Attention Management in Semi- Automated Systems

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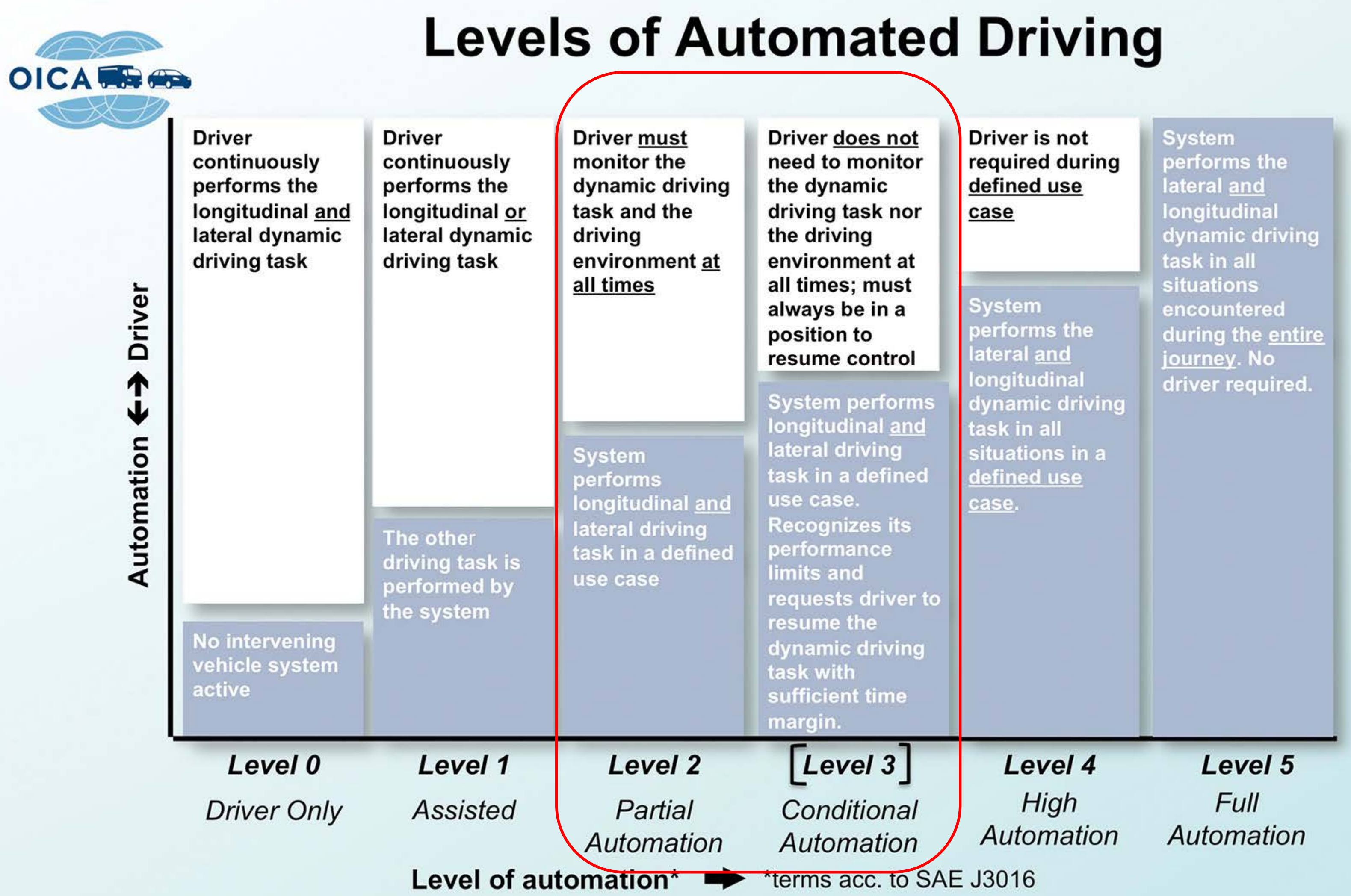
Autonomous & Semi-autonomous Systems are increasingly pervasive

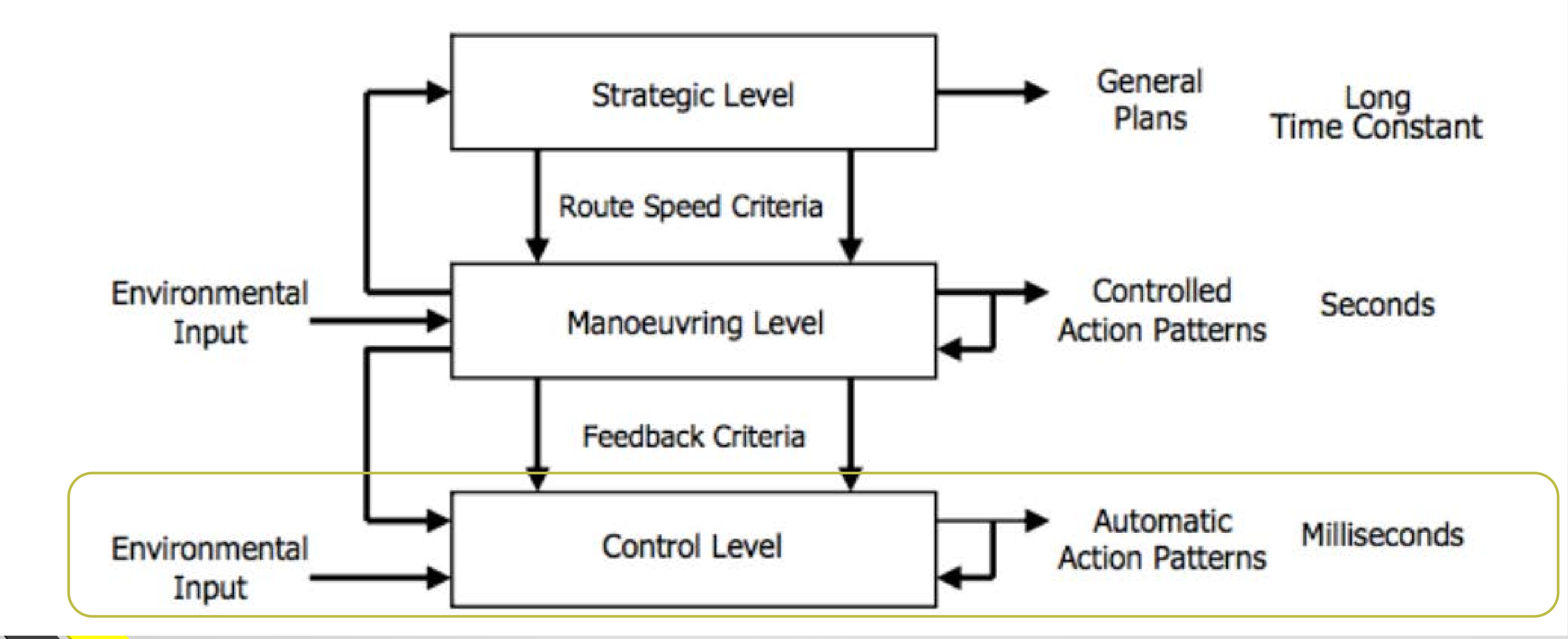
"Technological developments in computer hardware and software now make it possible to introduce automation into virtually all aspects of human-machine systems."

Parasuraman, Sheridan, & Wickens (2000).
IEEE Transactions on Systems, Man and Cybernetics.

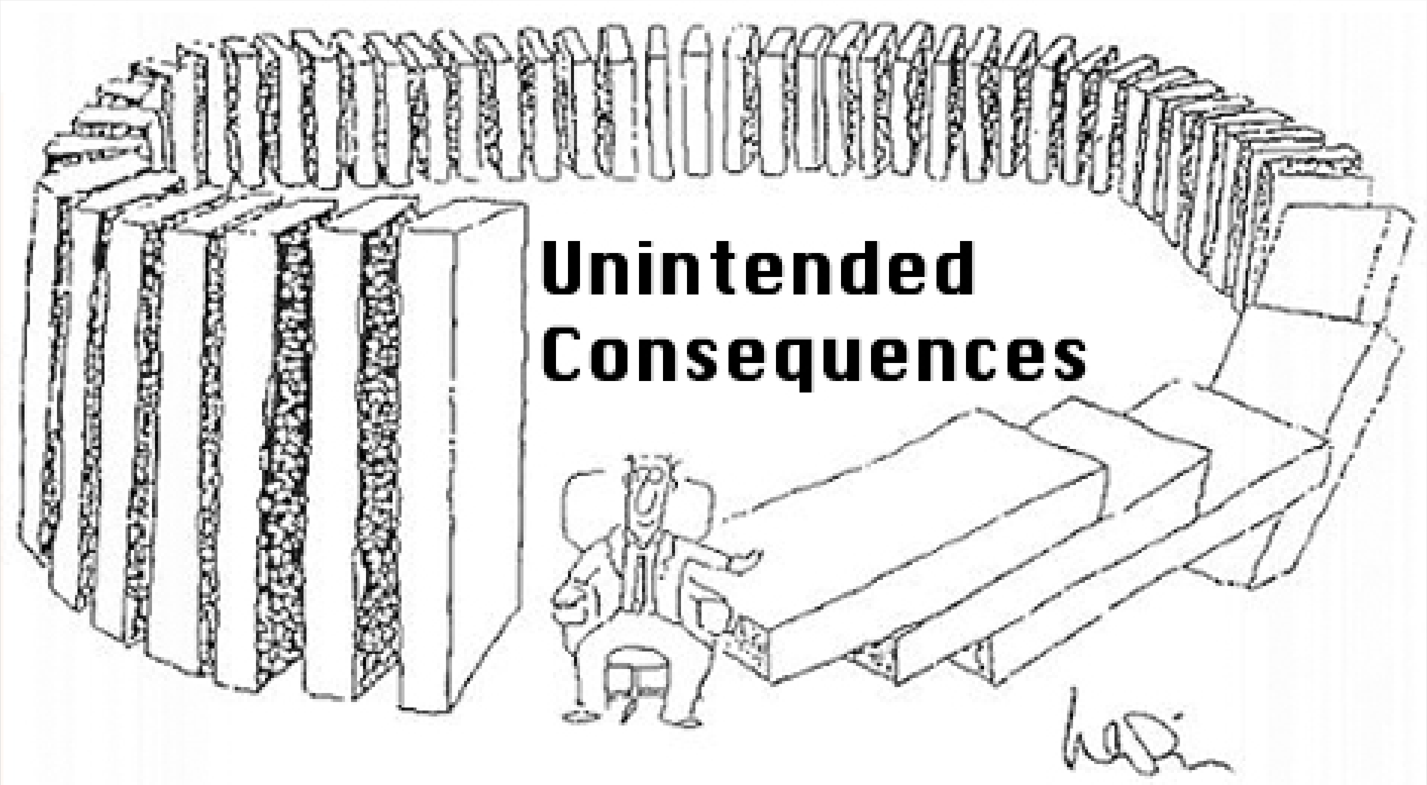


Levels of Automated Driving
OICA
Automation ↔ Driver
Driver continuously performs the longitudinal and lateral dynamic driving task
No intervening vehicle system active
Driver continuously performs the longitudinal or lateral dynamic driving task
The other driving task is performed by the system
Driver must monitor the dynamic driving task and the driving environment at all times
System performs longitudinal and lateral driving task in a defined use case
Driver does not need to monitor the dynamic driving task nor the driving environment at all times; must always be in a position to resume control
System performs longitudinal and lateral driving task in a defined use case. Recognizes its performance limits and requests driver to resume the dynamic driving task with sufficient time margin.
Driver is not required during defined use case
System performs the lateral and longitudinal dynamic driving task in all situations in a defined use case.
System performs the lateral and longitudinal dynamic driving task in all situations encountered during the entire journey. No driver required.
Level 0
Driver Only
Level 1
Assisted
Level 2
Partial Automation
Level 3
Conditional Automation
Level 4
High Automation
Level 5
Full Automation
Level of automation*
*terms acc. to SAE J3016

Updating Michon's (1985) hierarchy in light of automation



“Automation doesn’t just supplant human activity…..it changes it…often in unintended and unanticipated” ways…



1st Fatal Tesla Crash in 2016

- Three bad assumptions:
  - White side of the tractor trailer was part of the sky
  - Driver understood the limits of the automation
  - Driver was paying attention

Semi- Automated Vehicles

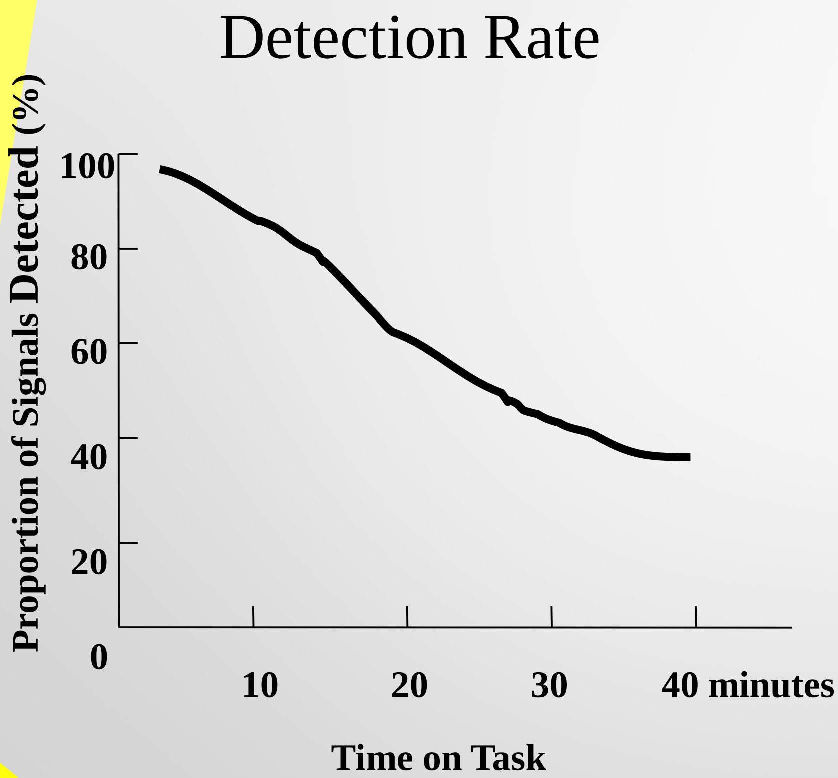
- Driver's are expected to stay in-the-loop
  - Do they even understand this?
- Requires vigilance – something humans are not good at

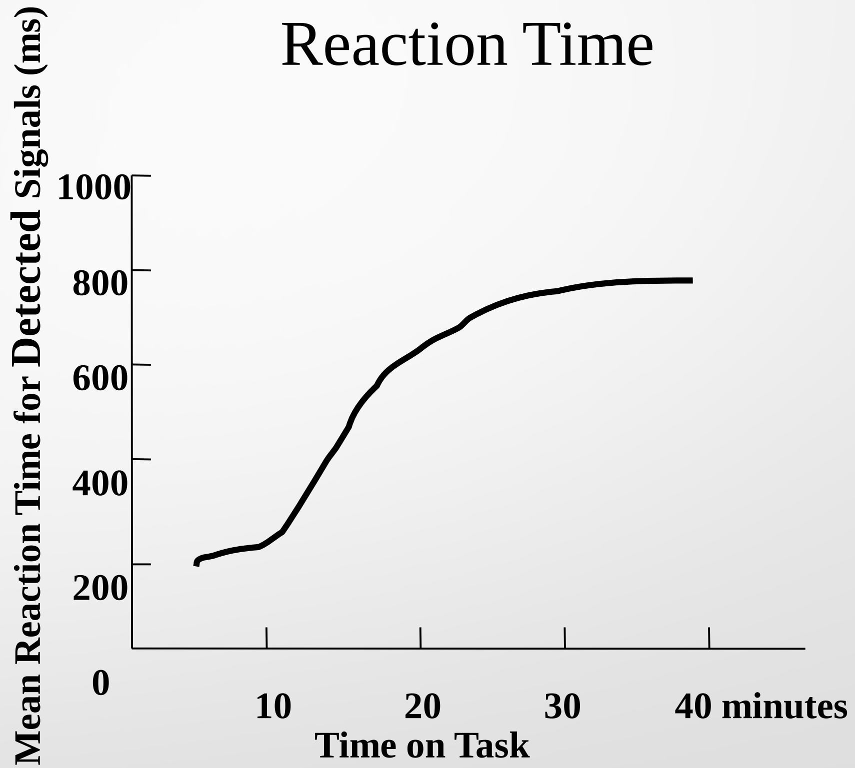
-particularly when there is little to do and critical events are rare.

If humans are rarely required to respond, they will rarely respond when required

-Peter Hancock

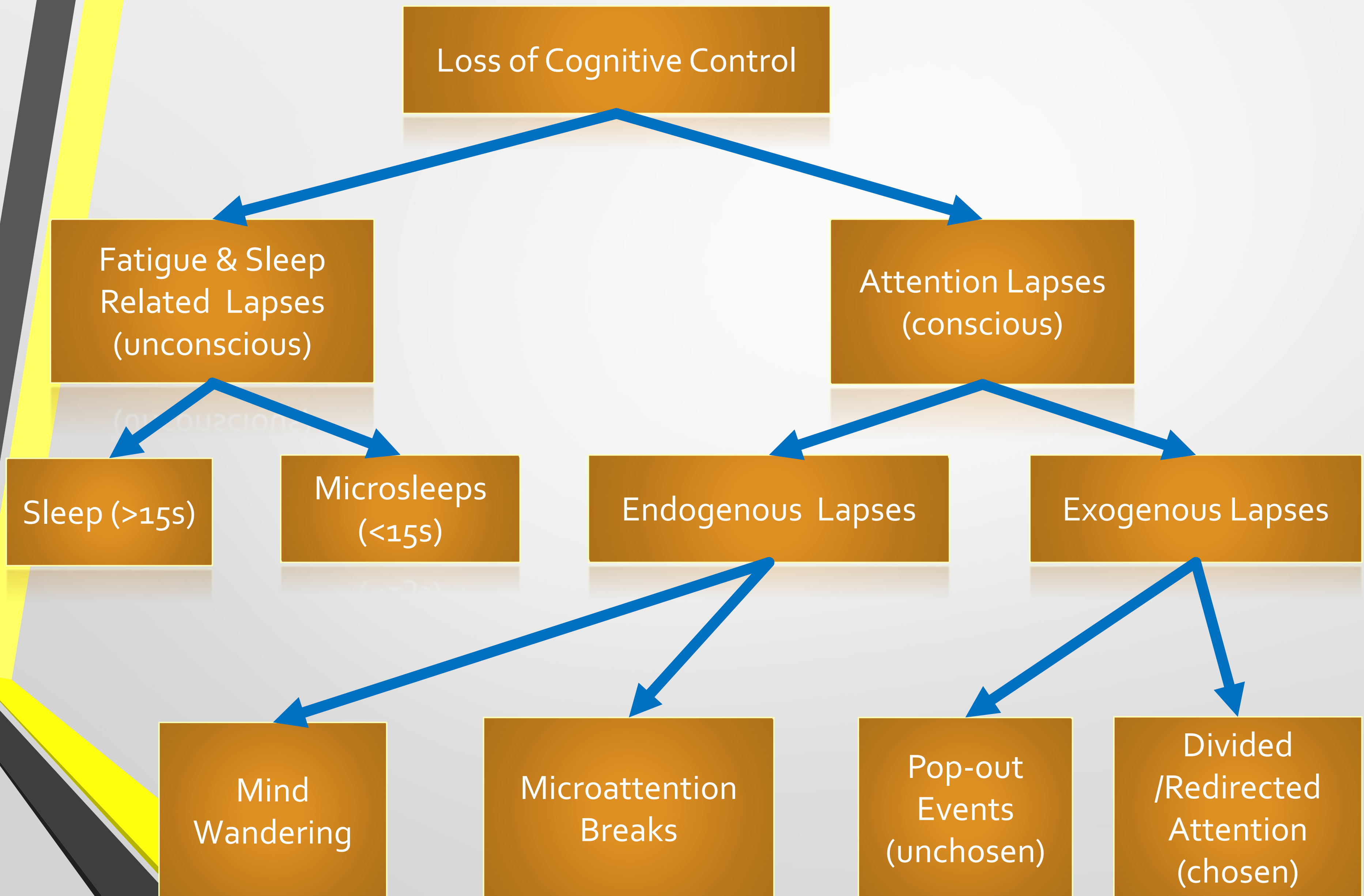
Typical Vigilance Results





How do we keep drivers engaged when they're not actually driving?

- Our sensory systems respond to change
  - They quickly adapt to steady state stimuli
  - Attention systems?
    - Boksem & Tops (2006)
- Dynamic Cognitive Control
  - Adaptive behavior relies on balance between focus and reorienting (Corbetta, et al., 2008)
  - Goal stabilization and goal destabilization (Cools, 2015)
  - Dorsal attention network vs Default mode network (Dang, et al., 2012)
  - Dynamics of Distraction (Lee,2014)


Loss of Cognitive Control
Fatigue & Sleep Related Lapses (unconscious)
Attention Lapses (conscious)
Sleep (>15s)
Microsleeps (<15s)
Endogenous Lapses
Exogenous Lapses
Mind Wandering
Microattention Breaks
Pop-out Events (unchosen)
Divided /Redirected Attention (chosen)

So what can we do about it?

Mental Model

Fatigue

Stress/ Emotion

Engagement/ Mind wandering

Mental Models

- To achieve automation benefits users must understand, accept and appropriately calibrate trust

  - Over-trust (Complacency)—Inappropriate use and over-reliance on automation

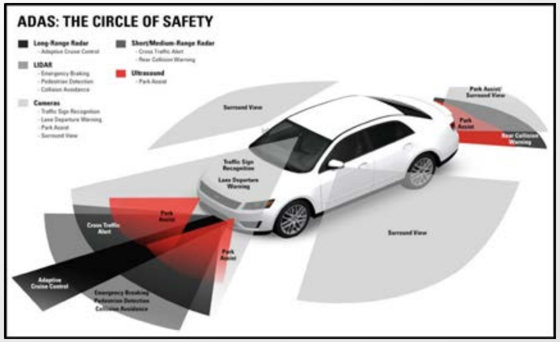
    -loss of situation awareness

  - Under-trust (Distrust)—Disuse or turning off of automation

The goal is to achieve calibrated trust that is matched to the situation

Mental Models of ADAS

- Advanced Driver Assistance Systems (ADAS)
- What do drivers actually understand about SAE Level 2 & 3?
  - Known limitations?
- Where do the get the information & how can we best provide more accurate information?
  - Where do operators get information?
  - What sources/types of info most influential?

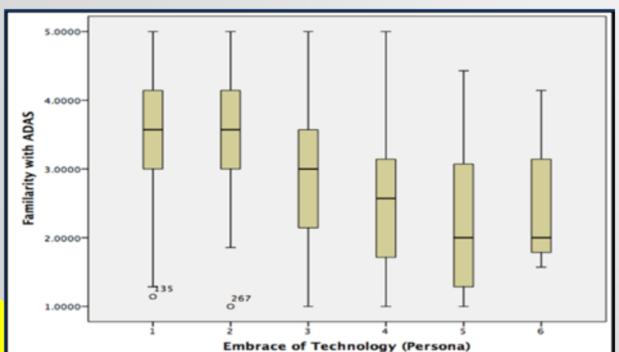


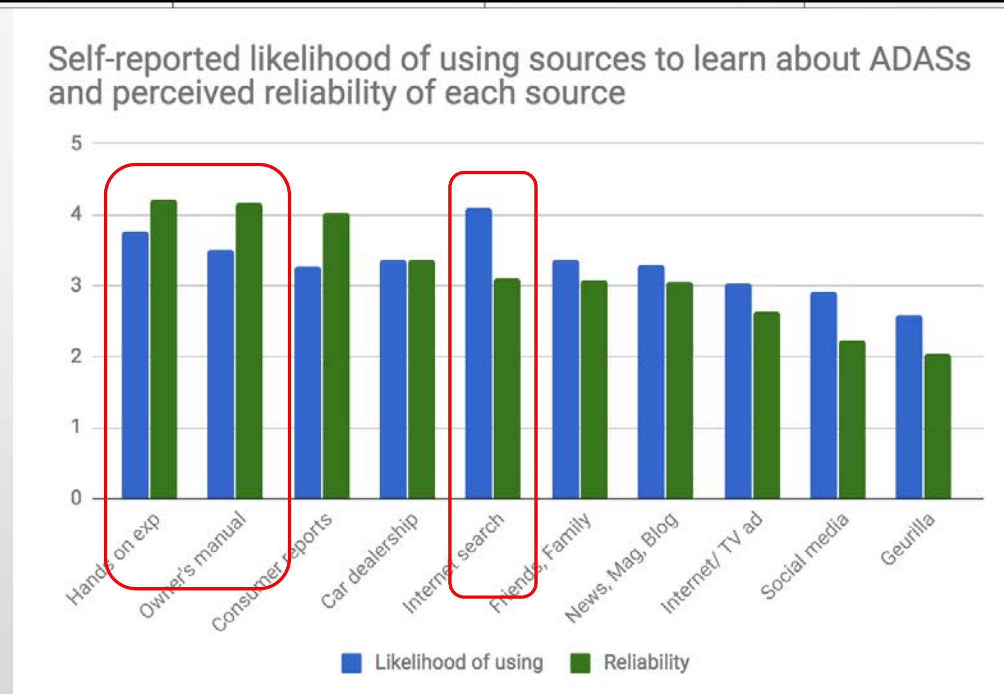
- Neuroergonomics approach
  - Neurophysiological metrics to understand human-automation
    - ERPs to assess attentional engagement
    - EEG spectral analysis to predict when engagement, automation surprise, frustration
    - Eye gaze, pupillometry, heart rate variability, etc…

TOYOTA

Information source & familiarity depended on Tech Savviness…but general trends

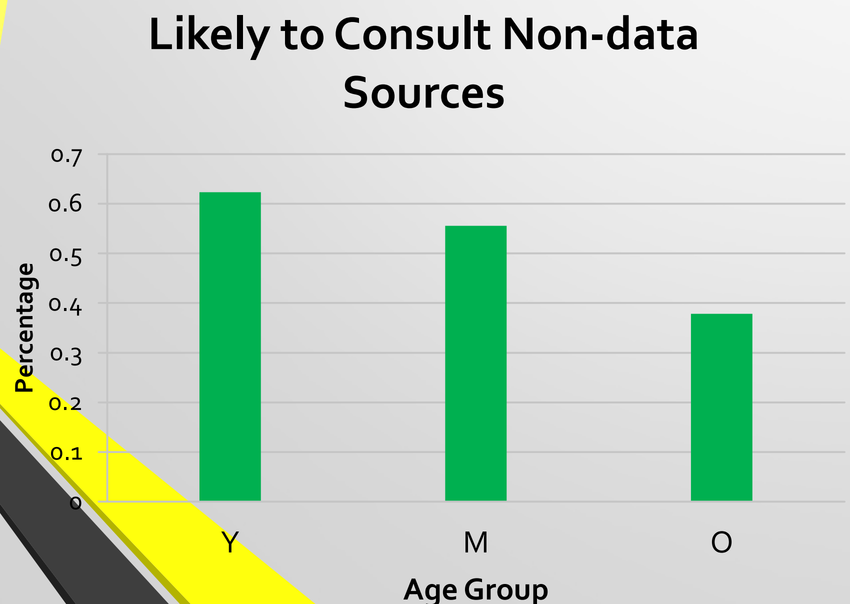
Persona Information - Varied on technological sophistication High ←→ low					
Roberta - Tech CEO who uses an autonomous car, travels often, writes code, and tinkers with her 3D printed inventions	Nick - Engineer who owns car w/ ADAS. Buys gadgets early, reads tech news, uses raspberry pi	Robin – Grad student who uses common software packages, owns new-ish phone, uses social media, drives 3 year old Camry	Mary – systems analyst, reads Chicago Tribune & Pinterest on older iPad, drives e-car, enjoys baking & painting	Taylor – Mom of 3, works at Sears, uses phone to call/text, rarely uses FB that her son set up, volunteers for girl scouts	Ralph – Dad of 2 adult sons, doesn't see need for tech, reads the paper, keeps flip-phone in glove box while hunting/fishing
					

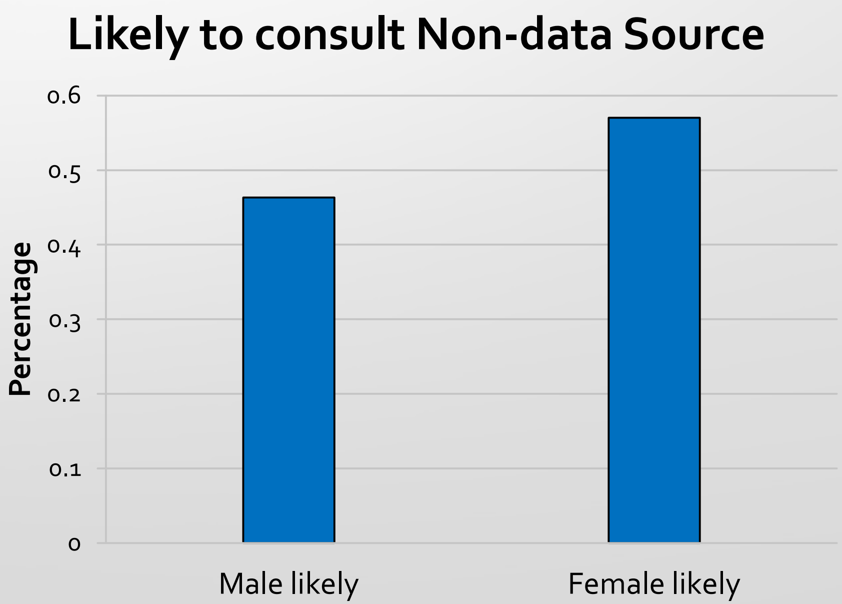




Where do people get information about ADAS?

- Varys by demographics
  - Older adults less likely to consult non-data sources (e.g., family or friends, TV ads, social media…)
  - Females more likely to consult non-data sources





Bottom Line

- People do not currently understand how these systems work
  - Ineffective mental models
    - e.g., 56% believed ALK avoids hazards (i.e., potholes) by switching lanes (n=>500)
  - Don't understand Limitations and capabilities
    - Need appropriate trust calibration
- Systems capabilities will change – sometimes overnight
  - Need effective methods of "just-in-time" training

Mental Model

Fatigue

Stress/ Emotion

Engagement/ Mind wandering

Neuroergonomics Approach to Attention Monitoring & Management

Mental Workload and Attentional Engagement while learning novel systems

Mind wandering detection

Predicting Sustained Attention Failures with Semi-Automation

Novel Attention Management Approaches

Mental Workload and Learning of using ADAS among novice users

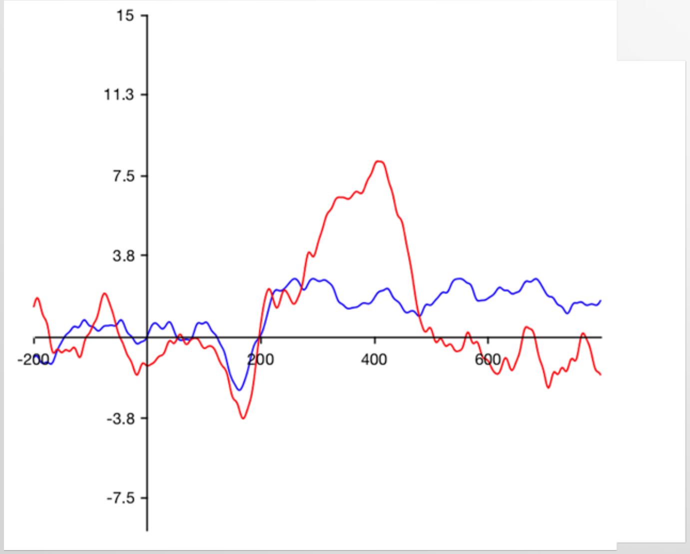
- Experience ADAS simulations
  - Adaptive Cruise Control (ACC) system
  - Active Lane Keeping (ALK) system
- Engage each system, then encounter events
  - Slow traffic in construction zone
  - Sudden cut-in event
- Auditory Oddball task concurrently – to assess workload & learning
  - EEG measured throughout
  - P300 response to targets v distractor tones
- Knowledge & trust surveys before drive

Results

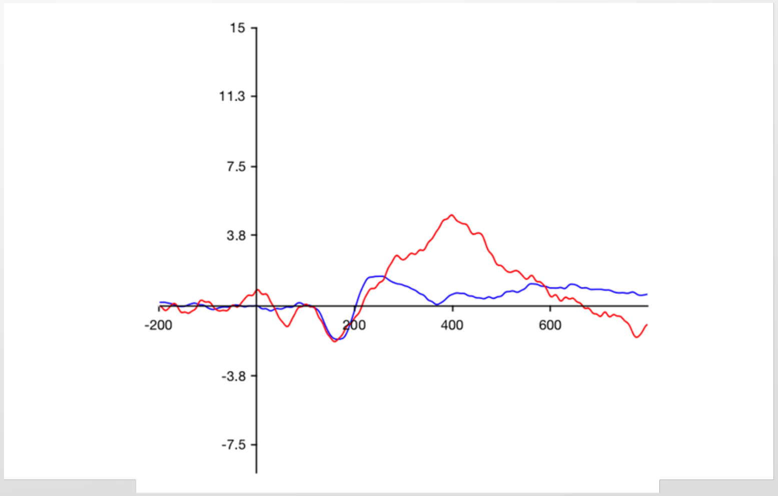
-Sensitivity (correct oddball responses) decreased when driving with ACC – so some increased workload even with this basic driving automation.

-P300 amplitude also decreased indicating less spare attentional capacity during ACC

P300 at baseline



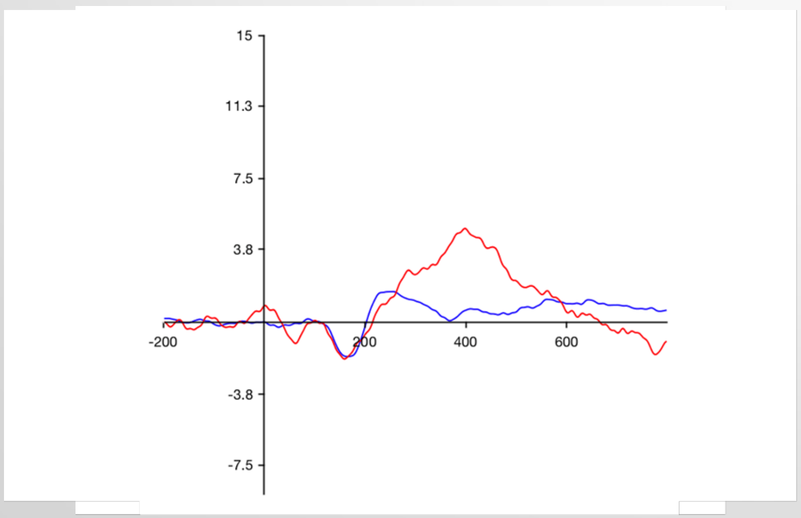
P300 at Pz in ACC



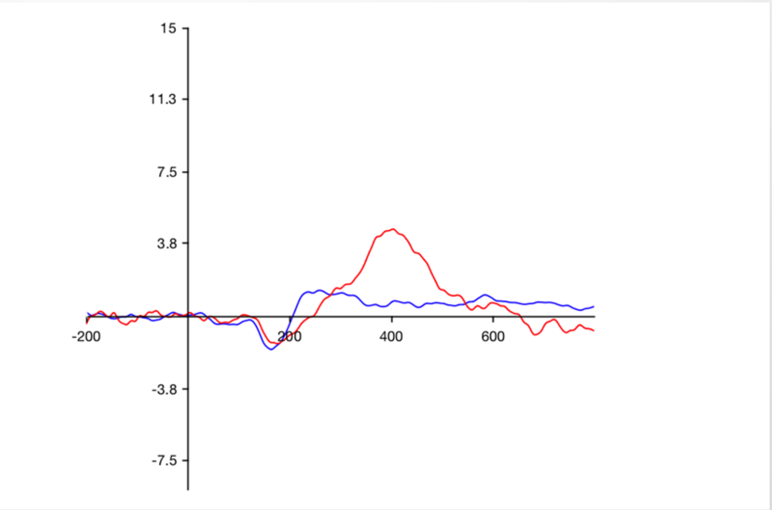
Drivers experience greater workload when engaged in driving with ACC and ALK , relative to driving with just ACC.

-Decreased sensitivity and P300 amplitue

P300 at Pz with ACC



P300 at Pz in ACC & ALK



Bottom line

- Increased driver automation does not always make things easier.
- Particularly if drivers are inexperienced with the automation.
- Further work needed to determine time course of acquiring/learning appropriate use of the systems.

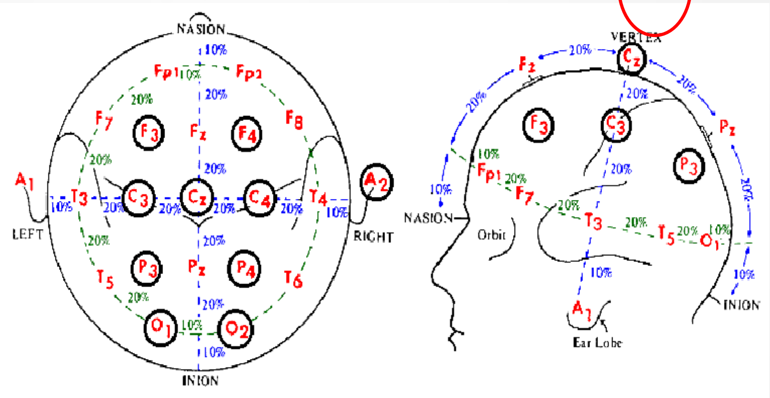
Mind wandering behind the wheel

We may spend ~50% of the time while driving (manually) mind wandering. Is it a problem?

Can we detect it?
Low cost physiological sensors?

Physiological Measures

- EEG
  - Parietal alpha
  - Frontal theta
- ECG
  - Heart rate
  - Heart rate variability
- Eye-tracking
  - Gaze dispersion
    - Horizontal
    - Vertical
  - Pupil diameter



Series of Studies

- All Self-report of Mind wandering
  - Single Day (self–caught)
  - Single Day (probe-caught)
  - Five Day (probe-caught)
- Physiological metrics (e.g., EEG, ERP)
  - + & - 13 s window
    - + & - 3 seconds around button push eliminated

DAY 1	Drive 1	SART	Drive 2
DAY 2	Drive 1	SART	Drive 2
DAY 3	Drive 1	SART	Drive 2
DAY 4	Drive 1	SART	Drive 2
DAY 5	Drive 1	SART	Drive 2
	~ 20 min	~ 20 min	~ 20 min

www.nhtsa.gov

Mind wandering state

Daniel Roberts

- During mind wandering relative to periods of alertness:
  - Increased alpha power in the EEG*
  - Decreased P300 response to external stimuli
    - auditory probes*
  - ECG interbeat interval significantly longer
  - Increased gaze concentration

*Baldwin, C. L., Roberts, D. M., Barragan, D., Lee, J. D., Lerner, N., & Higgins, J. S. (2017). Detecting and Quantifying Mind Wandering during Simulated Driving. *Frontiers in Human Neuroscience, 11*, 406. doi:10.3389/fnhum.2017.00406

Detected mind wandering during manual driving…

What about while using partial automation?

Can we predict when drivers are likely to miss a cue that the automation has become unreliable?

Cisler, Dean, Greenwood, Pamela M., Roberts, Daniel M., McKendrick, Ryan, & Baldwin, Carryl L. (2019). Comparing the Relative Strengths of EEG and Low-Cost Physiological Devices in Modeling Attention Allocation in Semiautonomous Vehicles. *Frontiers in Human Neuroscience*, *13*. doi:10.3389/fnhum.2019.00109

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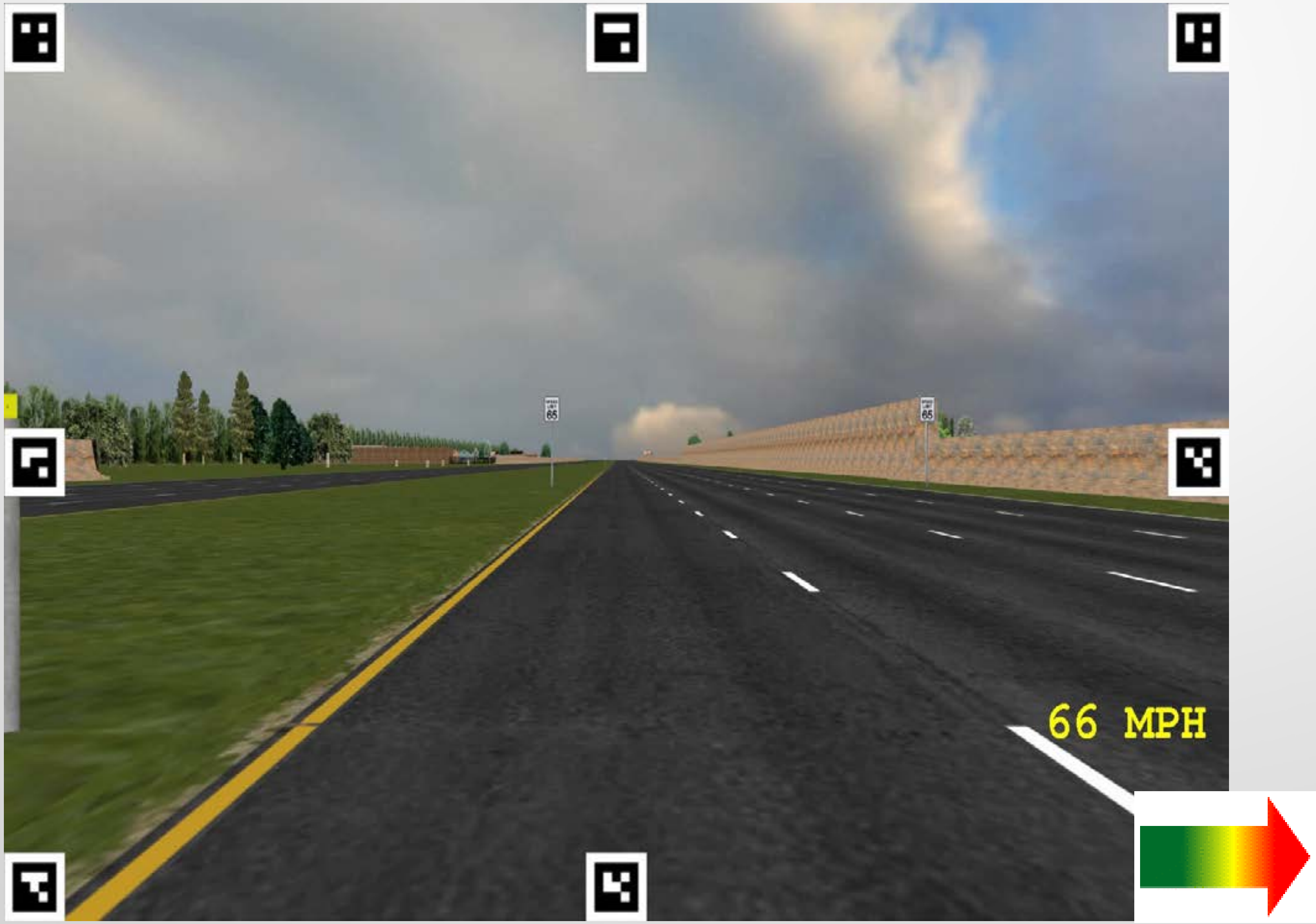
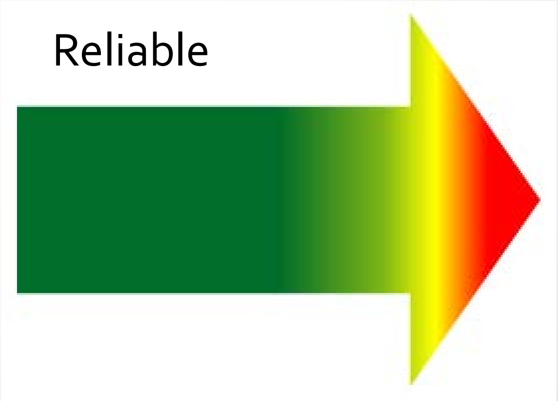
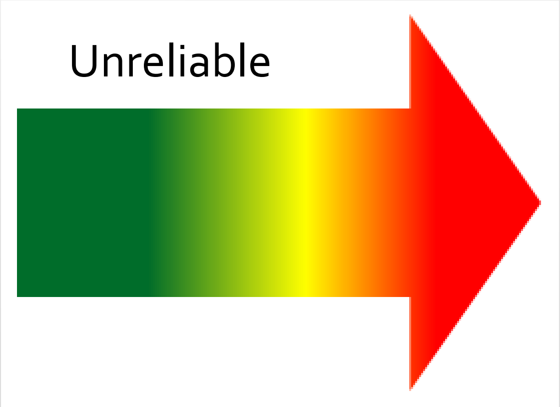
Automated Lane Keeping Task



Methods

- Driving Task
  - Automated Lane-changing task
    - 5 drives @ ~11 mins each
  - Automation reliability interface
    - Arrow presentations
      - Duration = 170 ms
      - Appeared roughly every 13 secs
      - Varied in direction and color
    - Unreliable – 20%
      - No lane change = 60%
      - Correct = 20%
      - Incorrect = 20%
    - Respond with serial button press





Primary Goal

- Could we predict by looking at metrics just prior (1-3 s) to unreliable cue indicators…
  - When people would be likely to fail to notice or be slow to respond to the unreliable cue?

Results

- Prestimulus alpha (alpha power at Pz 1 s before the automation reliability cue change) predicts time to respond & accuracy of detection.
- So far…
  - HRV adds to predictive capability, but not currently sufficient on its own.
  - Gaze concentration predictive, but not sufficient

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Bottom line

- Near future we may be able to successfully detect when people have lost vigilance.
- But! Or, so…
  - Perhaps it is impossible (or irresponsible) to expect people to maintain vigilant attention for a sustained period of time.
  - May need:
    - To let them mind wander & then bring them back quickly when they are needed?
    - Intuitive Alarms
      - Elicit appropriate response on 1st exposure

Summary

- Semi- Automated Vehicles
  - Driver's are expected to stay in-the-loop
    - Help them understand this
    - Help them do this - vigilance is not something humans are not good at
- Support attention allocation by ..
  - Providing cues to automation reliability
  - Monitoring physiological state of driver/operator to
    - Determine & support minimum levels of vigilance needed
    - Predict when drivers/operators might lose cognitive control/vigilance
      - Potentially change the alert type based on driver state
  - Re-engage distracted drivers when needed
    - Consider all types of cognitive lapses
  - Provide driver demographic appropriate interfaces and training
    - Age, experience level, tech savviness, etc…

Acknowledgements

- Acknowledge some of our sponsors for their generous support for this research.

Thanks for your attention!