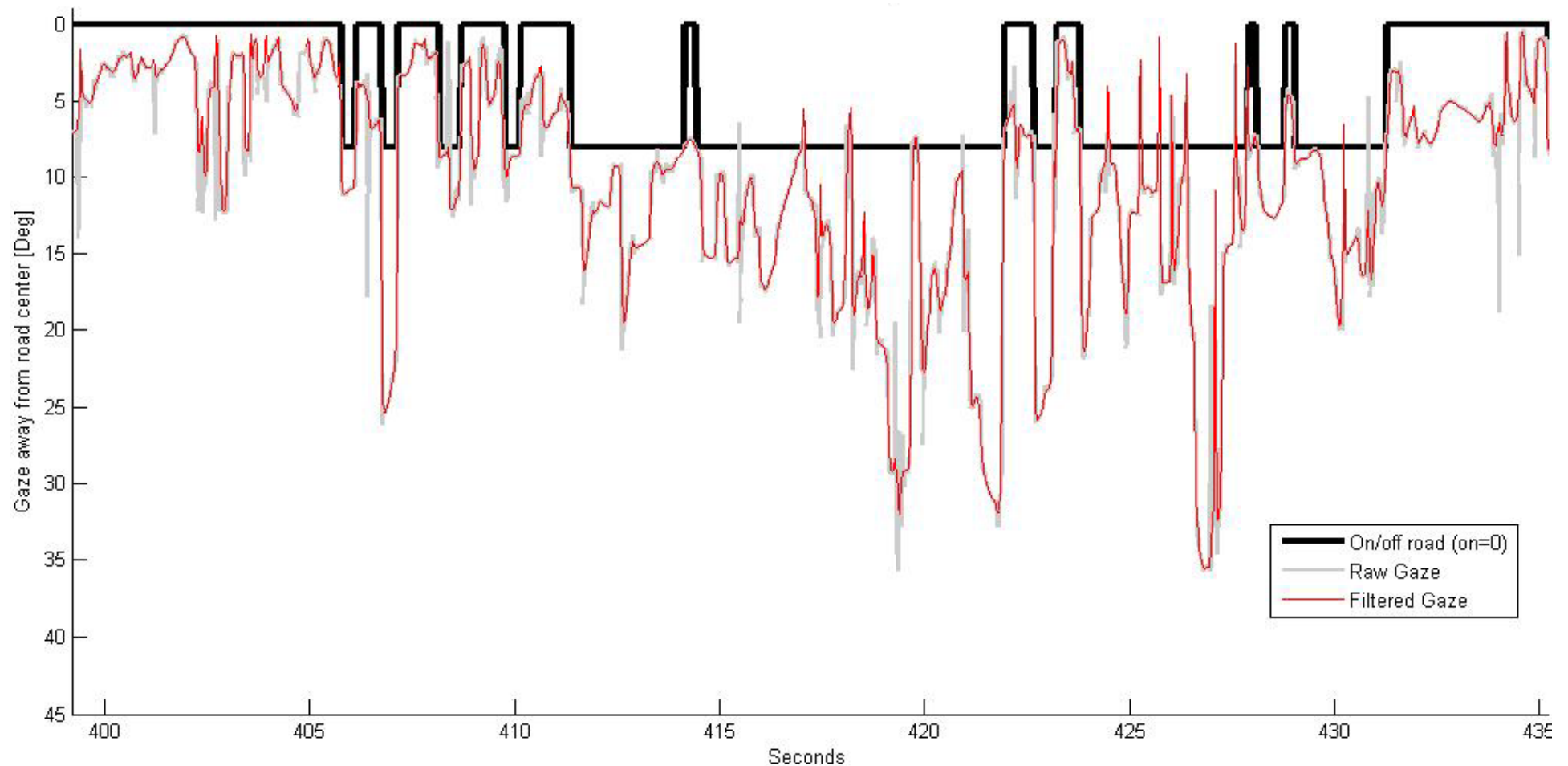


# Automatic Visual Time Sharing Identifier Algorithm





# Automatic Visual Time Sharing Identifier Algorithm



## (Current) Candidate Eyetracking Data

- 44 Drivers, 6367 trips, 2628 hrs total

Total 13 vehicles with eyetracking:

- 2 Volvo cars with SmartEye Pro (stereo)
- 3 Volvo cars with SmartEye Antisleep (mono)
- 1 Volvo car with DSS (mono)
- 2 Saab cars with DSS
- 2 Volvo trucks with DSS
- 3 Scania Trucks with DSS



# Visual Time Sharing Events

## All cars

nrOfSegments	4209
nrOfUniqueDrivers	12
nrOfUniqueVehicles	7
nrOfUniqueTrips	562

## All trucks

nrOfSegments	42
nrOfUniqueDrivers	16
nrOfUniqueVehicles	4
nrOfUniqueTrips	14

## All Vehicles

nrOfSegments	
nrOfUniqueDrivers	28
nrOfUniqueVehicles	11
nrOfUniqueTrips	
11,3%*	

## Candidates

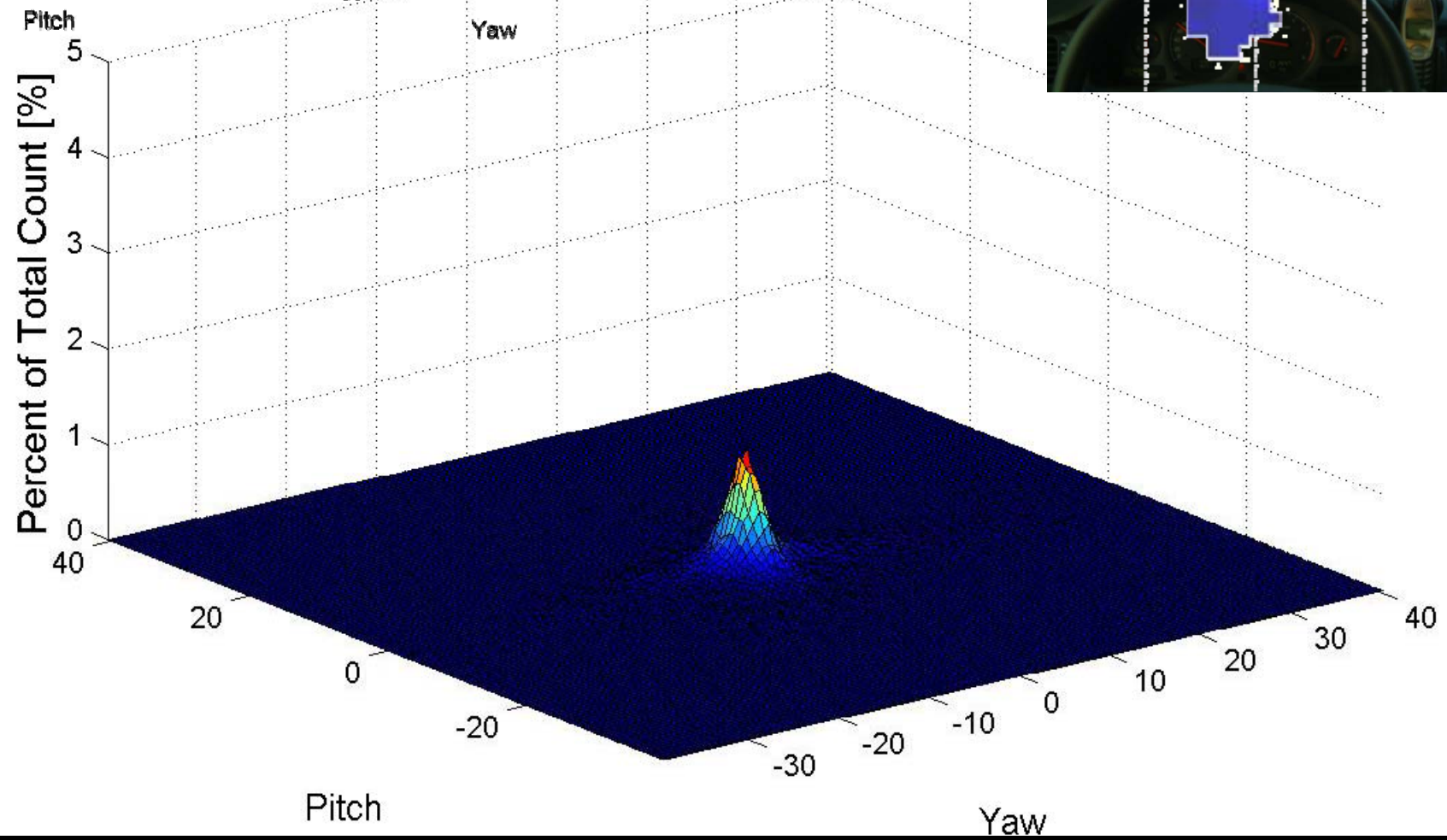
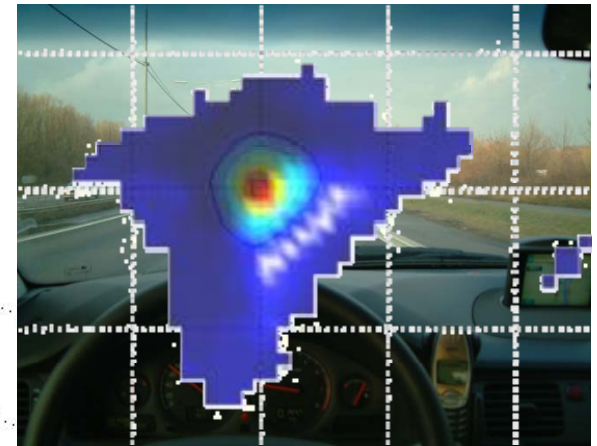
8453	
44	
13	
717	6367

## %

64%  
85%

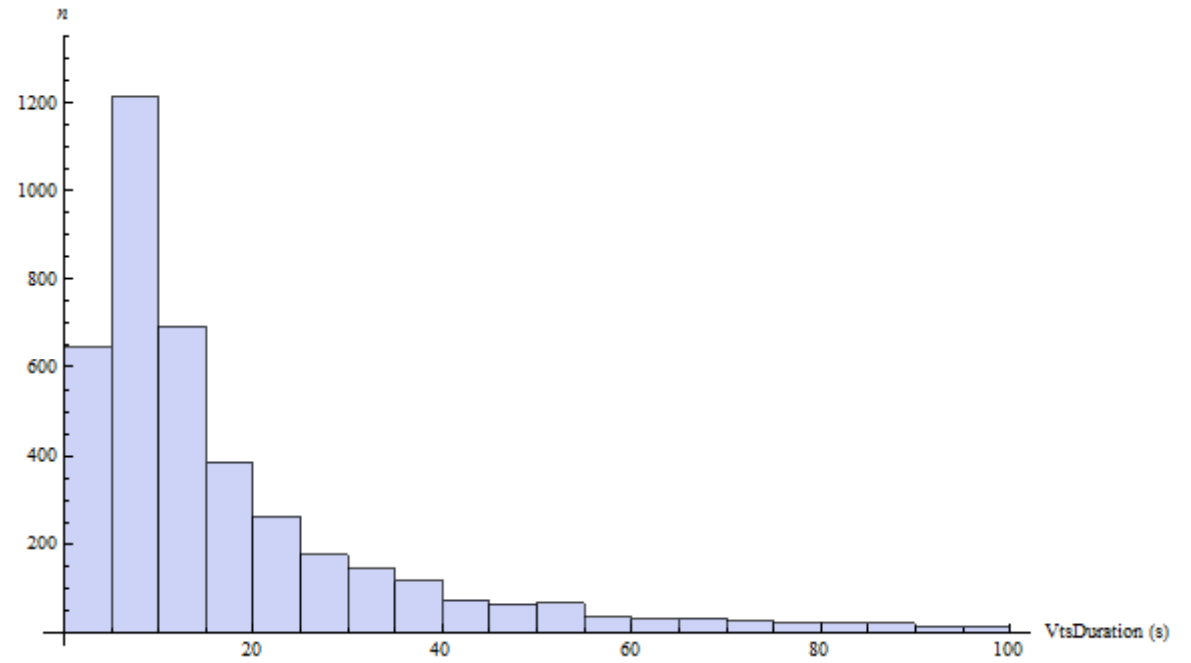
\*>60k  
m/h  
\*quality

# Results

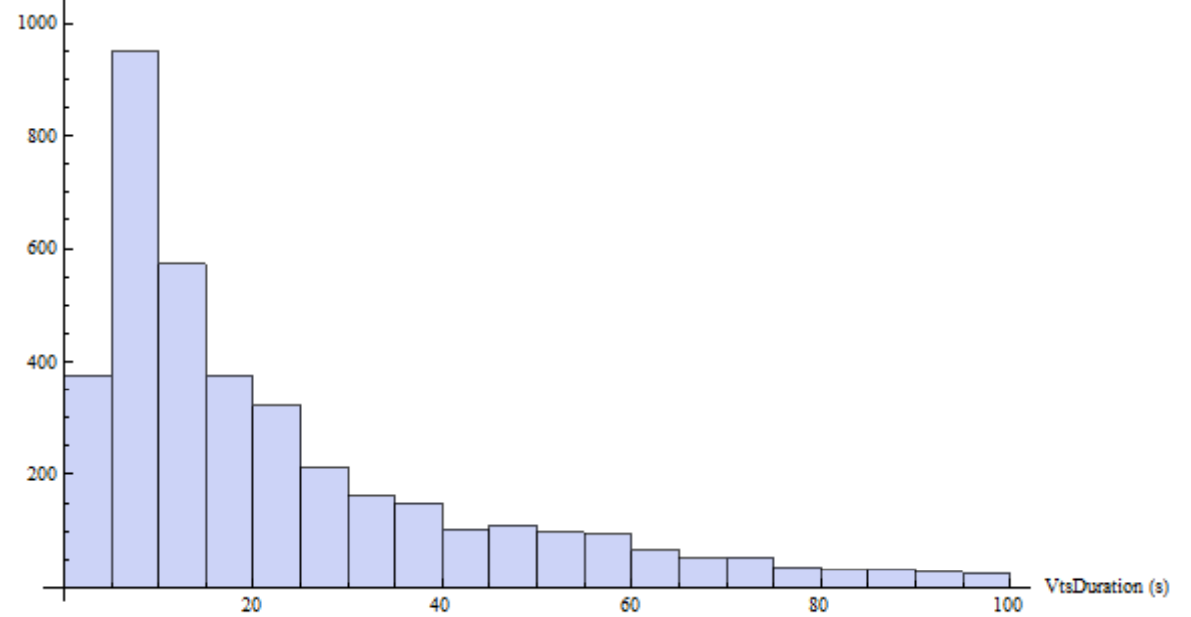


# VTs Duration (0-100sec)

Cars

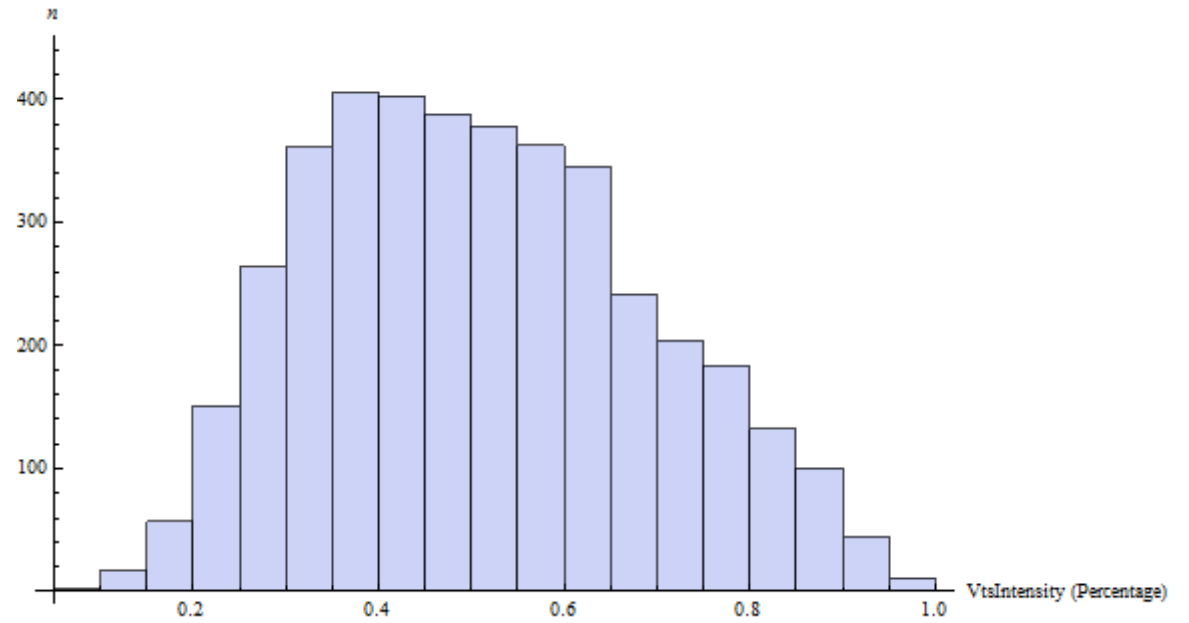


Trucks

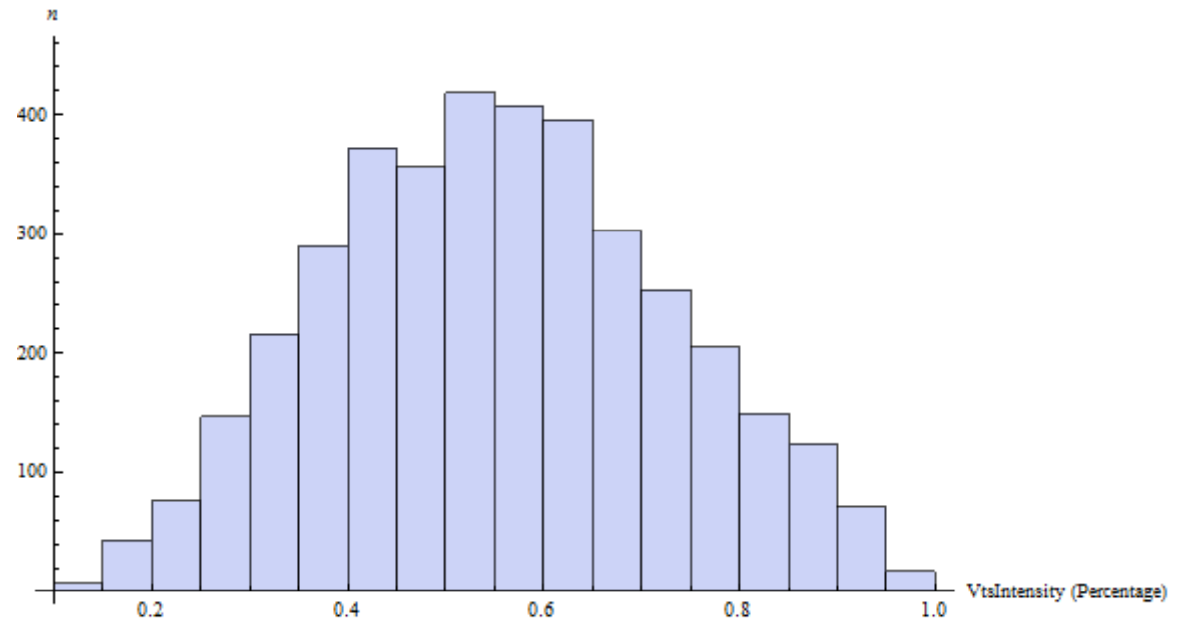


# VTs Intensity (VTsd 0-100s)

Cars

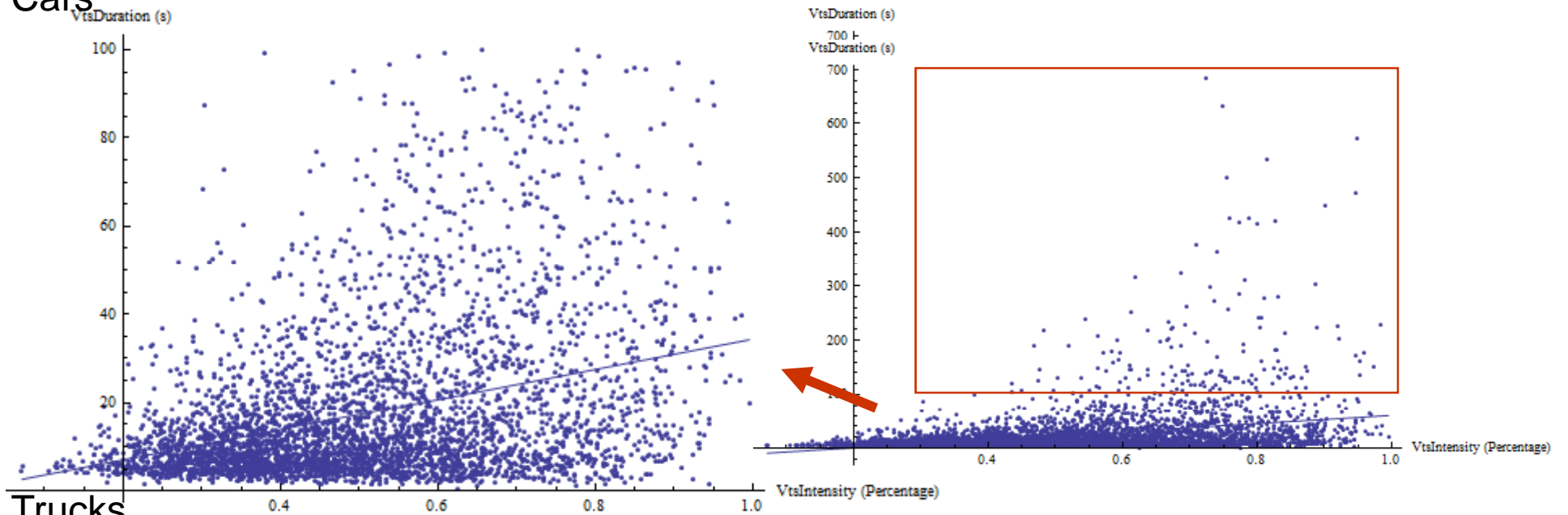


Trucks

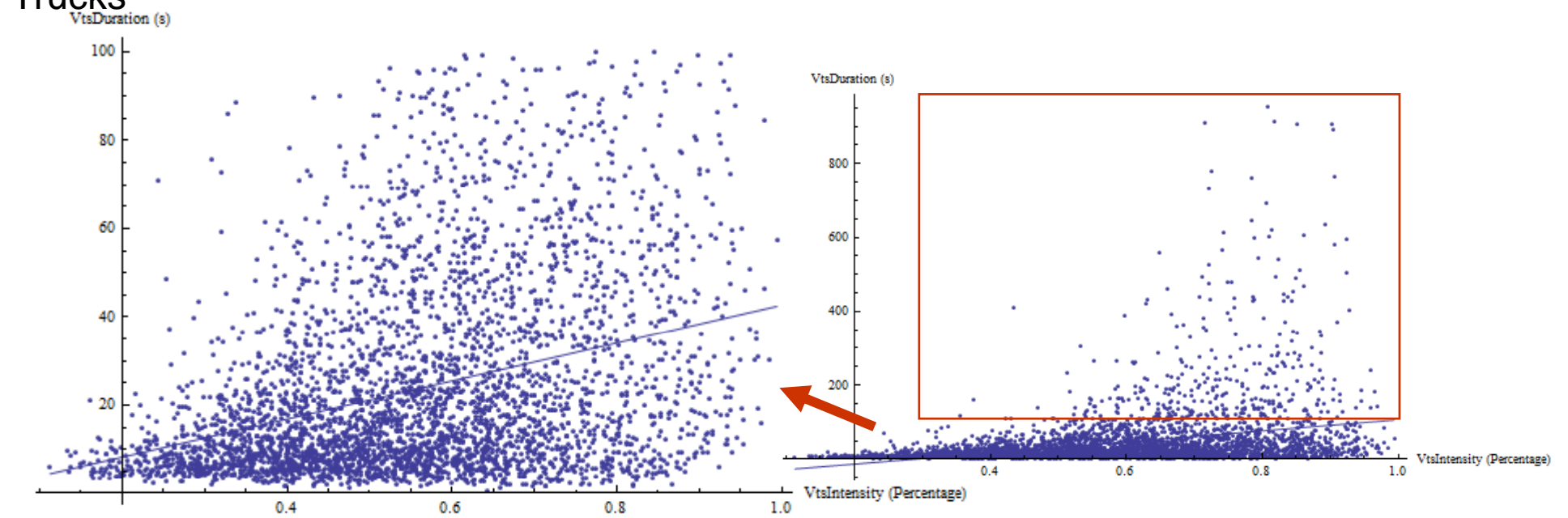




# Cars

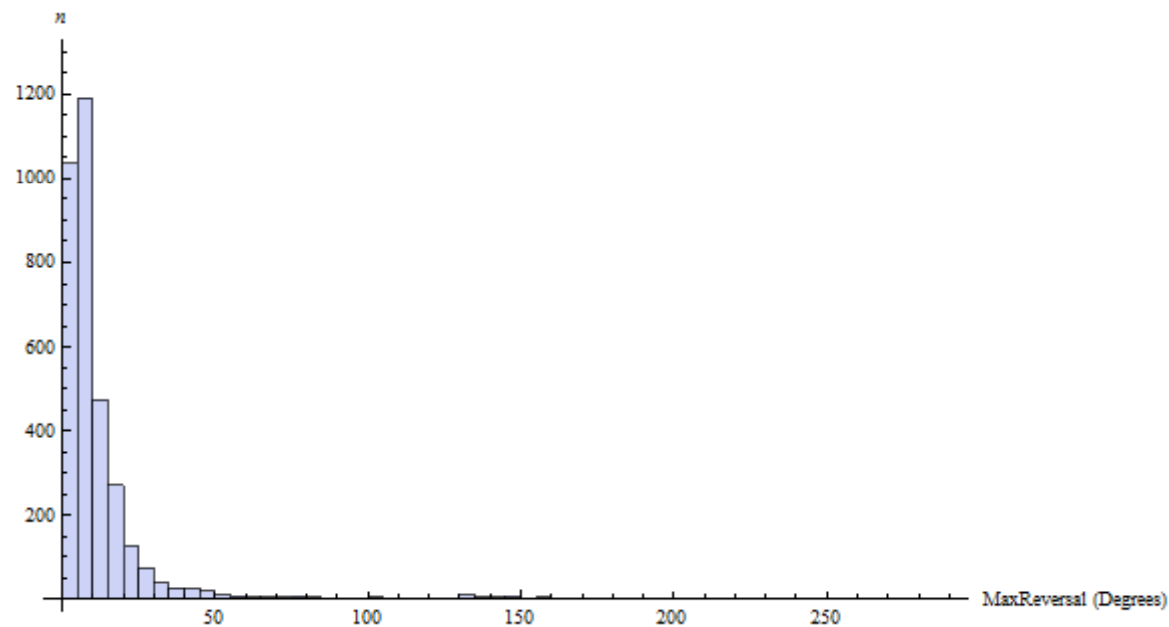


# Trucks

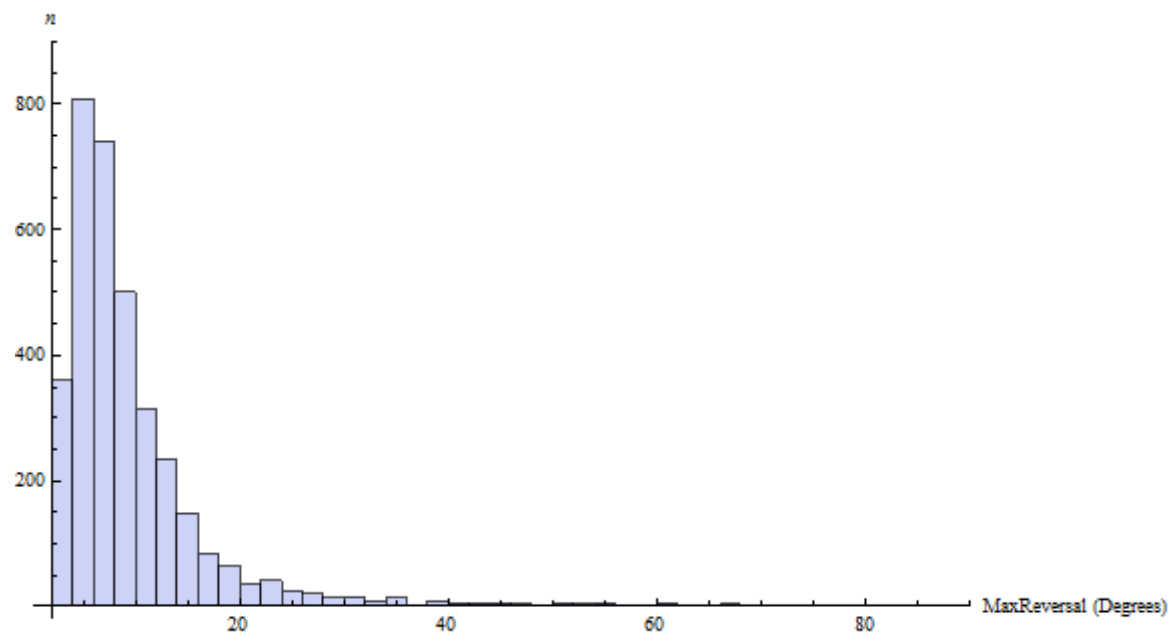


# MaxReversal (SW) (VTSd 0-100s)

Cars

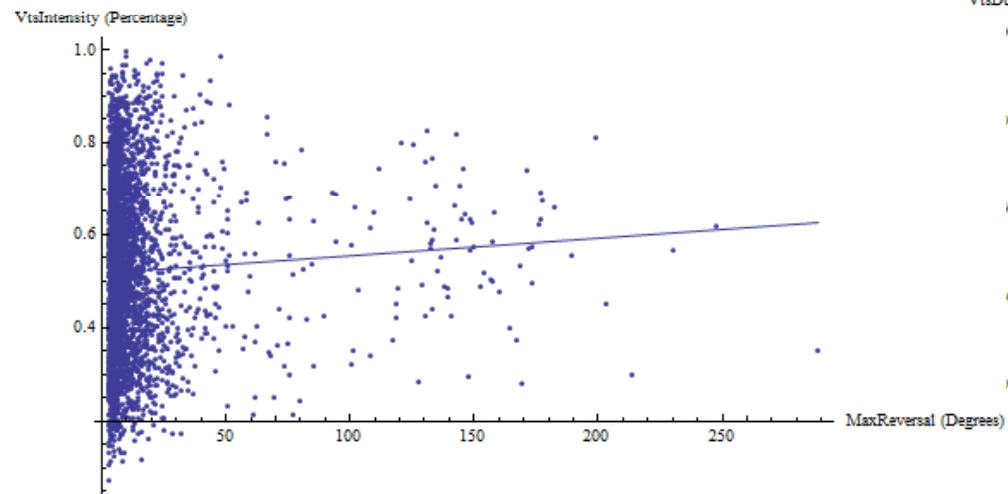


Trucks

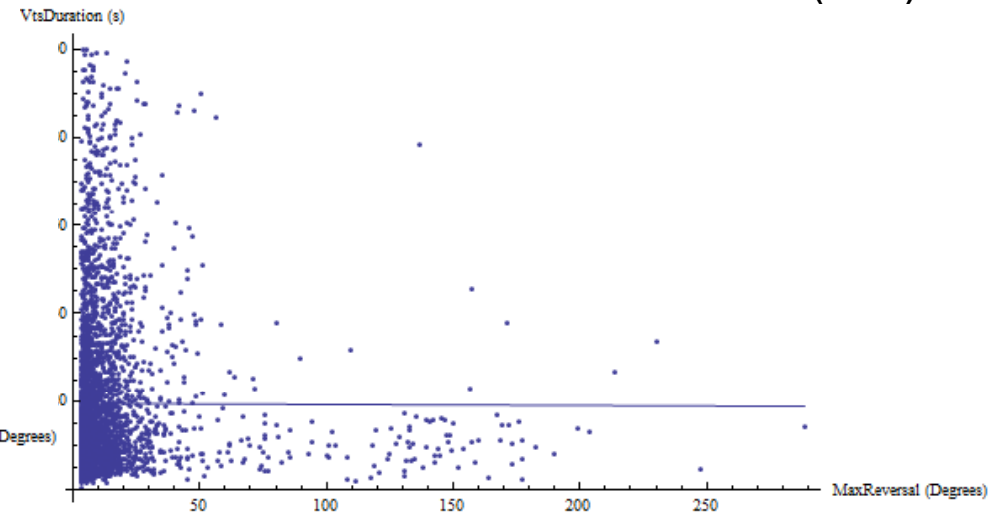


## Cars

VTSi vs MaxReversal (SW)

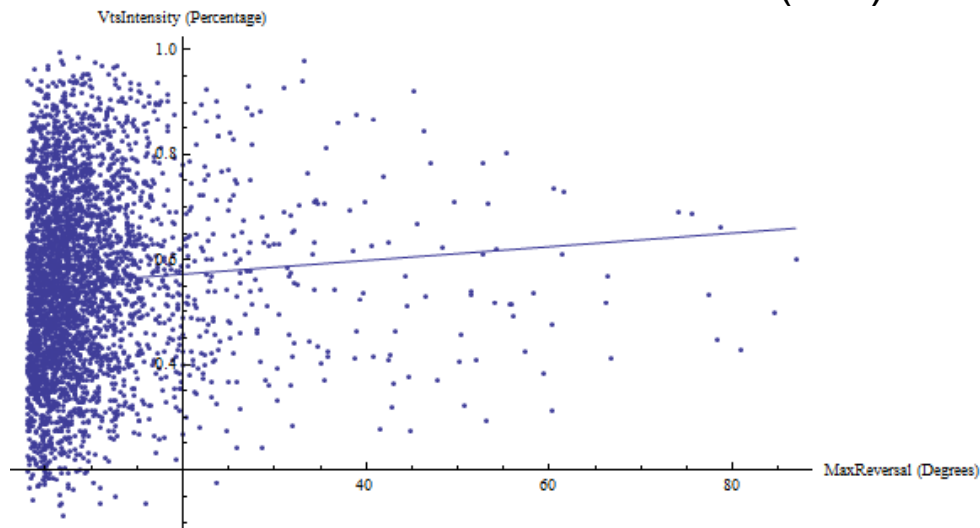


VTSD vs MaxReversal (SW)

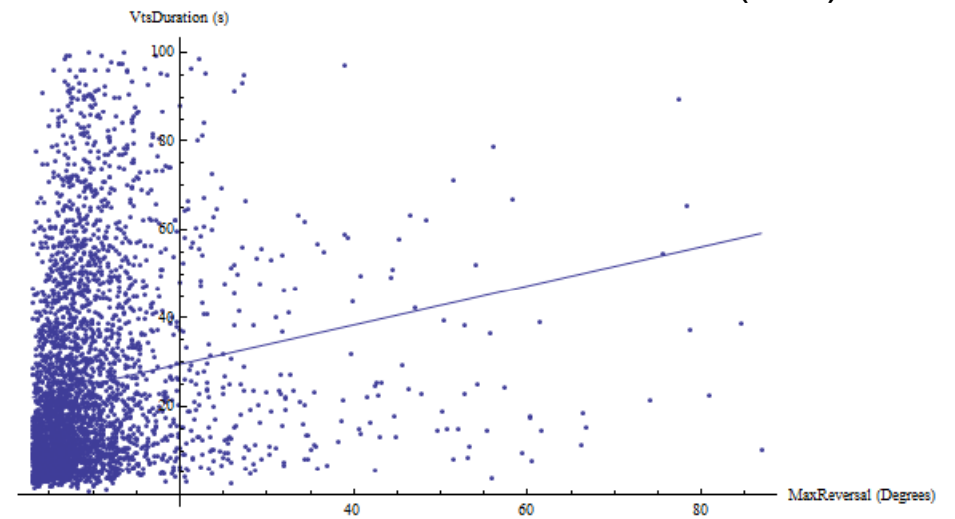


## Trucks

VTSi vs MaxReversal (SW)

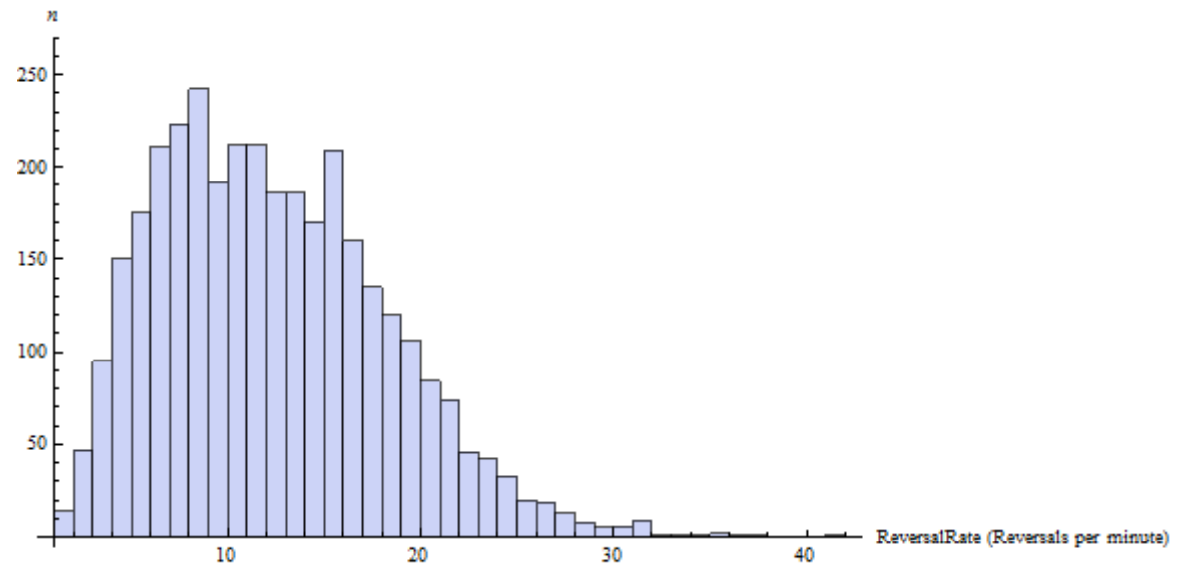


VTSD vs MaxReversal (SW)

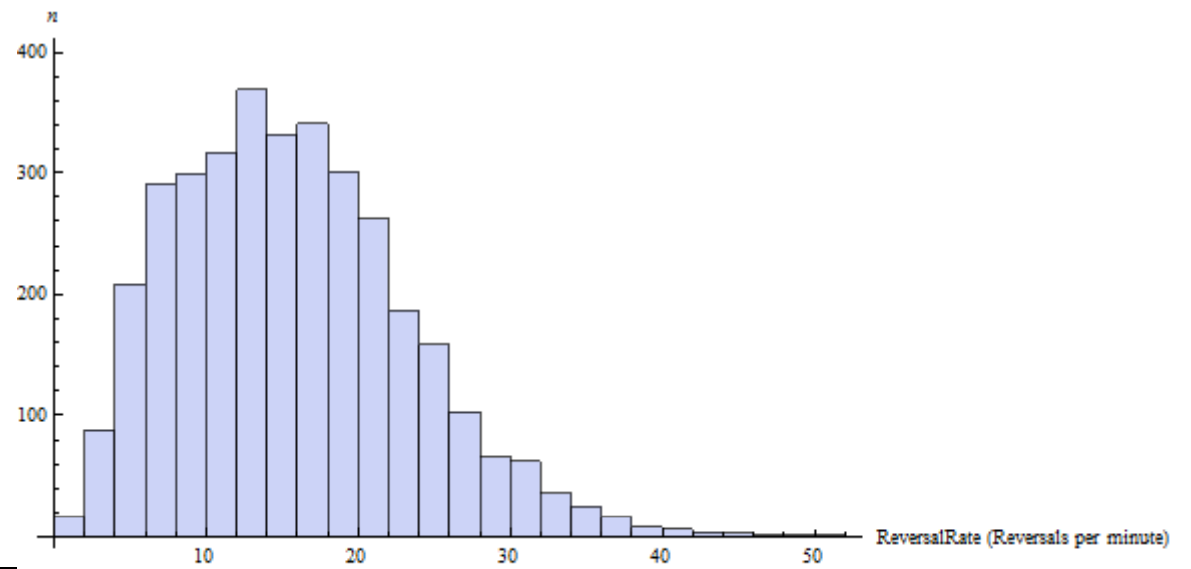


# ReversalRate (SW) (VTSd 0-100s)

Cars

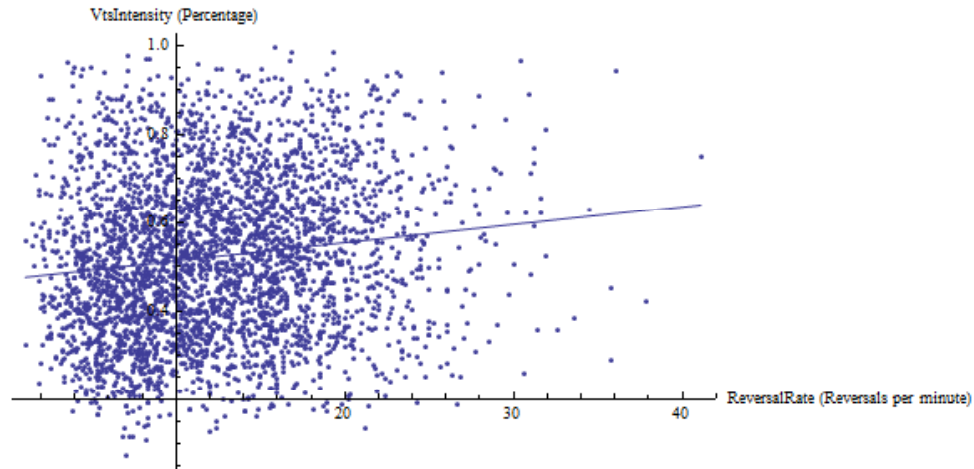


Trucks

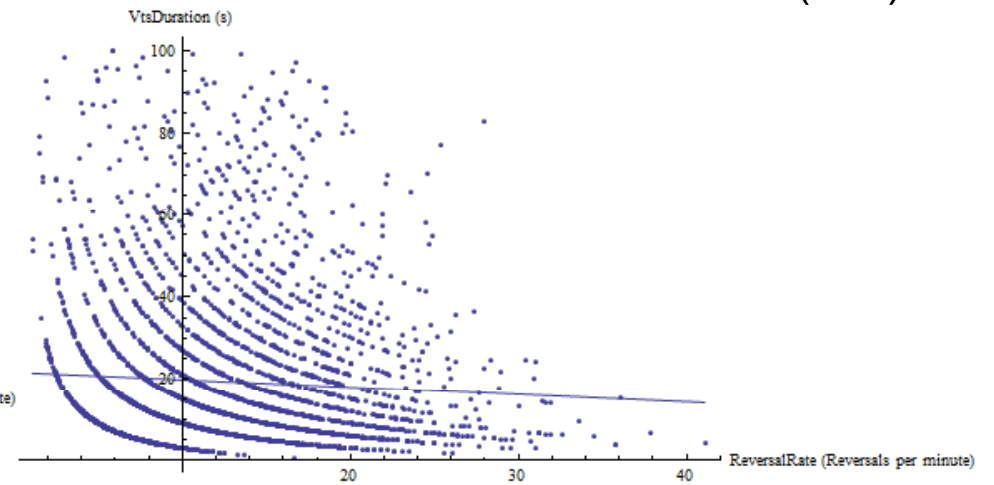


## Cars

VTSi vs ReversalRate (SW)

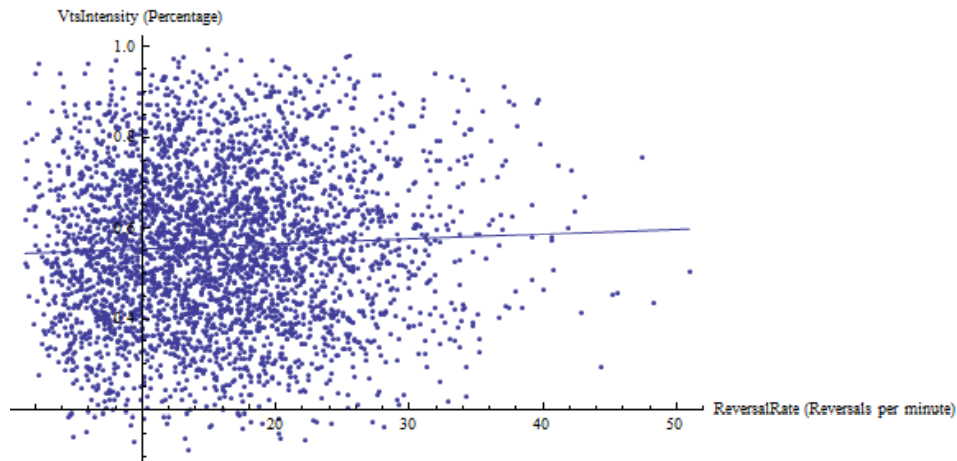


VTSD vs ReversalRate(SW)

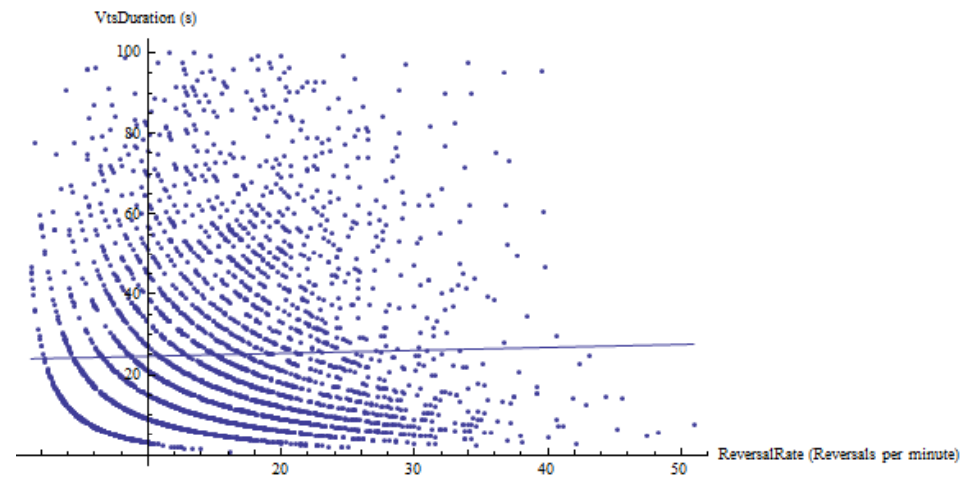


## Trucks

VTSi vs ReversalRate(SW)

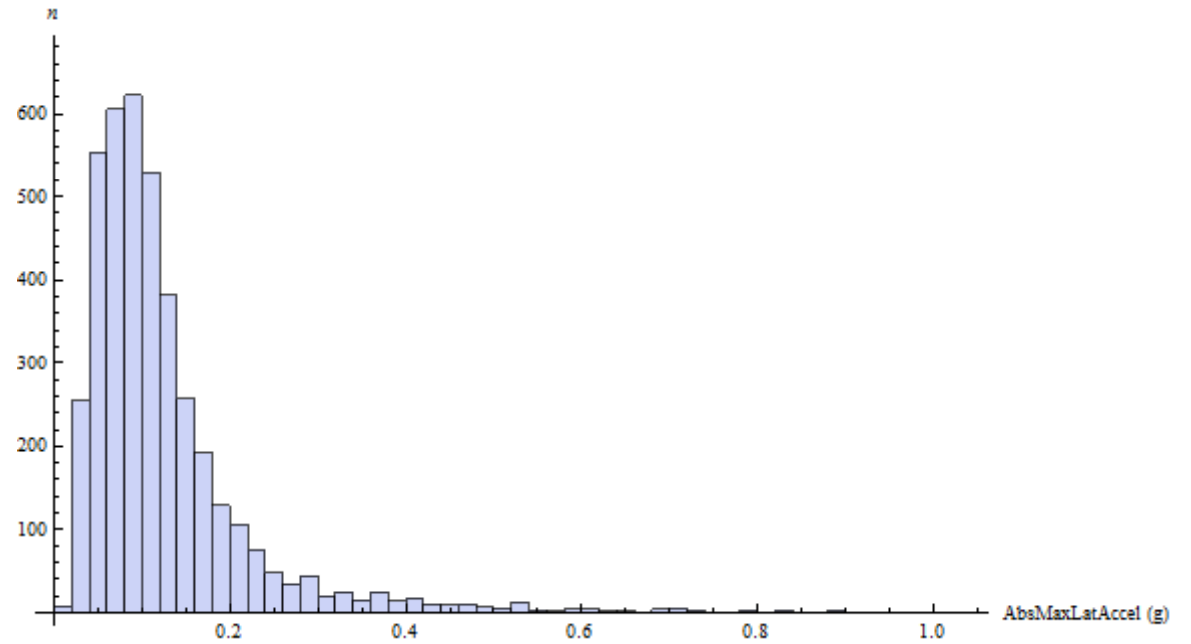


VTSD vs ReversalRate(SW)

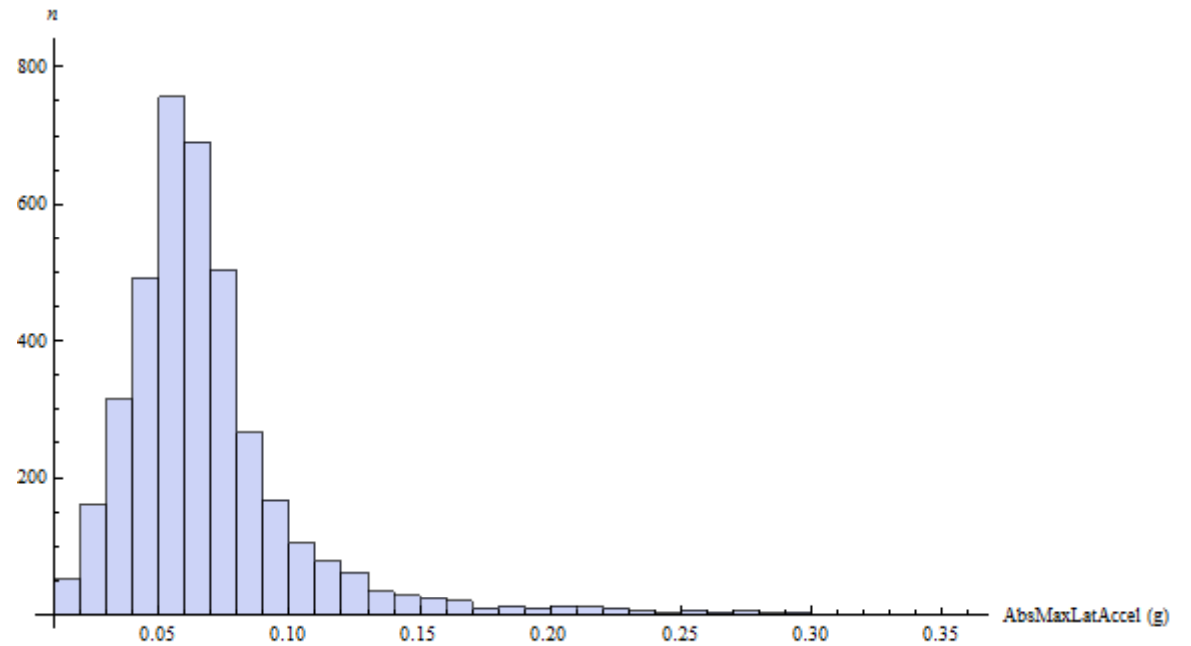


# AbsMaxLatAccel (VTSd 0-100s)

Cars

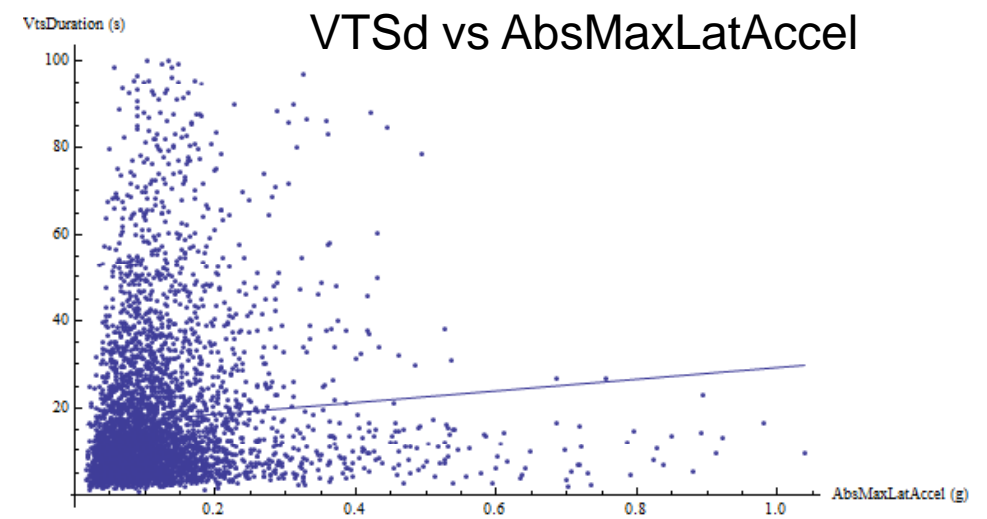
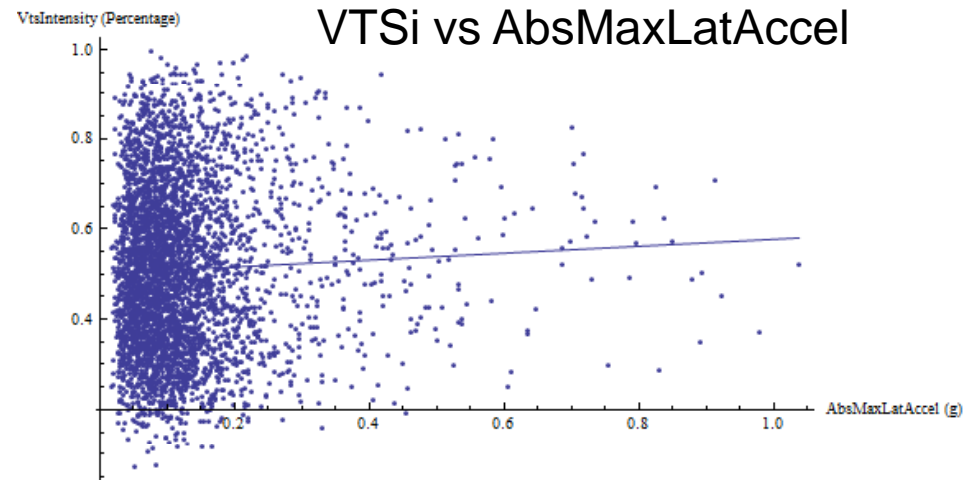


Trucks

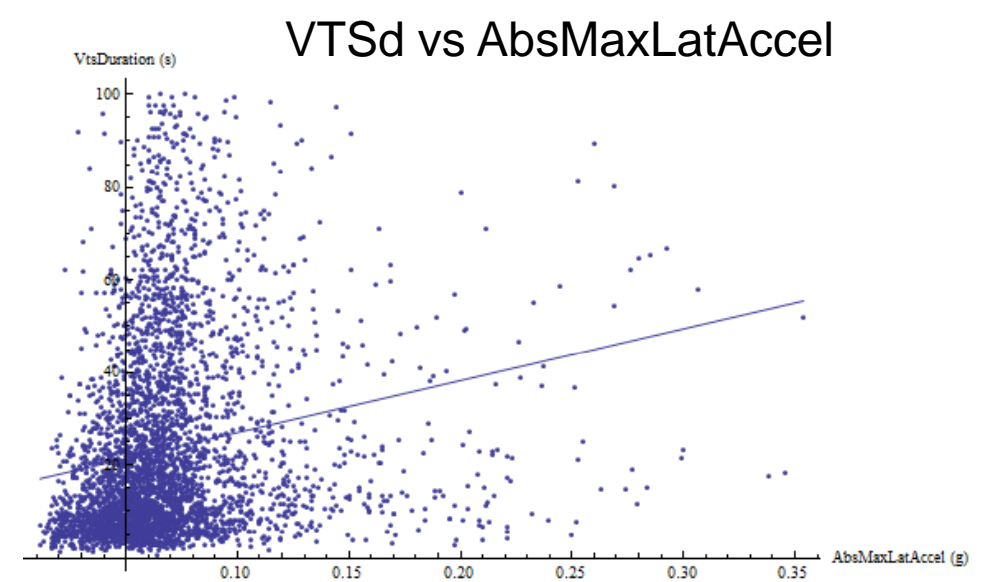
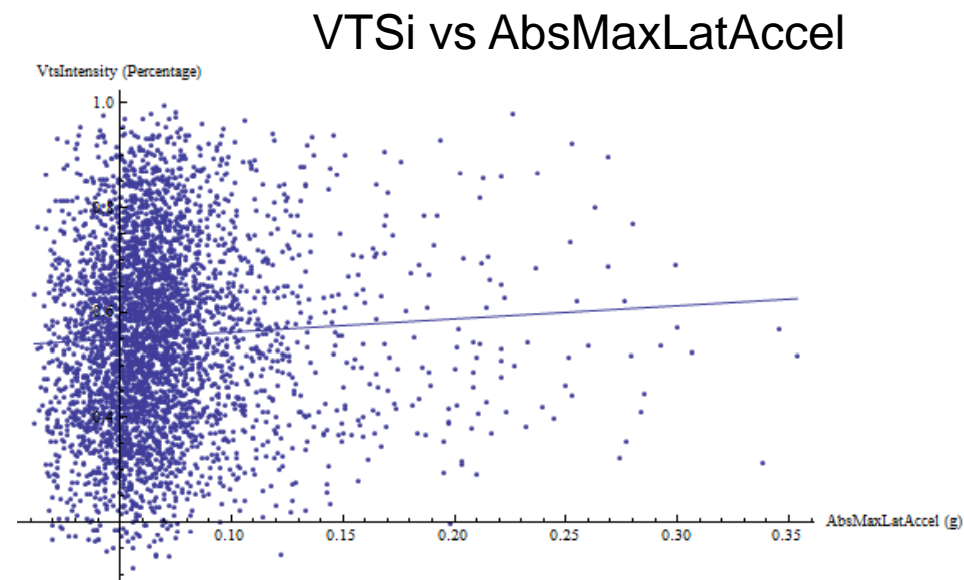




## Cars

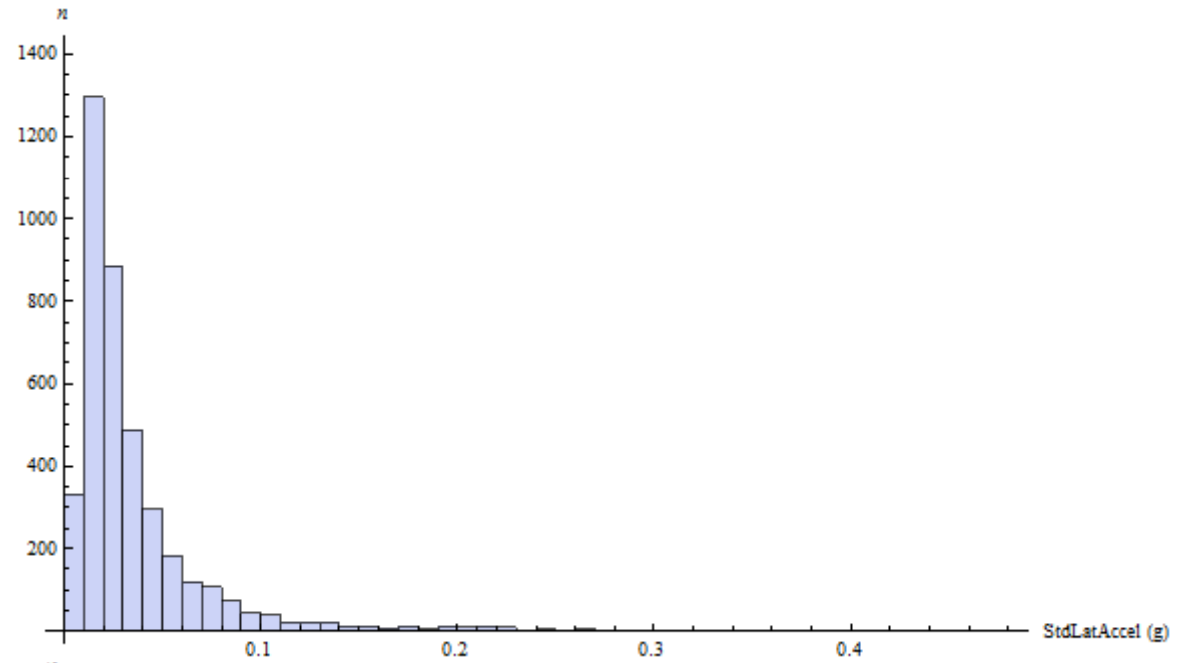


## Trucks

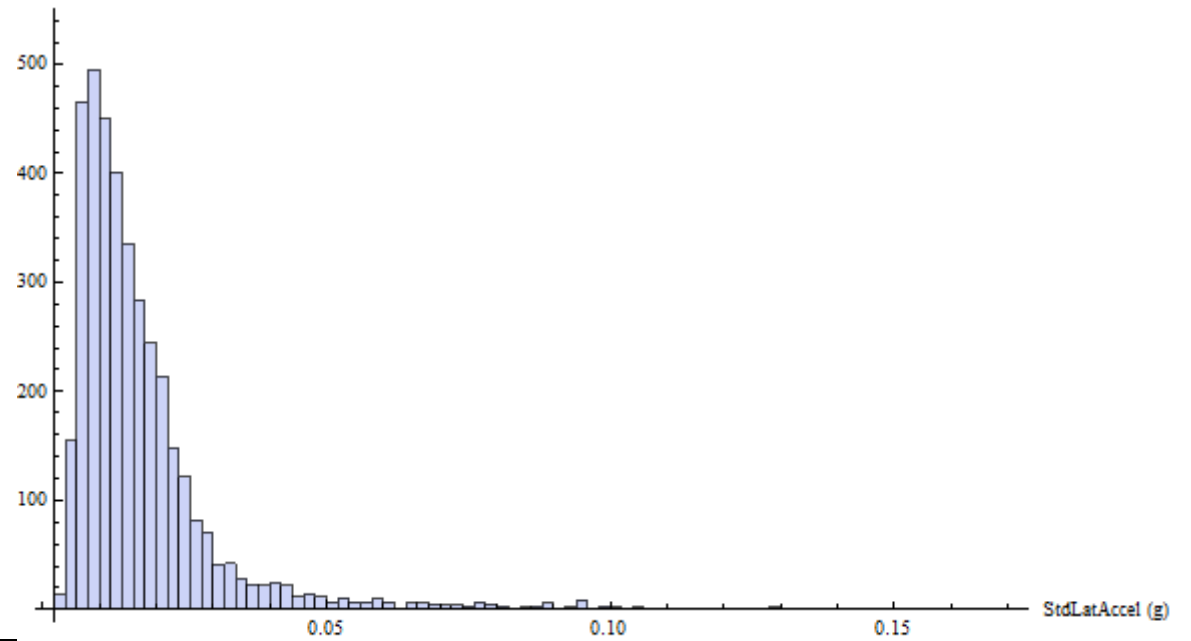


# StdLatAccel (VTSd 0-100s)

Cars

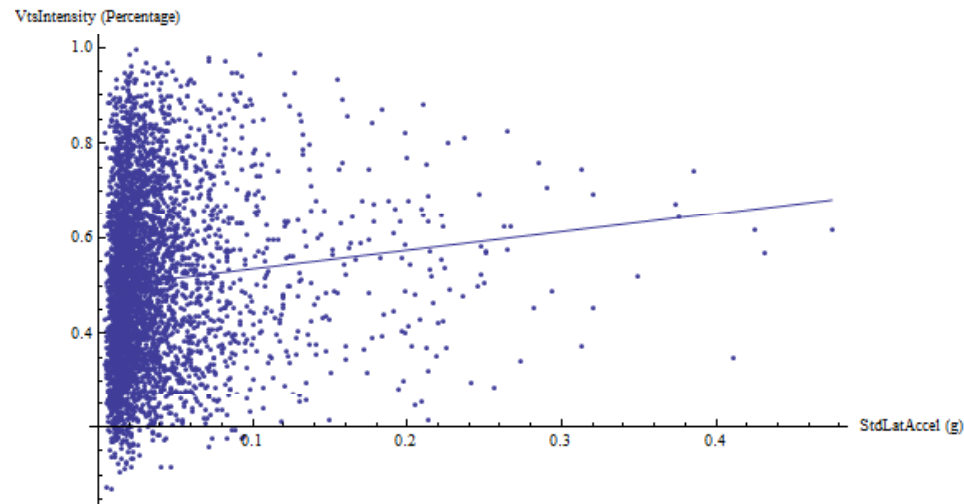


Trucks

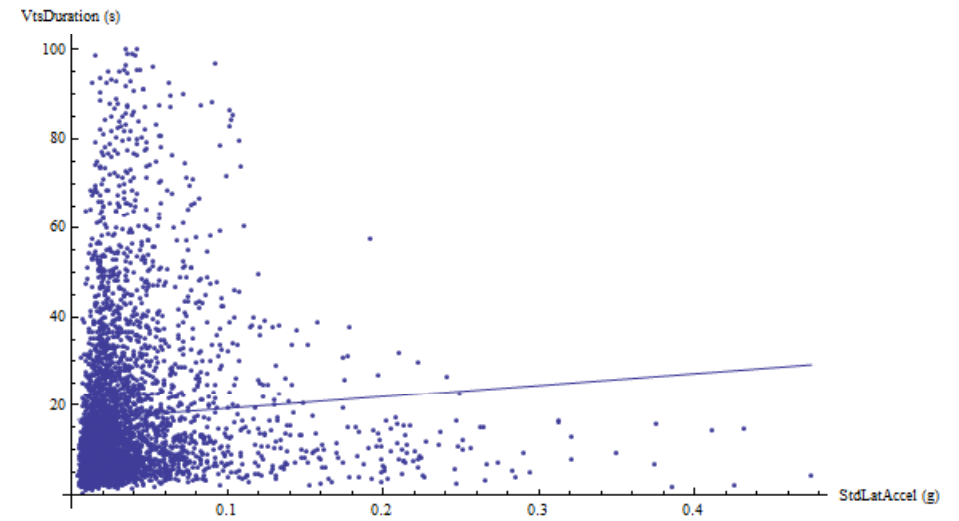


## Cars

VTSi vs StdLatAccel

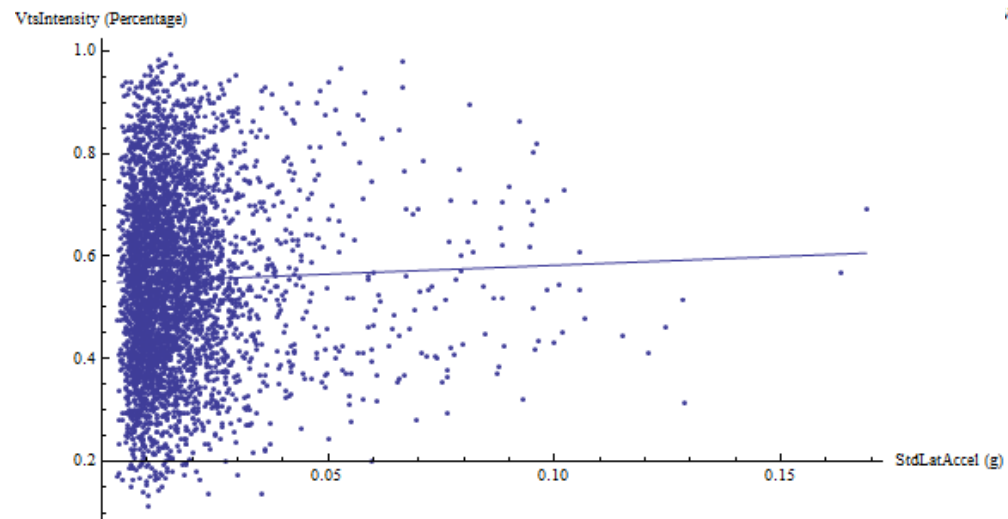


VTsd vs StdLatAccel

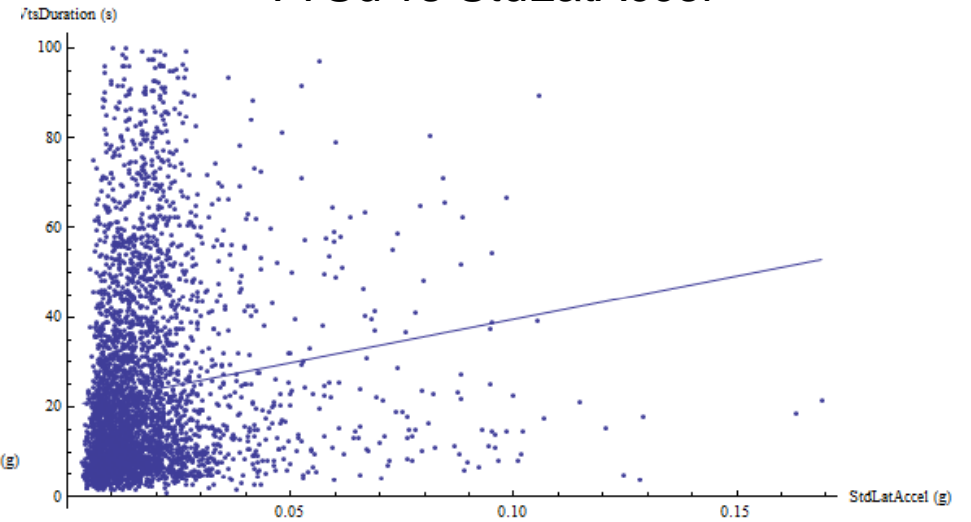


## Trucks

VTSi vs StdLatAccel

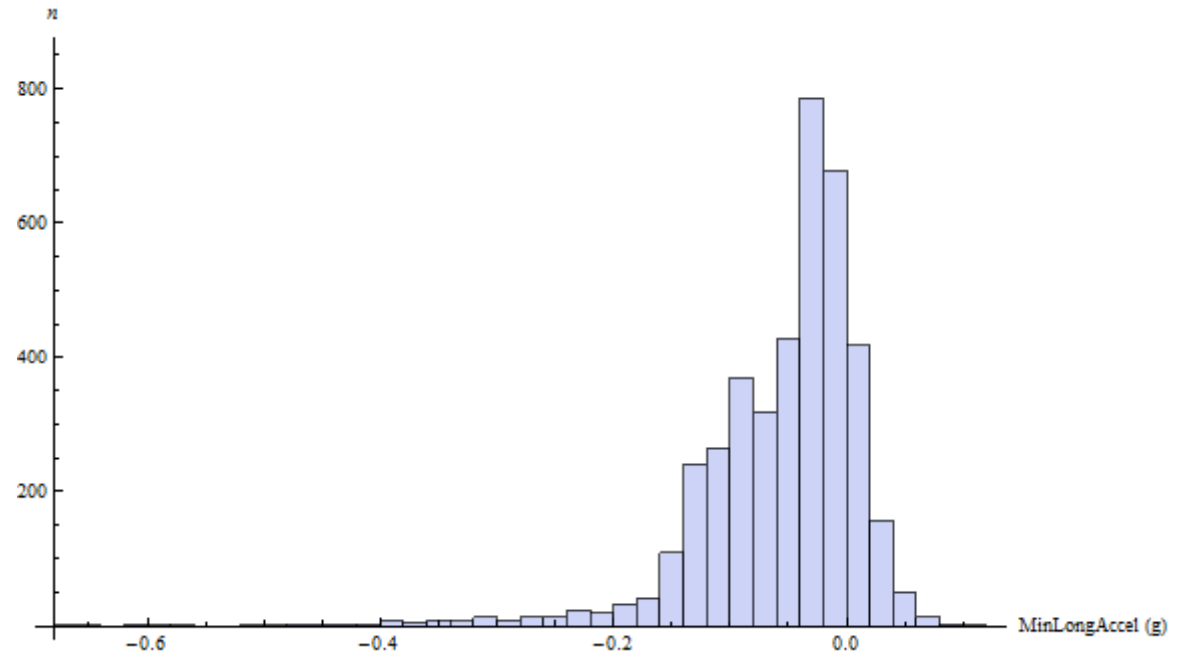


VTsd vs StdLatAccel

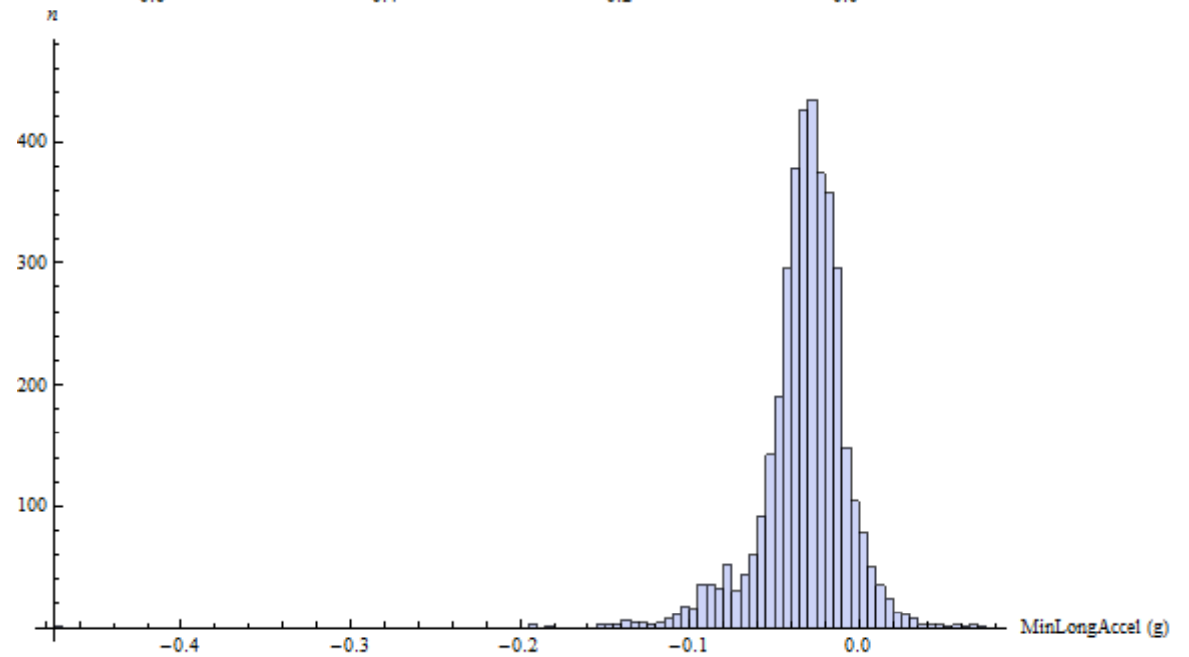


# MinLongAccel (VTSd 0-100s)

Cars

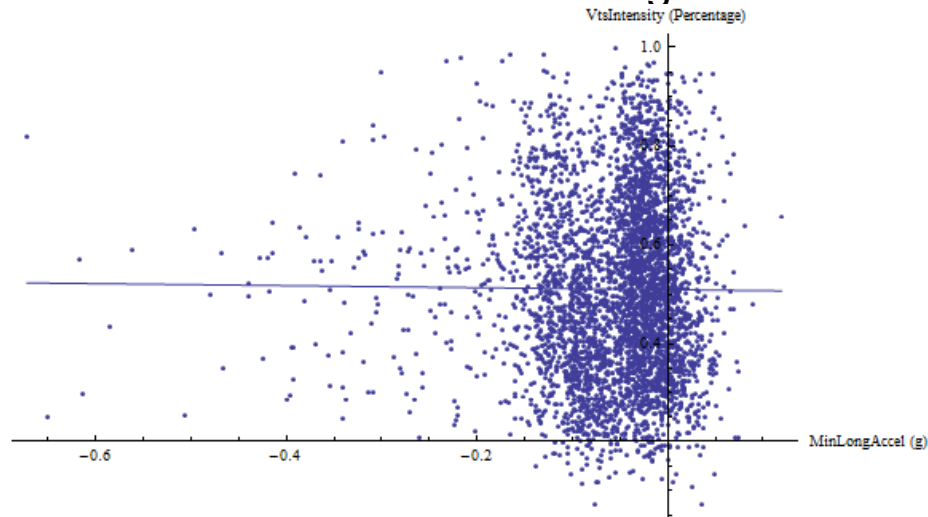


Trucks

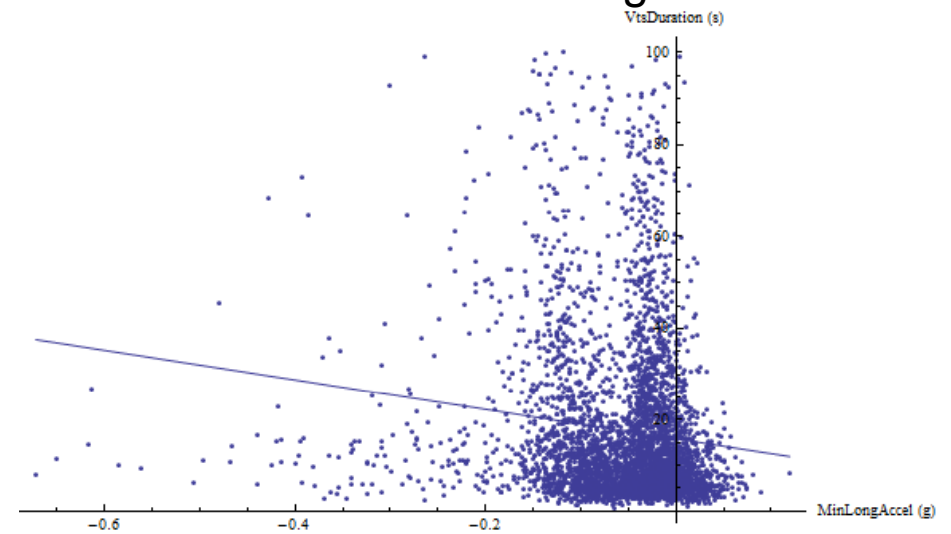


## Cars

### VTSi vs MinLongAccel

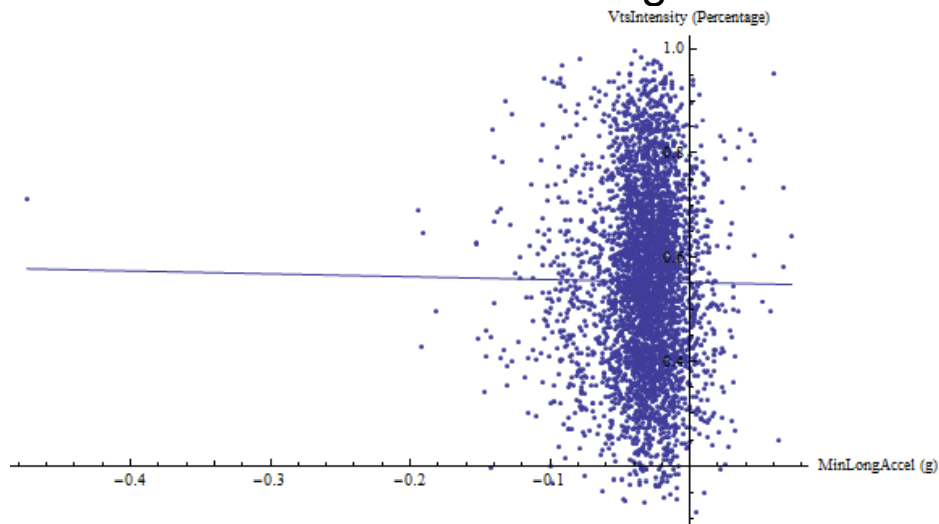


### VTSD vs MinLongAccel

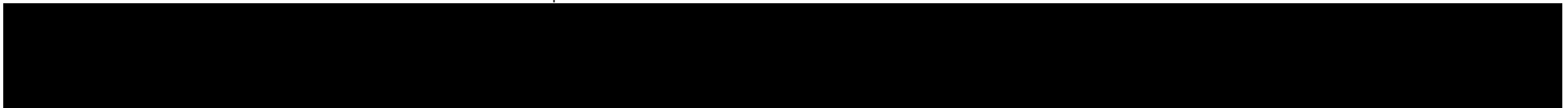
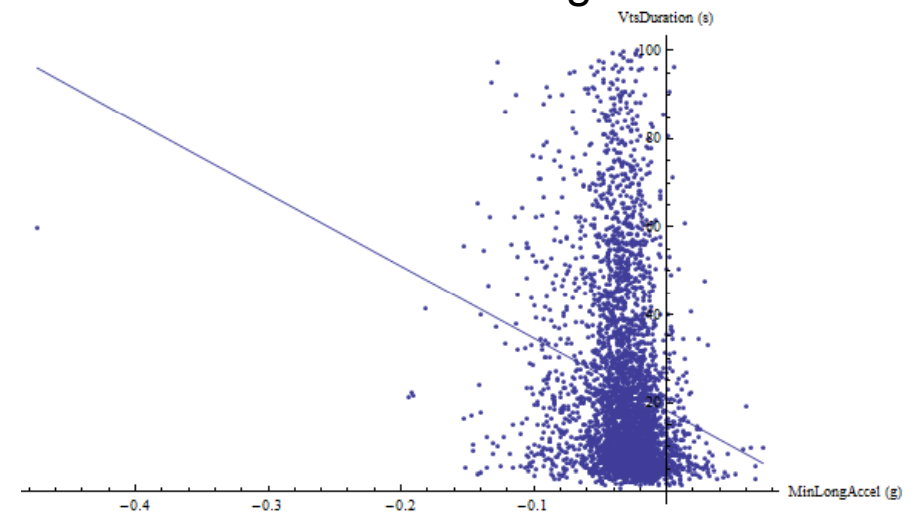


## Trucks

### VTSi vs MinLongAccel

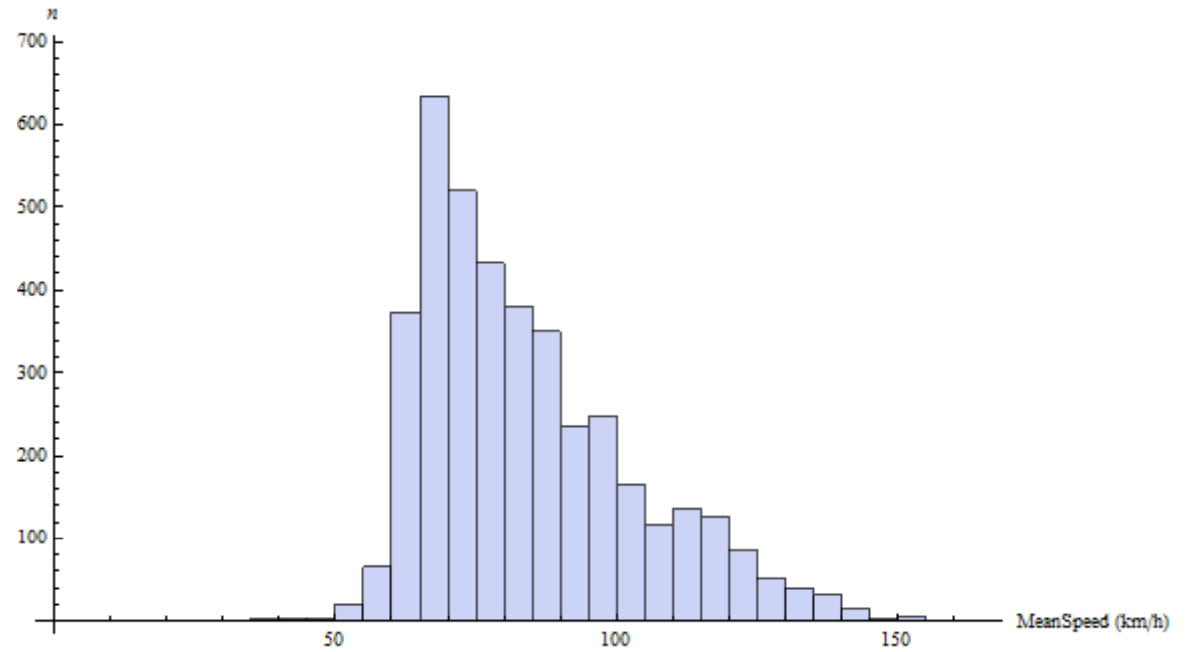


### VTSD vs MinLongAccel

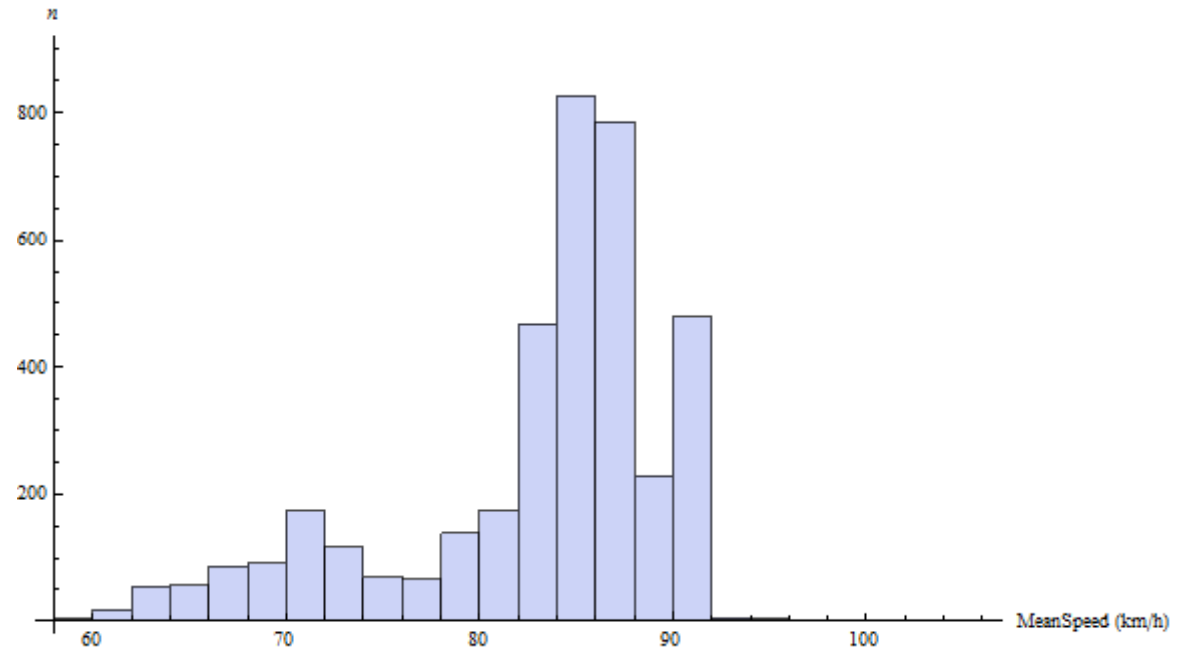


# MeanSpeed (VTSd 0-100s)

Cars



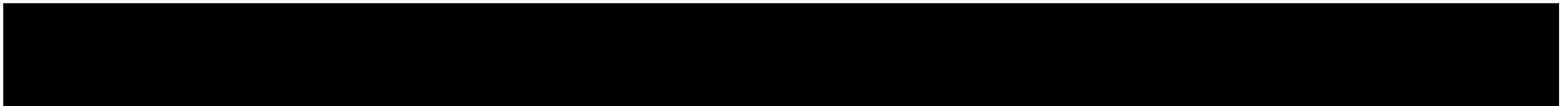
Trucks





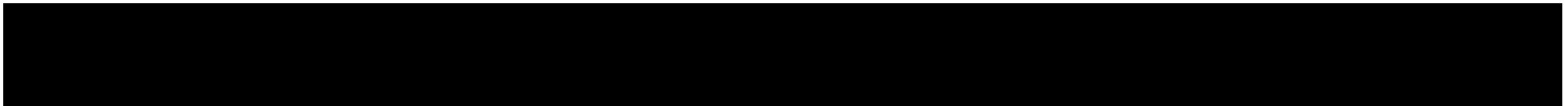
# Conclusions

- Null results most likely an effect of the definition of Visual Time Sharing (VTS)
  - There are some fundamental issues in defining Visual time sharing!
- Need to validate the Oops reaction driving performance metrics
- Could the null results be true? – Is there no true relationship between VTS & Oops reaction?
  - i.e. the relationship is momentary chance of glance off road and an unexpected event occurring
  - e.g. 100-car & "Hanowski et al 2009" may be measuring an intermittent signal showing it could easily occur within 6s of crash/near-crash

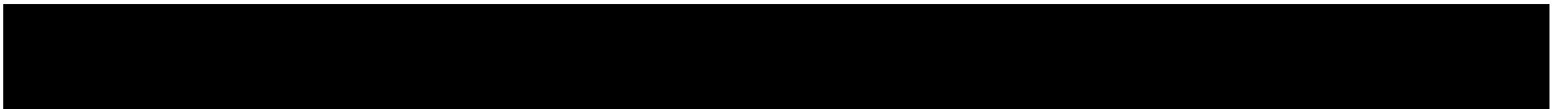


# Future Steps

1. Validate the driving performance metrics
2. VTS quantification development
  - Human inspection of video/data on each VTS event
  - Develop better VTS identifier e.g. use real-time distraction algorithms
    - Data-driven clustering
    - 10s window,
    - buffer..
  - Develop more sophisticated VTS metrics
    - The combination of the single glance duration and the total number of glances in the time window
    - SafeTE metric (Engström & Mårdh, 2007) – explicitly considers the glance eccentricity and the effect of long glances
3. Single Long Glance identifier
  - Total eye-off-road glance duration greater than two seconds in a six-second window increased crash/near-crash risk at least twice, relative to baseline driving (Klauer et al., 2006).
  - More difficult pattern recognition/signal processing
4. Analysis of the temporal relationships between steering wheel metrics and eye movements (see e.g. Markkula and Engström, 2006)
  - Algos on the timing of glance back and oops reaction



End



	Mean	Median	Min	Max	Std
VtsDuration	33,67116	13,867	0,575	1399,51	68,18615
VtsIntensity	0,544618	0,539548	0,071429	0,995467	0,181597
MaxReversal	10,46191	6,882776	-1	288,7514	16,61971
ReversalRate	12,41628	12,08054	-1	50,9434	8,338398
MeanSpeed	83,71191	84,32509	3,013072	160,6854	14,36446
AbsMaxAccel	0,099041	0,075782	0,011406	1,038449	0,081625
StdLatAccel	0,027394	0,018449	0,003439	0,475051	0,03167
MinLongAccel	-0,046691	-0,033776	-0,67232	0,119694	0,05644

