Selected Observations Drawn from the AHEAD & AVT Consortia on Human Attention in Modern Driving with & without Automation

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UNECE Global Forum for Road Traffic Safety (WP.1) & World Forum for the Harmonization of Vehicle Regulations (WP.29)
Meeting on Automation in Transport: Safe Deployment of Automated Vehicles in Traffic
Panel III: Activities Other than Driving
Geneva, Switzerland
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A Note on Interpretation & Views

The interpretation of data and views expressed during this talk are those of the speaker and do not necessarily represent the views of organizations that have contributed to the support of this work.

Principle Scientific Leads:

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The AHEAD Consortium

Advanced Human Factors Evaluator for Attentional Demand

Formal project start: June 2013

Aptiv DENSO Google JAGUAR LAND ROVER Panasonic Automotive SUBARU

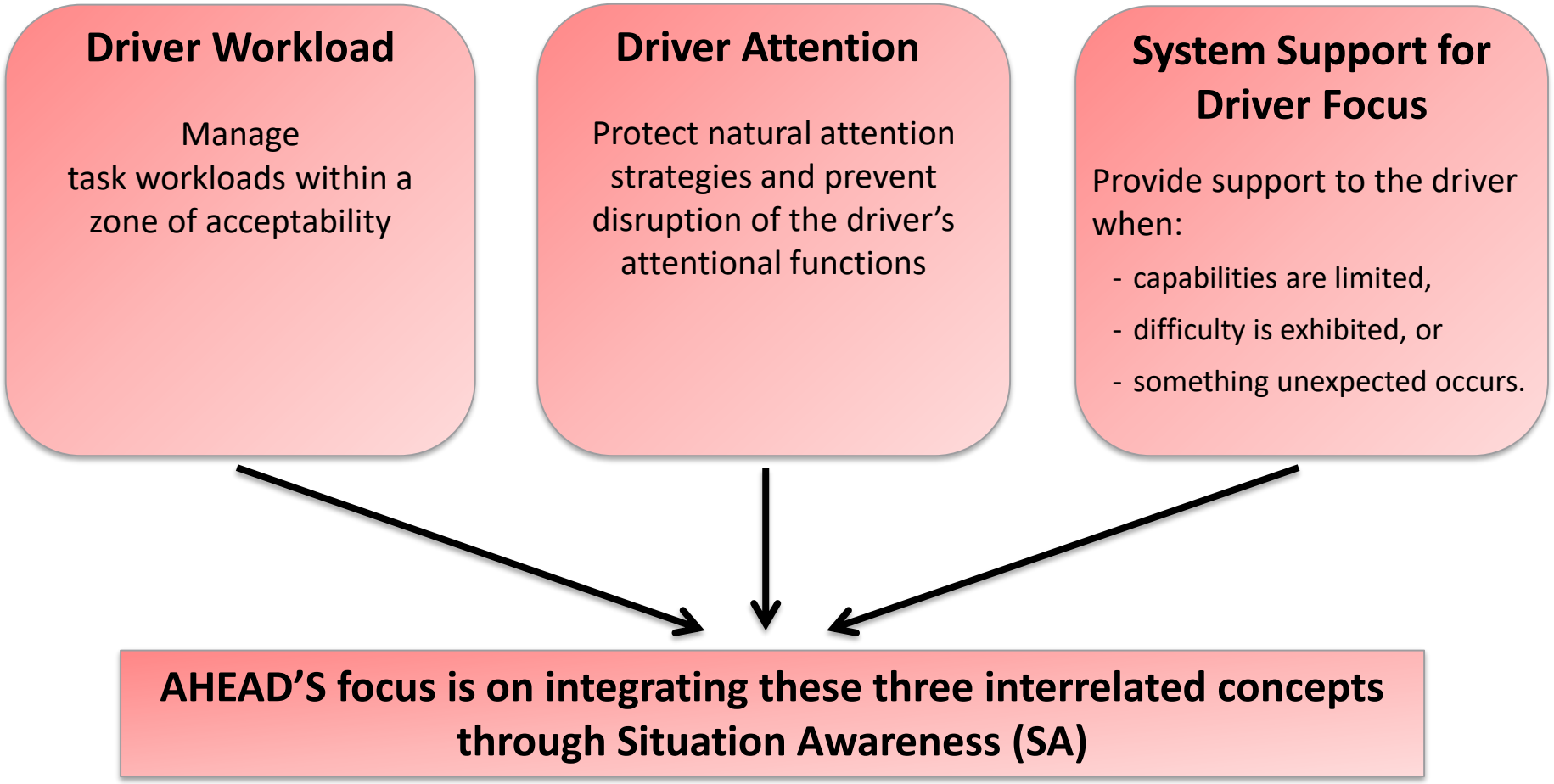
Focus on broadening scientifically valid **perspectives and methodologies** for the **objective measurement of demand** placed on drivers by in-vehicle systems and technologies

Early emphasis on:

- Developing a framework in which HMI designers could evaluate demand across multiple dimensions, i.e. visual, auditory, haptic, vocal, manual, etc., by taking into consideration the relative cost / benefit interactions of various input, output and processing modalities to find an optimal balance to minimize impact on the primary driving task
- Understanding the role of spatial and temporal characteristics of a task
- Considering interactions between non-driving tasks and the broader operating environment

An evolving aim of AHEAD has been to move the language of assessment from **one focused on distraction**, to one **that emphasizes driver attention management and safe operation**, such that *demands on the driver*, *active safety systems*, and *other higher order forms of automation* can be considered as a whole.

Strategic Elements in the AHEAD Framework for Attention Management



Adapted from Angell (2012).

Data collection and analysis drawn from:

- Basic laboratory visual perception studies
- Driving simulator studies
- On road experimental studies of surrogate reference tasks & real production HMIs
- Reanalysis of naturalistic crash datasets (100-car & SHRP 2)

The Advanced Vehicle Technology Consortium

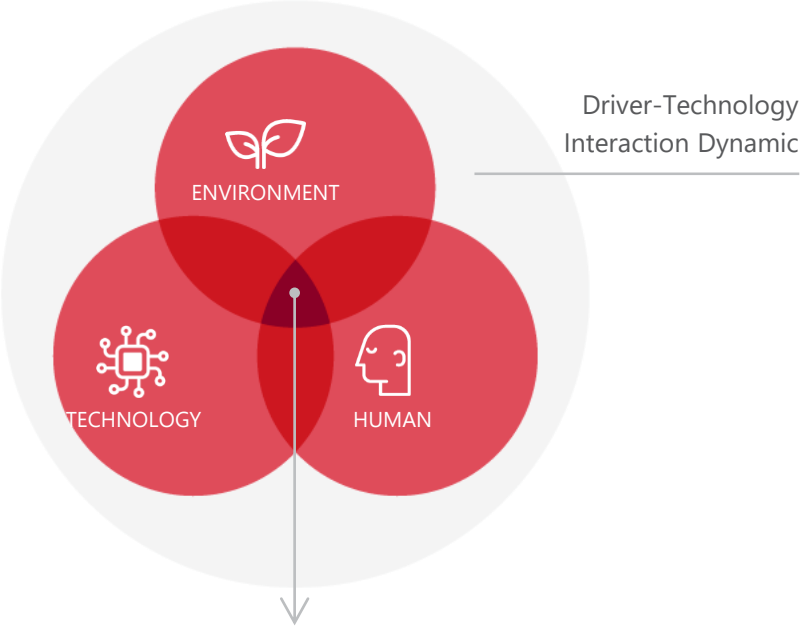
Founded: 2016 by MIT AgeLab, Touchstone Evaluations & Agero

Focus: To collect and analyze objective data that characterizes the behavioral and safety benefit of **advanced driver assistance systems**, higher **levels of automation**, and other **production** in-vehicle technologies **under real-use conditions**

Membership: Agero, Aptiv, Consumer Reports, Google, Insurance Institute for Highway Safety (IIHS), Jaguar Land Rover, J.D. Power, Liberty Mutual Insurance, Progressive, Toyota, TravelCenters of America, Veoneer, & Volvo

A collaborative undertaking by OEMs, suppliers, insurance industry, and consumer advocacy entities

Looking Beyond the Technology
Towards Consumer Understanding



To develop: An understanding of system performance and **how drivers adapt to, use (or do not use), and behave** with advanced vehicle technologies

Investigating Advanced Technology Use in the Wild

Advanced Vehicle Technologies

- **Two pronged study:**
  - Users in their own cars (1 year+)
  - MIT owned vehicles (1 month)
- **Current vehicles**
  - Tesla models S & X
  - Range Rover Evoque
  - Volvo S90 (Pilot Assist)
  - Cadillac CT6 (Supercruise)
- Approximately 1000 miles of multi-camera HD video, audio, GPS, accelerometer and CAN data is being added per day.

MIT Autonomous Vehicle Technology Study

Study months to-date: **33**
Participant days: **12,834**
Drivers: **110**
Vehicles: **29**
Miles driven: **427,043**
Video frames: **5.78 billion**

Study data collection is ongoing.
*Statistics updated on: **Sep 19, 2018**.*


Tesla Model S
19,944 miles
698 days in study


Tesla Model S
15,256 miles
714 days in study


Tesla Model X
9,556 miles
378 days in study


Tesla Model S
6,718 miles
194 days in study


Tesla Model S
3,808 miles
123 days in study


Tesla Model S
41,966 miles
651 days in study


Tesla Model S
25,491 miles
572 days in study


Tesla Model X
21,915 miles
499 days in study


Tesla Model X
17,035 miles
701 days in study


Tesla Model S
13,010 miles
463 days in study


Tesla Model S
9,076 miles
183 days in study


Tesla Model S
6,492 miles
299 days in study


Tesla Model S
1,207 miles
51 days in study


Tesla Model S
33,177 miles
861 days in study


Range Rover Evoque
23,048 miles
811 days in study


Volvo S90
21,140 miles
716 days in study


Volvo S90
16,283 miles
723 days in study


Tesla Model S
12,353 miles
321 days in study


Tesla Model X
8,587 miles
316 days in study


Tesla Model X
5,854 miles
470 days in study


Cadillac CT6
1,161 miles
53 days in study


Tesla Model X
31,600 miles
748 days in study


Range Rover Evoque
22,957 miles
598 days in study


Tesla Model S
20,456 miles
665 days in study


Tesla Model S
15,735 miles
322 days in study


Tesla Model S
10,149 miles
146 days in study


Tesla Model S
8,484 miles
325 days in study


Tesla Model X
4,587 miles
233 days in study


Cadillac CT6
(Offload Pending)

MIT AGELAB | MIT University Transportation Center

Automation & Other Tasks While Driving

We are talking about it more, but this is not a totally new issue.

Automatic transmissions reduce drivers' operational workload.
Drivers have used the "freed up" resources to do other things…

Slide adapted from Bryan Reimer

The AVT Consortium

Advanced Vehicle Technology

Video Removed to Respect Participant Privacy

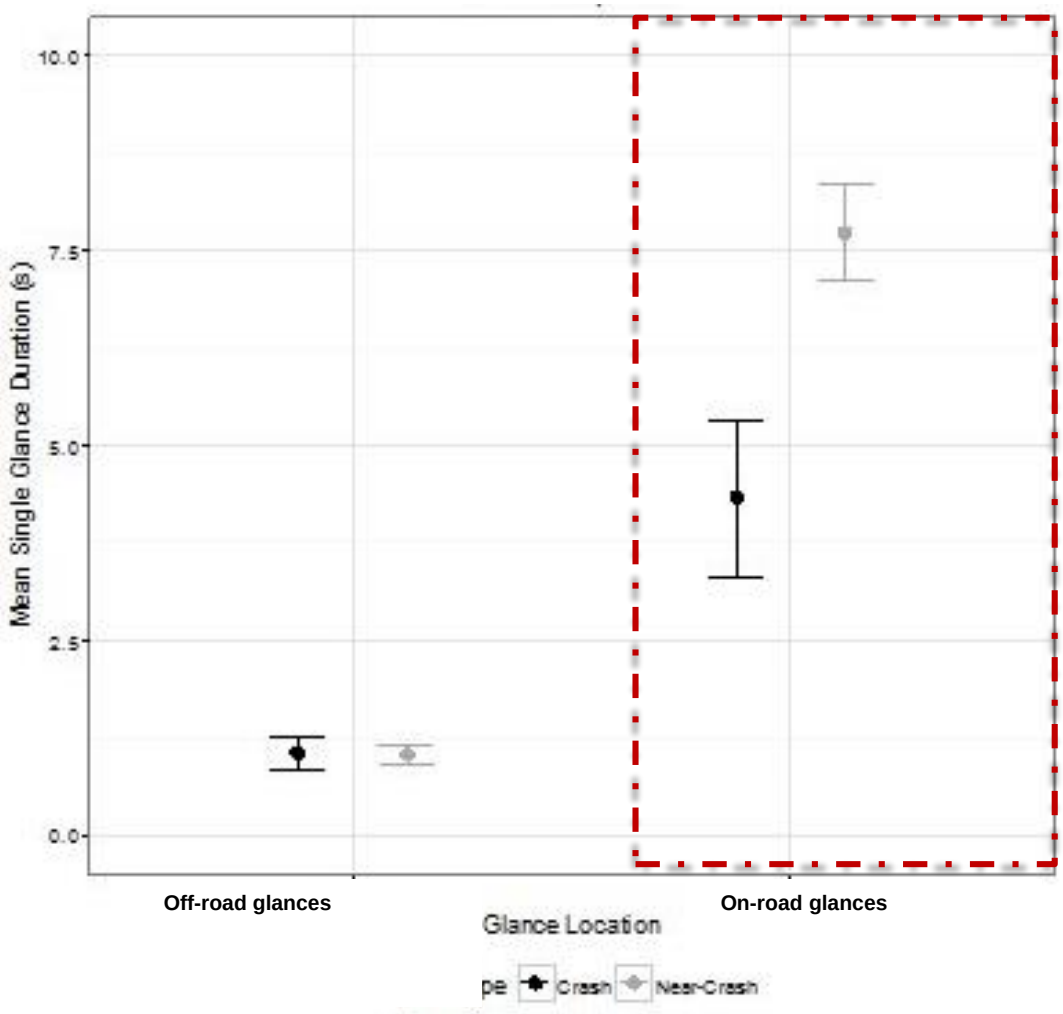
AN ATTENTION EPIDEMIC?

Drivers have long multi-tasked, but perhaps what appears on our roads now is pushing boundaries we would not have imagined even a few years ago.

Key Insight: Off-Road vs. On-Road Glance Duration & Crash Risk

ADVANCED HUMAN FACTORS EVALUATOR FOR AUTOMOTIVE DEMAND

Is off-road glance behavior all that matters? (100-Car dataset)



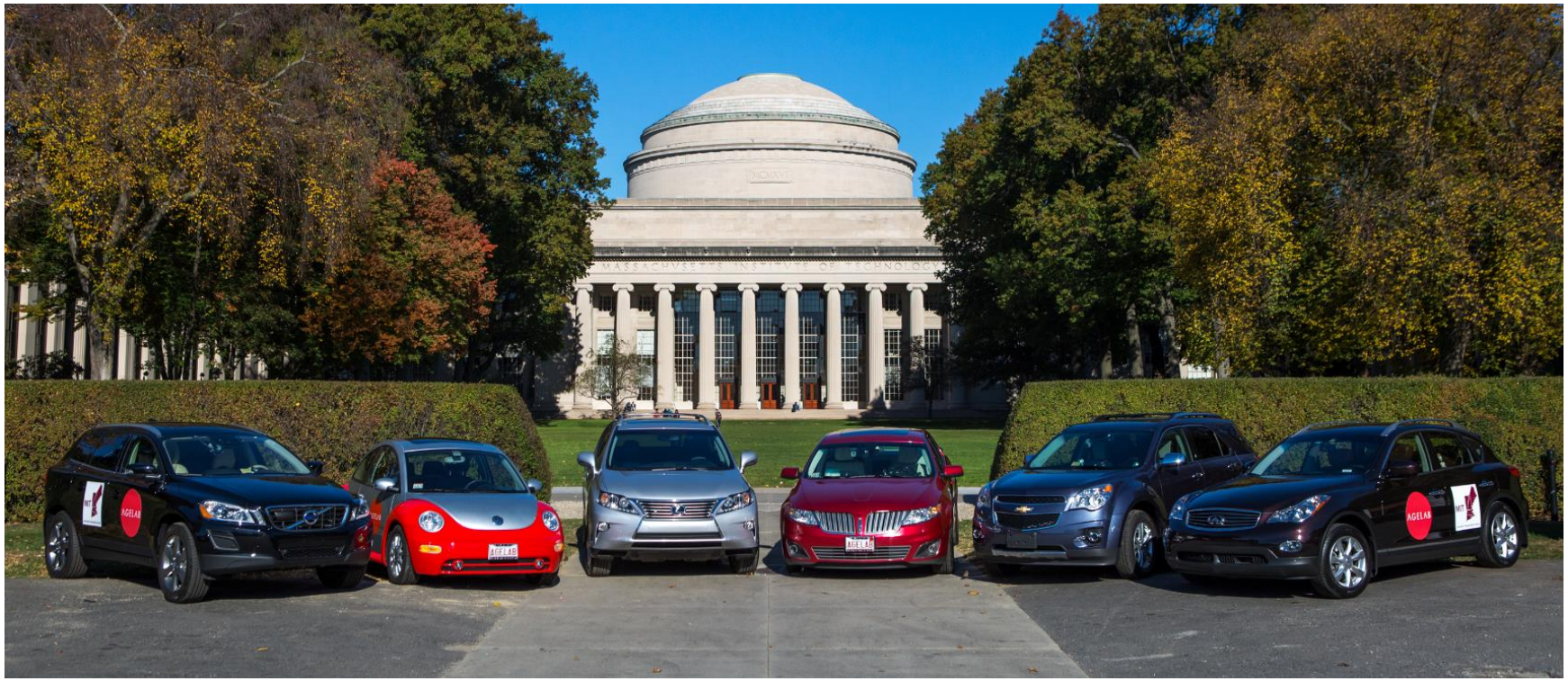
- Comparison of mean single glance duration off-road and on-road in crashes (black) and near-crashes (gray)
- No difference in off-road mean single glance duration between near-crash vs. crash epochs
- Mean on-road glances found to be longer for near-crash vs. crash epochs

Seppelt, B.D., Seaman, S., Lee, J., Angell, L.S., Mehler, B., Reimer, B. (2017). Glass Half-Full: Predicting Crashes From Near-Crashes in The 100-Car Data using On-Road Glance Metrics. *Accident Analysis and Prevention, 107, 48-62*.

Some Emerging Observations & Considerations from AHEAD & AVT Work

- "Other task" behavior is increasing in the vehicle during both manual & more automated driving
  - Is increased other task behavior during automation the problem? Or a symptom of driving being the new distraction?
- Automated systems offer the promise of increased safety, but…
  - Increased display of system state information and increasing number of controls to support multiple modes of operation are increasing monitoring demand on the "driver" – impacting the amount of time eyes are off the road
- Banning types of interfaces and tasks likely only a partial answer
  - Active monitoring of driver attention may be the solution / cost for the "right" to operate a vehicle
  - Tasks that are unwise during manual driving may become more reasonable with automation & may help drivers stay awake
- Developing take-over time rules for higher level automation based on bottom-up reaction capacity is problematic
- Taking into account how glace behavior is threaded together both **off** and **on** the road over time is likely to provide a more accurate measure of risk than just off-road glance metrics used in current guidelines.
  - Attention Buffer metrics are actively being refined for both HMI assessment & future deployment in real-time monitoring applications
- Driver monitoring should not be used only to penalize the driver, but also used to actively support and cue better attention
- Ironically, the need for monitoring & driver support will likely increase as ADAS technology becomes more reliable

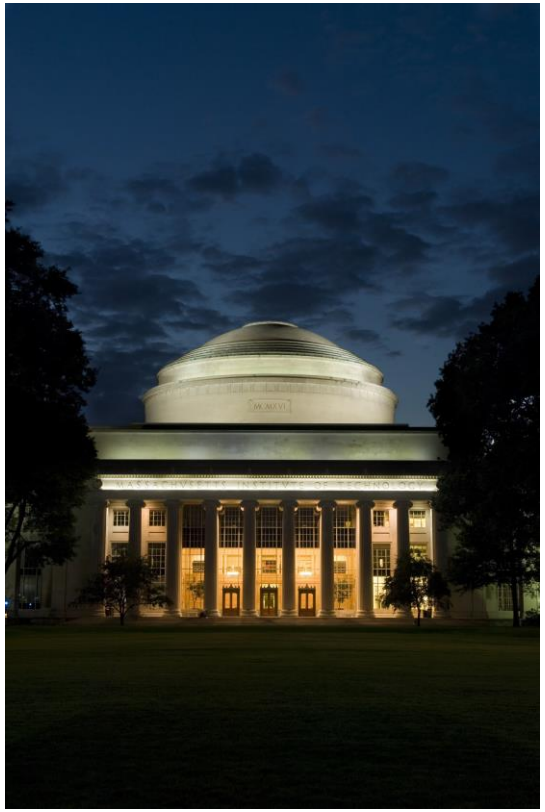
Appendix



Core Research Areas within the MIT AgeLab Transportation Group

Multi-disciplinary team at MIT studying aspects of the evolving advanced automotive technology ecosystem and it's impact on the future of mobility

- **Advanced Vehicle Technology (AVT) Consortium**
  - Studying currently available automated vehicle technologies
  - Implications for future technology development, policy, insurance, acceptance, etc.
- **Advanced Human Factors Evaluator for Automotive Demand (AHEAD) Consortium**
  - Driver workload metrics for HMI evaluation and driver monitoring
  - Situational awareness, attention management in an increasingly automated ecosystem
- **Driver workload evaluation**
  - Basic research on physiology, eye movements, etc.
  - Applied system evaluation
- **ADAS and highly automated vehicles**
  - Human centered considerations in trust, attention, situational awareness, etc.
  - Factors that may influence the adoption of automated vehicle systems
  - Non-verbal communication between road users
- **Applications of Deep Learning**
  - Driver monitoring
  - External scene perception



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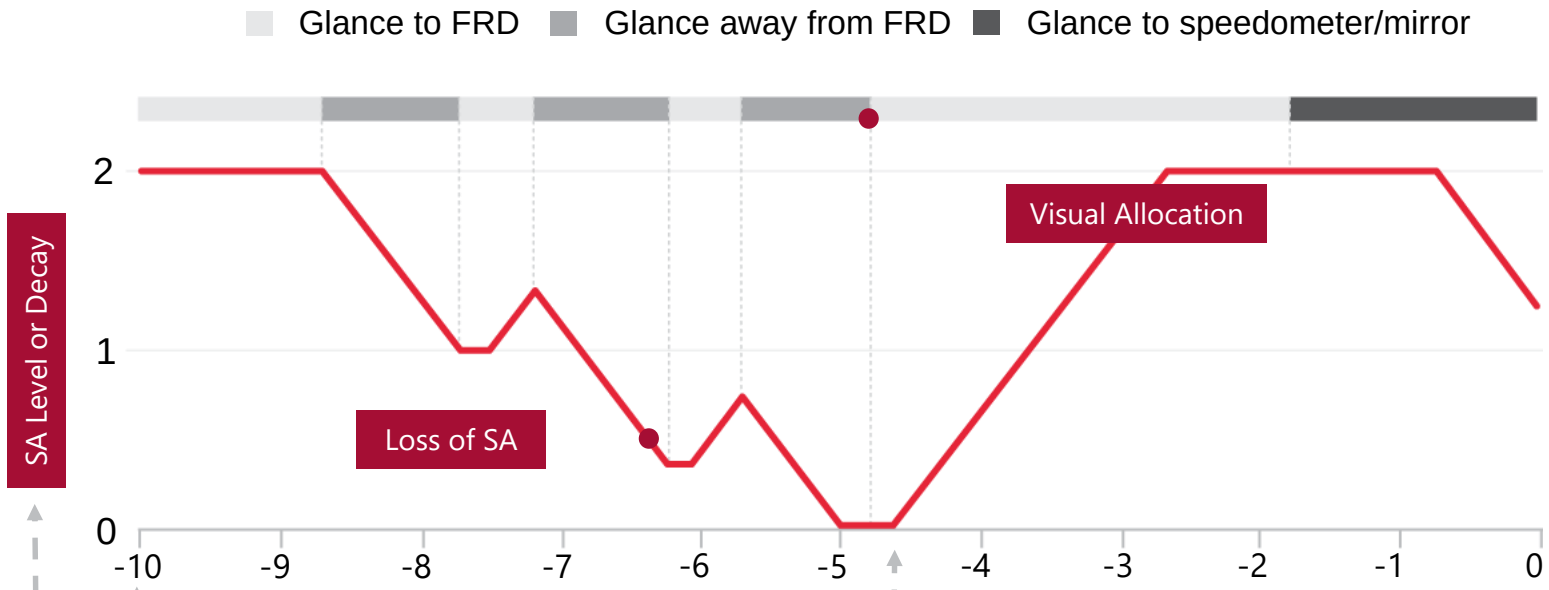
Measuring Attention over Time

An Attentional Buffer

The concept of an 'attentional buffer' can be used to describe both visual allocation and attention.

Figure adapted & extended from Kircher & Ahlstrom (2009)
AHEAD efforts have extended the base rules shown here.



Depth of buffer reflects sampling rate required to keep vehicle in lane (every 1.8-2s; cf. Senders, 1967) – potential changes with automation etc.

Driver's focus away from road - awareness of road situation declining

Driver needed to look back at the road and attend to it in order to refresh their awareness of the road situation.

Important Take-Away

Advanced Human Factors Evaluator for Automotive Demand

Full Glance Patterns Tell a More Complete Story of the Effect of HMI Demands on Driver Attention than Simple Off-Road Measures

- Standard off-road glance measures like mean single glance duration and TEORT calculations do not fully capture the effects of HMIs (an d other tasks) on how drivers are managing their attention over time and space.
- Hybrid metrics like AttenD provide a way to measure the combined spatial and temporal effects of glance patterns on a driver's stored knowledge of the scene when interacting with HMIs (or other tasks).
- The AHEAD effort has been actively refining the buffer construct specifically from the perspective of understanding attention management & support
    - Refining decrement and increment rates based on experimental evaluation and analysis of naturalistic datasets
    - Considering the distribution of glances ON road reflecting cognitive load