DDAW System monitoring strategy and warning delay performance

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DDAW system monitoring strategy and warning delay performance

PURPOSE: Support the development of future DDAW systems that accurately provide a warning to the driver at an excessive or unsafe level of drowsiness

1. Should an activated DDAW system continuously monitor the driver after providing the first warning, and subsequently continue to warn the driver, even though drowsiness is not typically a transient state (unlike distraction) [sic]?

2. Would the implementation of a continuous monitoring strategy require considerations of factors such as likelihood of false positive warnings, factors influencing likely self-assessment by the driver including elapsed time driving when the warning is first given, the possibility that the driver may have been changed during a single trip?

3. How long is too long for the delay between a driver becoming drowsy (KSS = 8) and the system detecting this drowsiness? For example, should the drowsiness regulation consider any data on the time-based safety risk increase for having an accident under continuous driving at a nominal drowsiness level?

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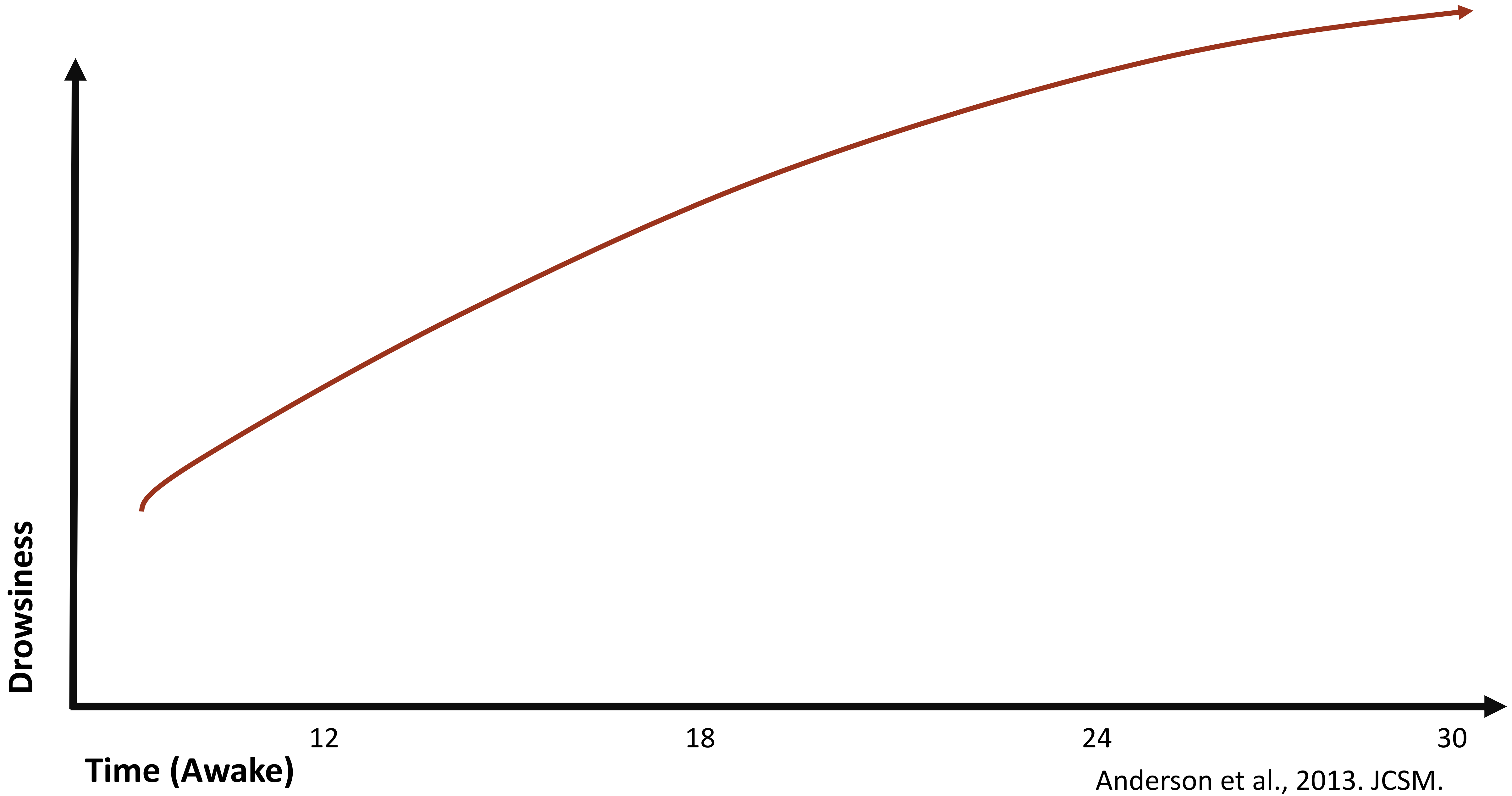
Topics for Discussion

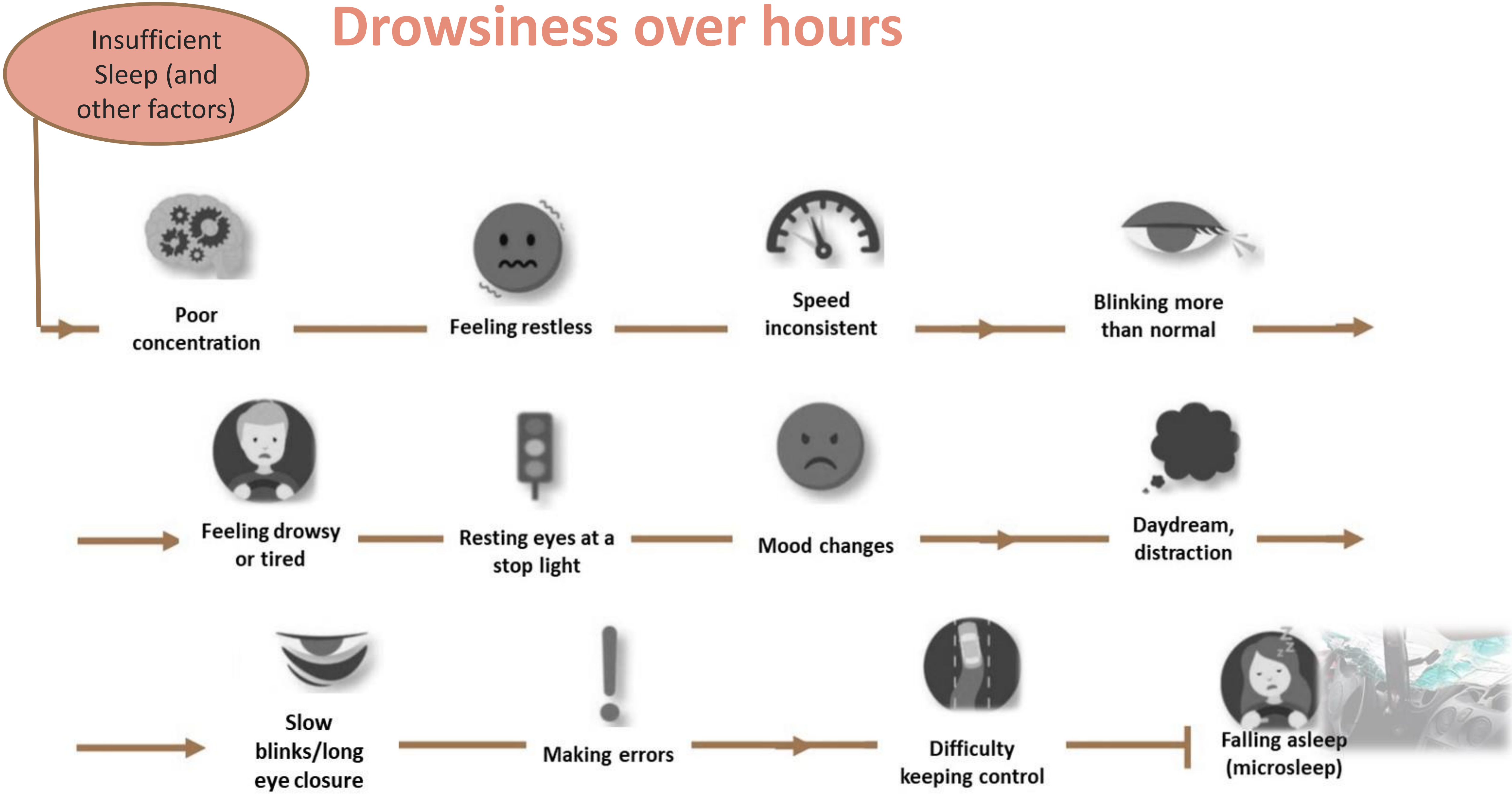
1. Characterise interplay between subjective sleepiness, physiological drowsiness and driving impairment
2. Warnings: To continue to stop after the first event
   - Issue of False (positive) Alarms
   - Impact of Drive Duration
   - Dealing with driver changes
3. Delay between alarms and drowsiness: how long is too long?

Drowsiness over 36 hours



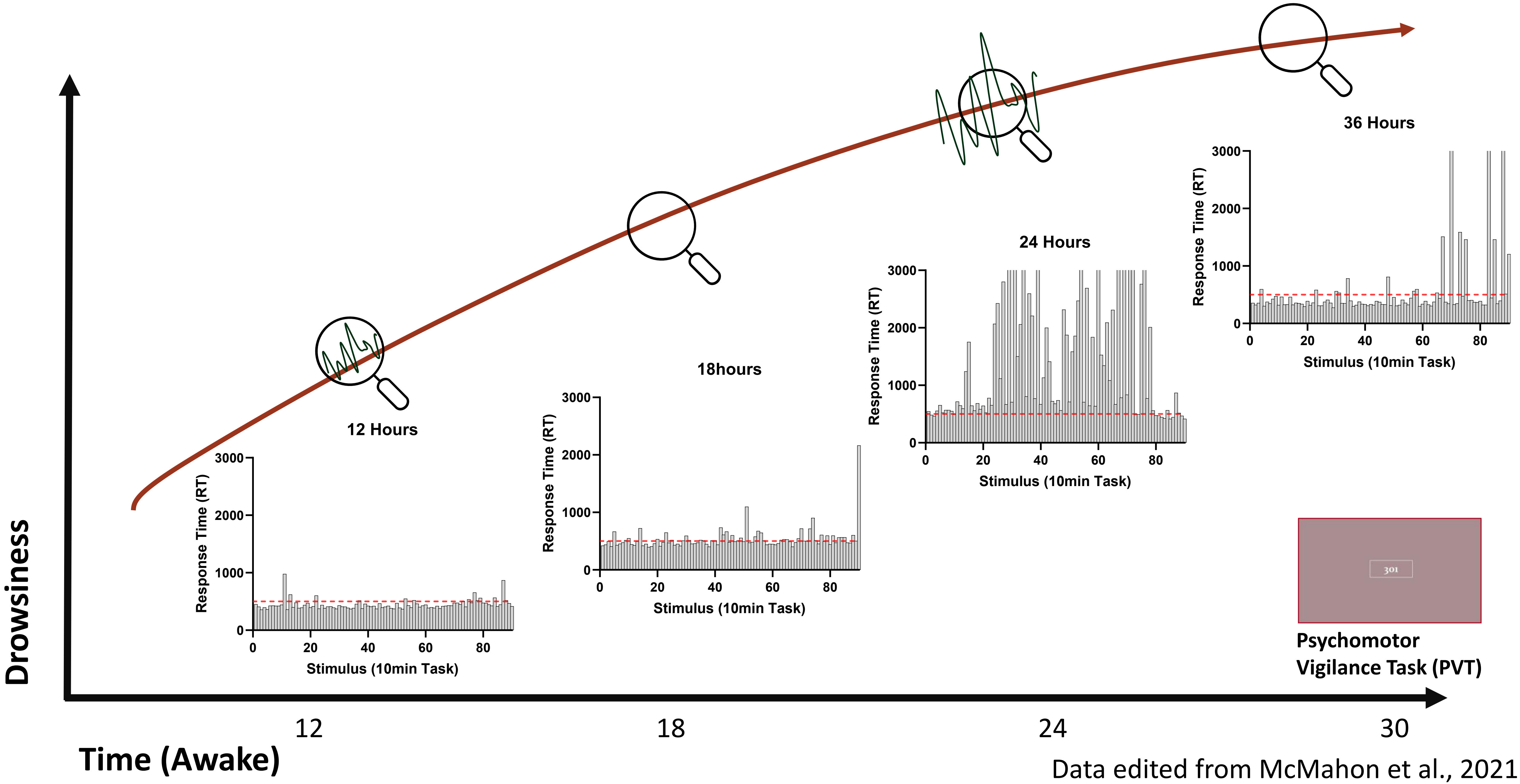
Anderson et al., 2013. JCSM.

Drowsiness over hours



Infographics courtesy of www.nrspp.org.au

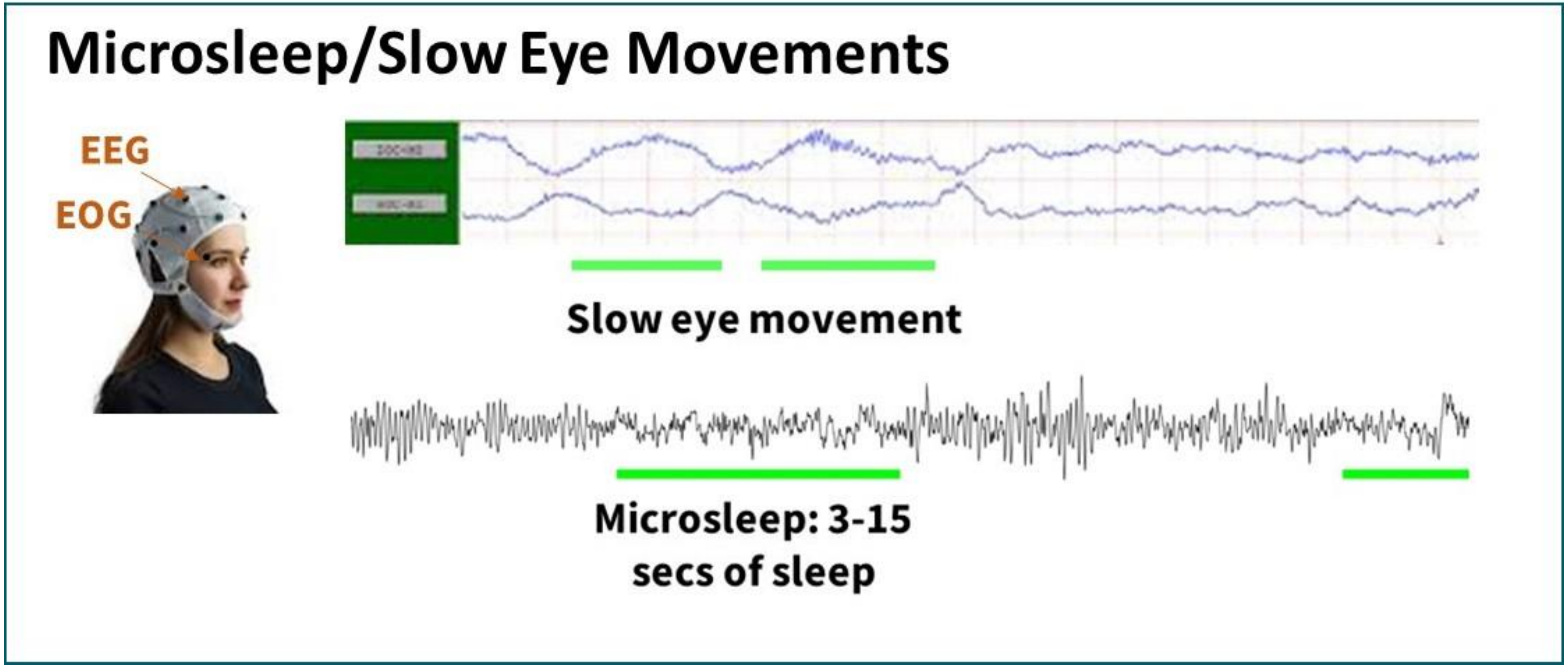
Drowsiness over minutes and seconds



Data edited from McMahon et al., 2021

Drowsiness and the process of falling asleep

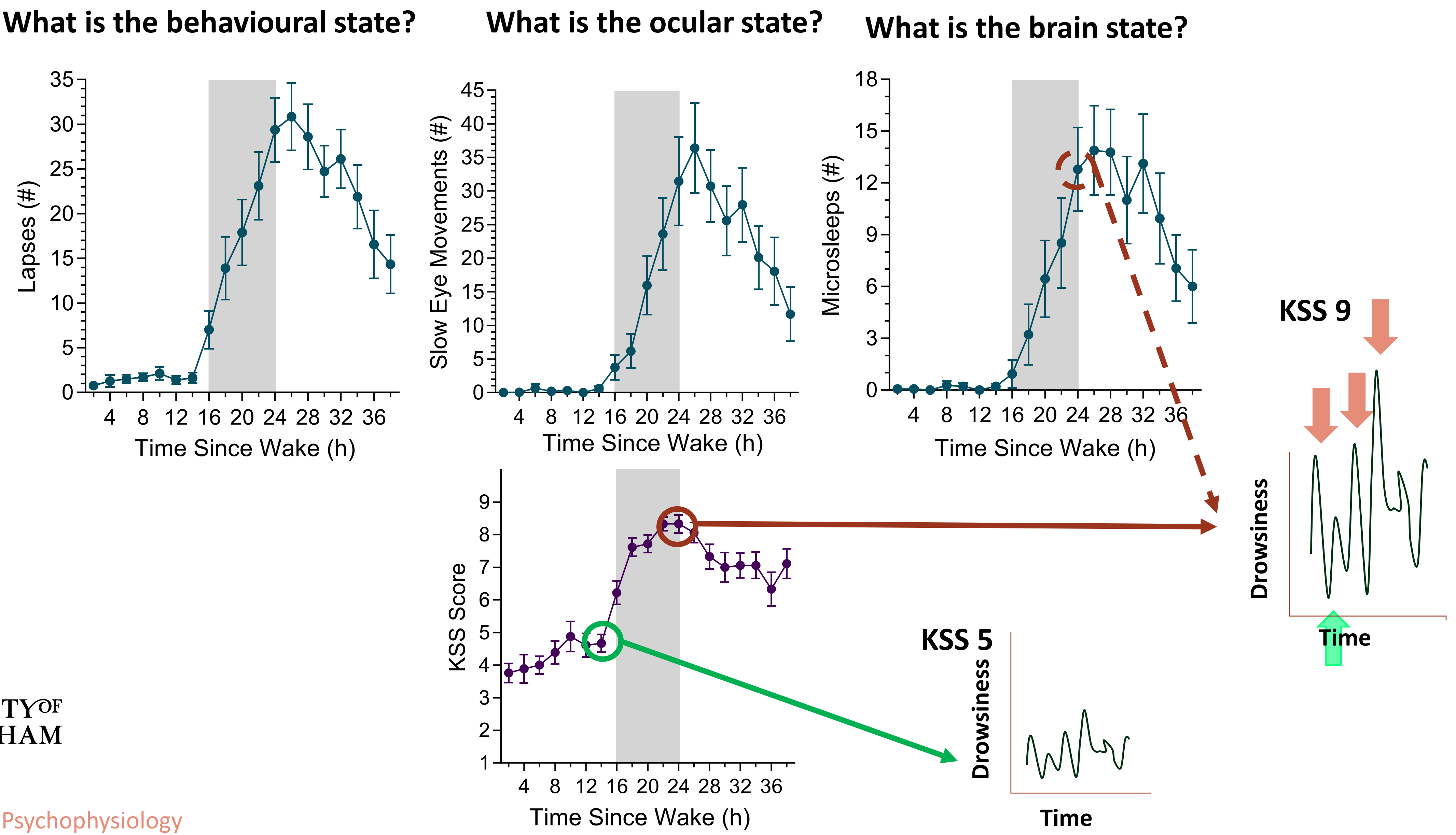
Drowsiness is the physiological process of falling asleep……



Drowsiness **is** highly dynamic ……

….. and microsleep are discrete safety critical events

Drowsiness and the 'ground truth'



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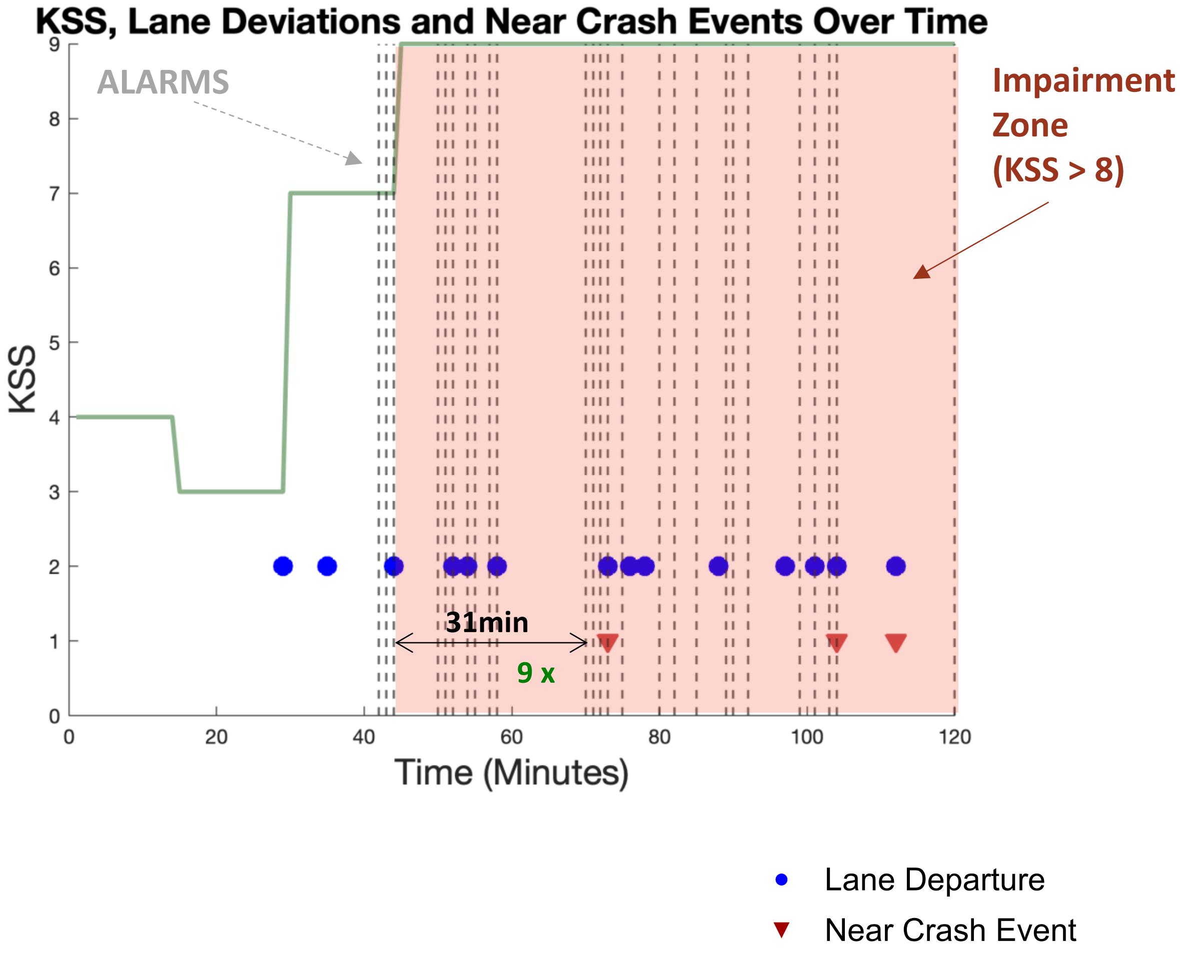
Manousakis et al., 2021. Psychophysiology

Switching off the system after the first alarm: a case study

- Dual control car, with instructor on a closed loop track
- KSS ratings every 15minutes
- End 2h or after an intervention procedures

- Subjective Sleepiness (KSS)
- Driving Impairment (Lane Departures)
- Critical Driving Impairment (Emergency Braking)
- ALARMS (Seeing Machines)



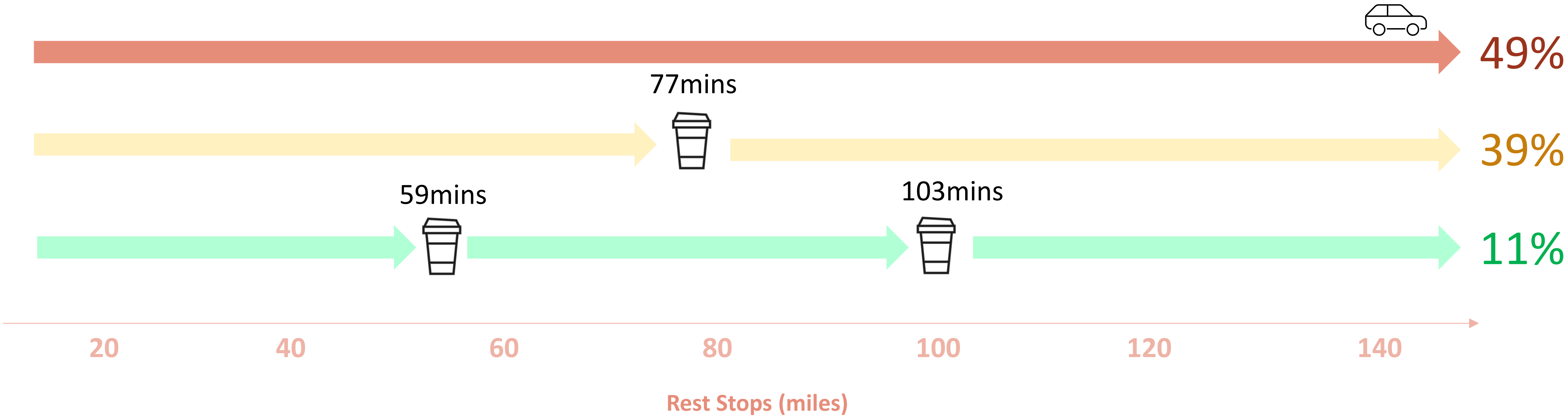
Data example taken from the study described here: Manousakis, J. E. et al. Evaluation, Validation and Comparison of Fatigued Driving Monitoring Systems Final Report. (https://www.aaa.asn.au/library/evaluation-validation-and-comparison-of-fatigued-driving-monitoring-technologies/, 2024).

Single alarm relies on immediate action

TASK: Drive 150 miles.
Rest stops every 20miles
INCENTIVE: $1 for every minute under 3hours
Forfeit if crash

Drivers already have an in-built warning system:
how does it affect their decision to stop?

86% of drivers continued to drive with a KSS of 8
76% of drivers continued to drive with a KSS of 9



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Gaspar JG, Carney C. Drowsiness and decision making during long drives: a driving simulation study. 2023; 1-37. https://aaafoundation.org/drowsiness-and-decision-making-during-long-drives-a-driving-simulation-study/

Drivers don't stop for many reasons…

- **Denial**
  - They don't believe the alarm
- **Over-confidence**
  - They believe they can 'push through'
- **Safer option**
  - They are concerned for their safety
- **Impaired judgment**
  - Fail to recognise drowsiness

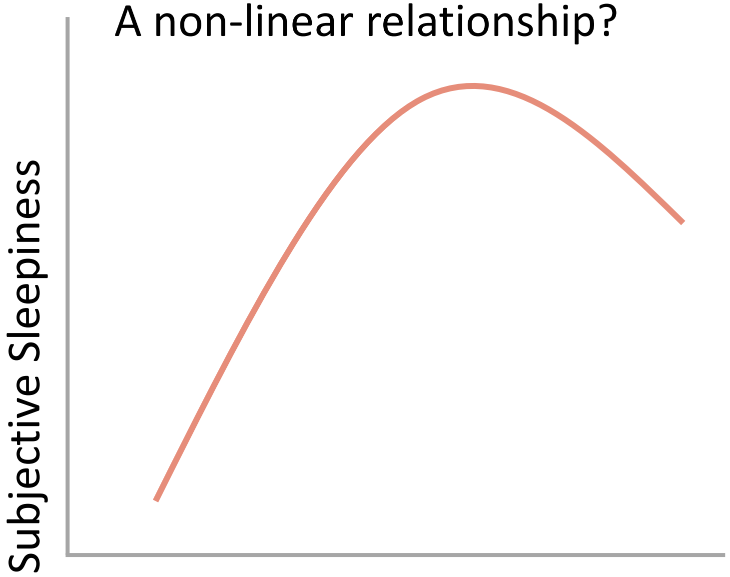
Can we reduce through effective use of alarms… ?

- **Validity** is essential. Long-term 'learning' leads to enhanced trust
- **Escalating** alarms indicate that 'pushing through' is not working
- **Earlier** alarms enable better planning to find a safe space to take action and avoid late-stage drowsiness failures.

Watling et al., 2015. Accident, Analysis & Prevention
Cai & Anderson, 2023, The ARROW Survey. Transport Accident Commission Report

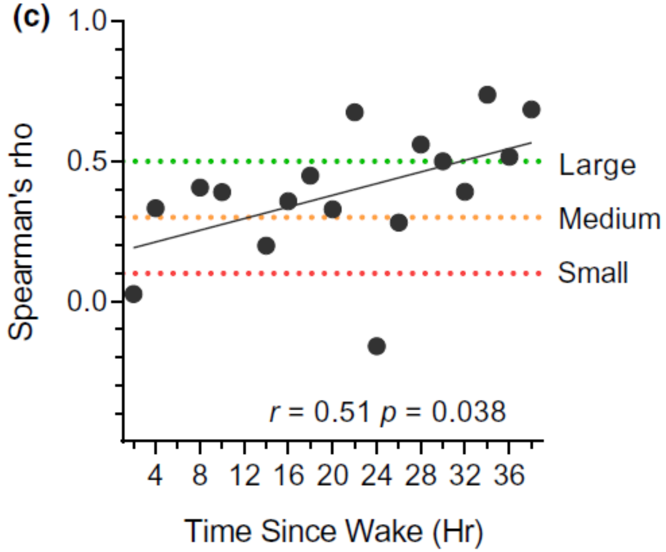
Continuous alarms allow for changing awareness with increasing drowsiness

A non-linear relationship?



PERCLOS \ KSS	Low (1-4)	Moderate (5-7)	High (8-9)
Low (<0.125)	25%	17%	7%
Moderate (0.125-0.25)	63%	65%	63%
High (>0.25)	13%	18%	30%

Correlation: KSS vs Microsleep



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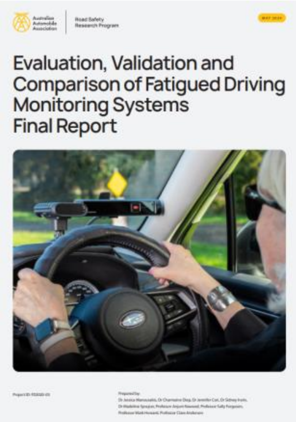
Manousakis et al., 2021. Psychophysiology

Active Monitoring Systems: Effectiveness of alarms


Evaluation, Validation and Comparison of Fatigued Driving Monitoring Systems Final Report

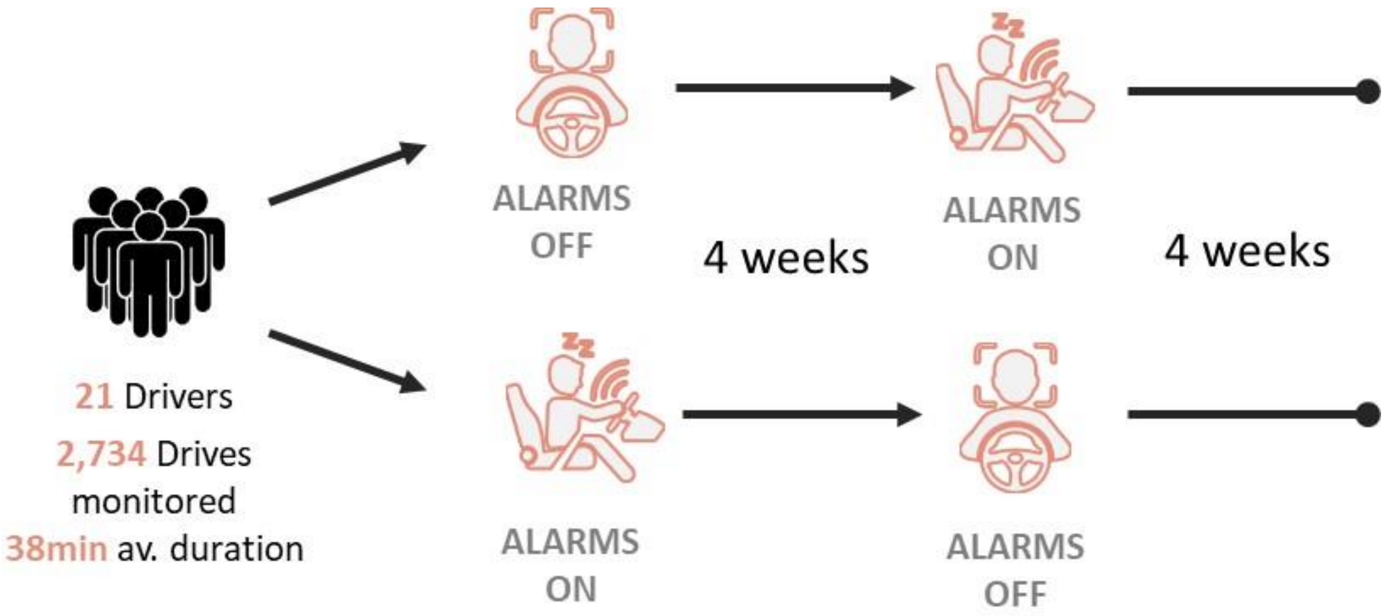
The D-TECH Program: 2020-2024

Consortium Lead/Principal Investigator: Clare Anderson

Consortium Leadership Team: Jessica Manousakis, Mark Howard, Sally Fergusson

Australian Automobile Association

STUDY 2A:
Naturalistic Study, with randomised cross-over design
Project Lead: Jen Cori



55% reduction validated fatigue events

48% reduction hard braking

34% reduction hard cornering

Reduced end of shift KSS

Increased caffeine consumption

52% improved recognition of fatigue

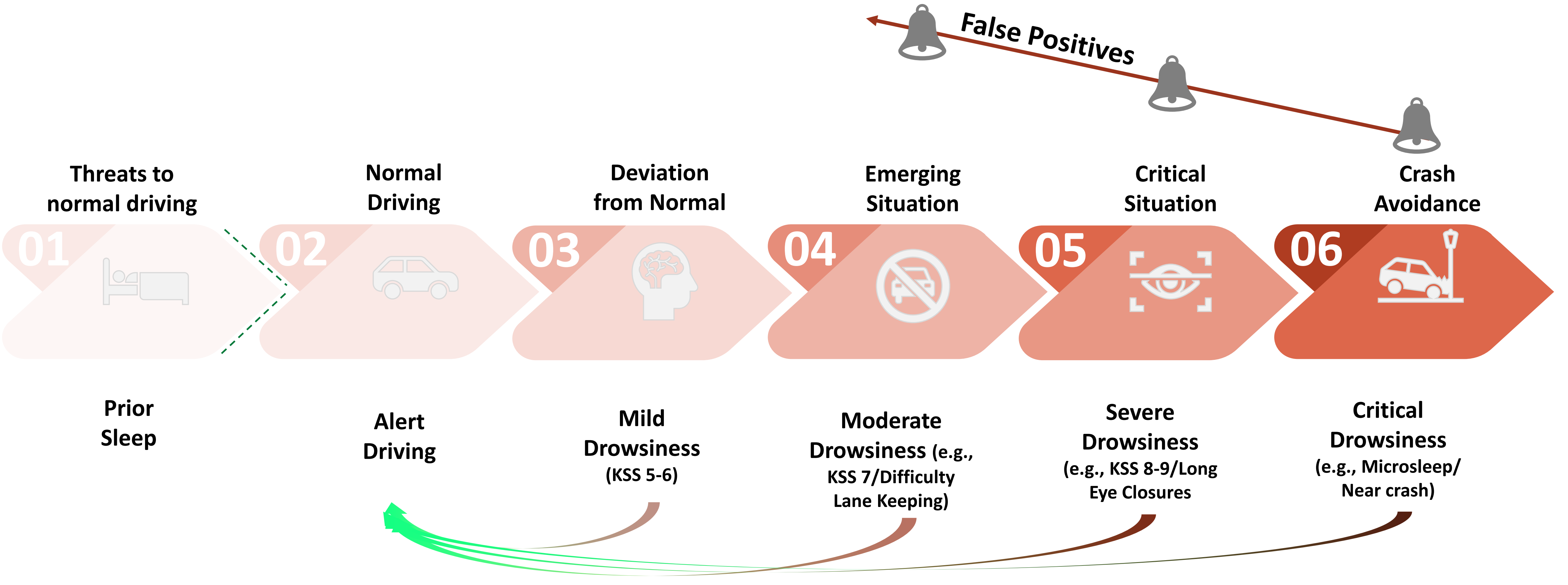
90% better equipped to handle fatigue

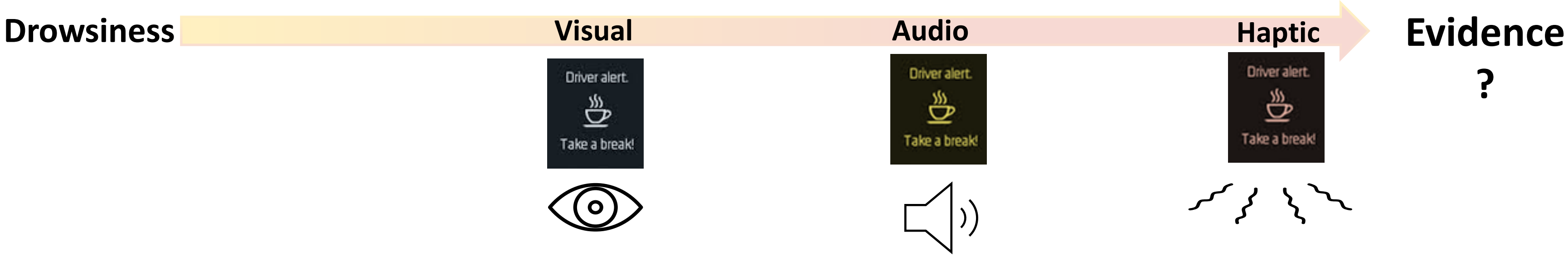
81% felt the alarms were not annoying

100% felt the alarms did not interfere with work

Manousakis, J. E. et al. Evaluation, Validation and Comparison of Fatigued Driving Monitoring Systems Final Report. (https://www.aaa.asn.au/library/evaluation-validation-and-comparison-of-fatigued-driving-monitoring-technologies/, 2024).

How and when alarms are activated matters





Adapted from Fitzharris, M., Corben, B., Lenné, M. G. et al. (2022). Understanding Contributing Factors for Serious Injury Crashes Using Crash Chain Analysis: ECIS Report 3 (MUARC Report 345). Available at: https://www.monash.edu/muarc/research/research-areas/transport-safety/enhanced-crash-investigation-study/ecis-reports

False Positive Warnings

		Predicted Drowsiness	
		NO	YES
Actual Drowsiness	NO	TRUE NEGATIVE	FALSE POSITIVE
	YES	FALSE NEGATIVE	TRUE POSITIVE

A contingency table* organizes the frequencies of two categorical variables, showing how often they occur together.

How FPs impact safety

- Driver may disengage/turn off system
- Driver may lose trust and ignore warnings
- Driver may be distracted (Anderson & Horne, 2013)

How to reduce FPs

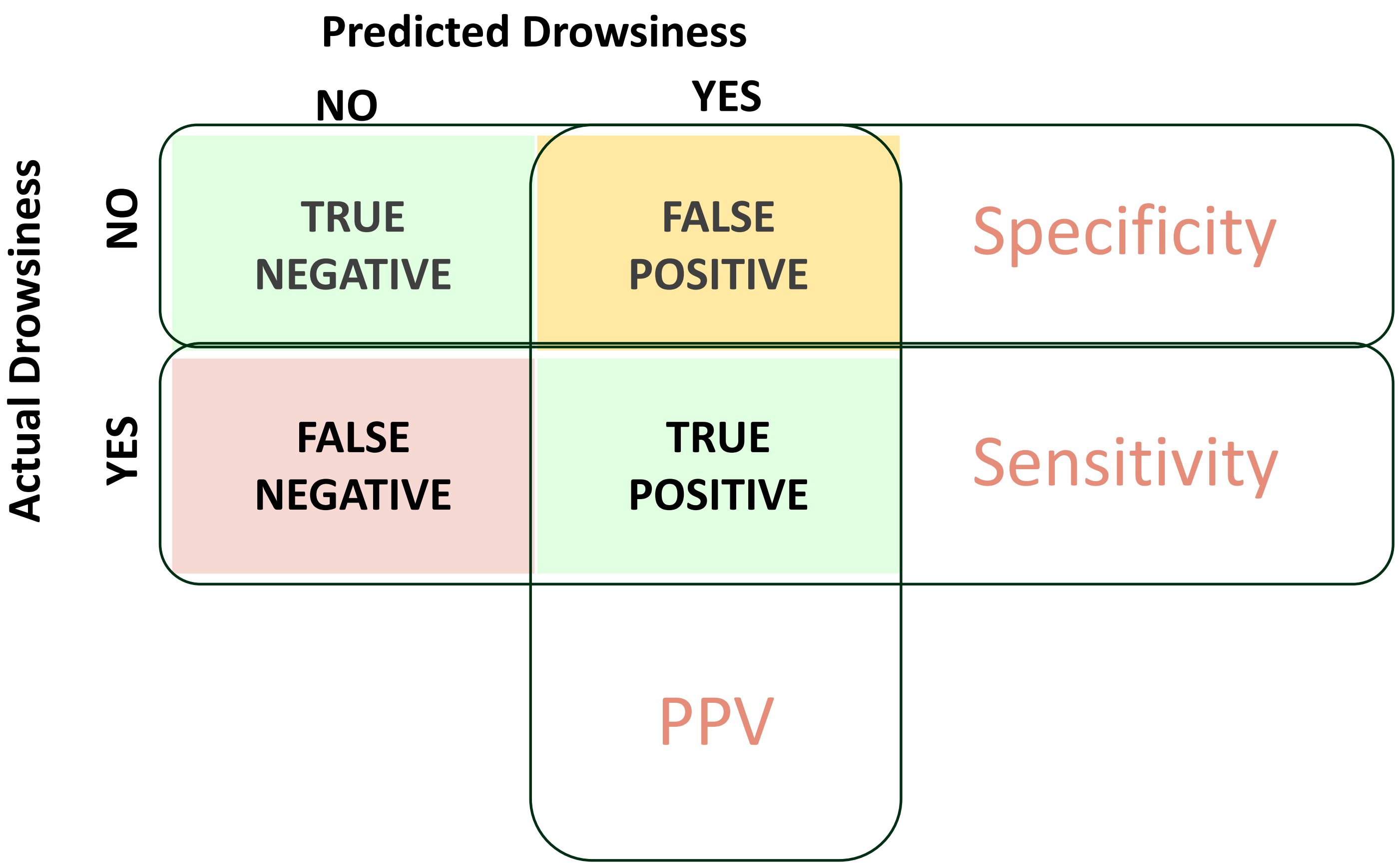
- Have single alarm/fewer alarms
- Have a ‘late warning’ system

How to reduce FPs safely

- Ensure the threshold for detection is reliably high
- Have escalating alarms

* Also referred to as a confusion matrix or cross-tabulation

Is sensitivity enough?



Sensitivity

Proportion of true positives correctly identified

Sensitivity = True Positives ÷ (True Positives + False Negatives)

Specificity

Proportion of true negatives correctly identified

Sensitivity = True negatives ÷ (True Negatives + False Positives)

Positive Predictive Validity (PPV

Proportion of predicted drowsiness events (e.g., Alarms) that are true.

PPV = True Positives ÷ (True Positives + False Positives)

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   Continued alarms increase potential for drivers to intervene short-term and long-term improving safety

2. Would the implementation of a continuous monitoring strategy require considerations of factors such as likelihood of **false positive warnings**, factors influencing self-assessment by the driver including **elapsed time driving** when the warning is first given, the possibility that the **driver may have been changed** during a single trip?

3. How long is too long for the delay between a driver becoming drowsy (KSS = 8) and the system detecting this drowsiness? For example, should the drowsiness regulation consider any data on the time-based safety risk increase for having an accident under continuous driving at a nominal drowsiness level?

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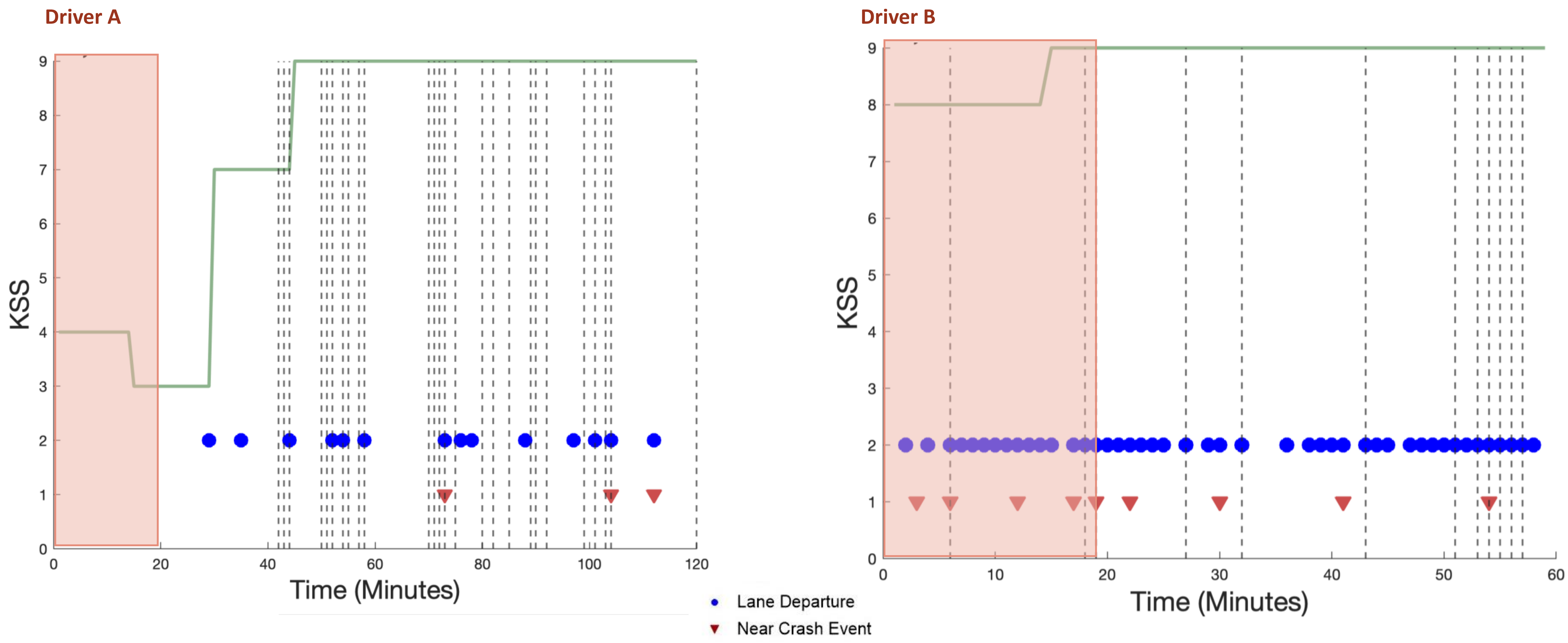
Time factor should be carefully considered: case study

What's the potential impact on ignoring the first 20 minutes (as an example) to reduce FPs:



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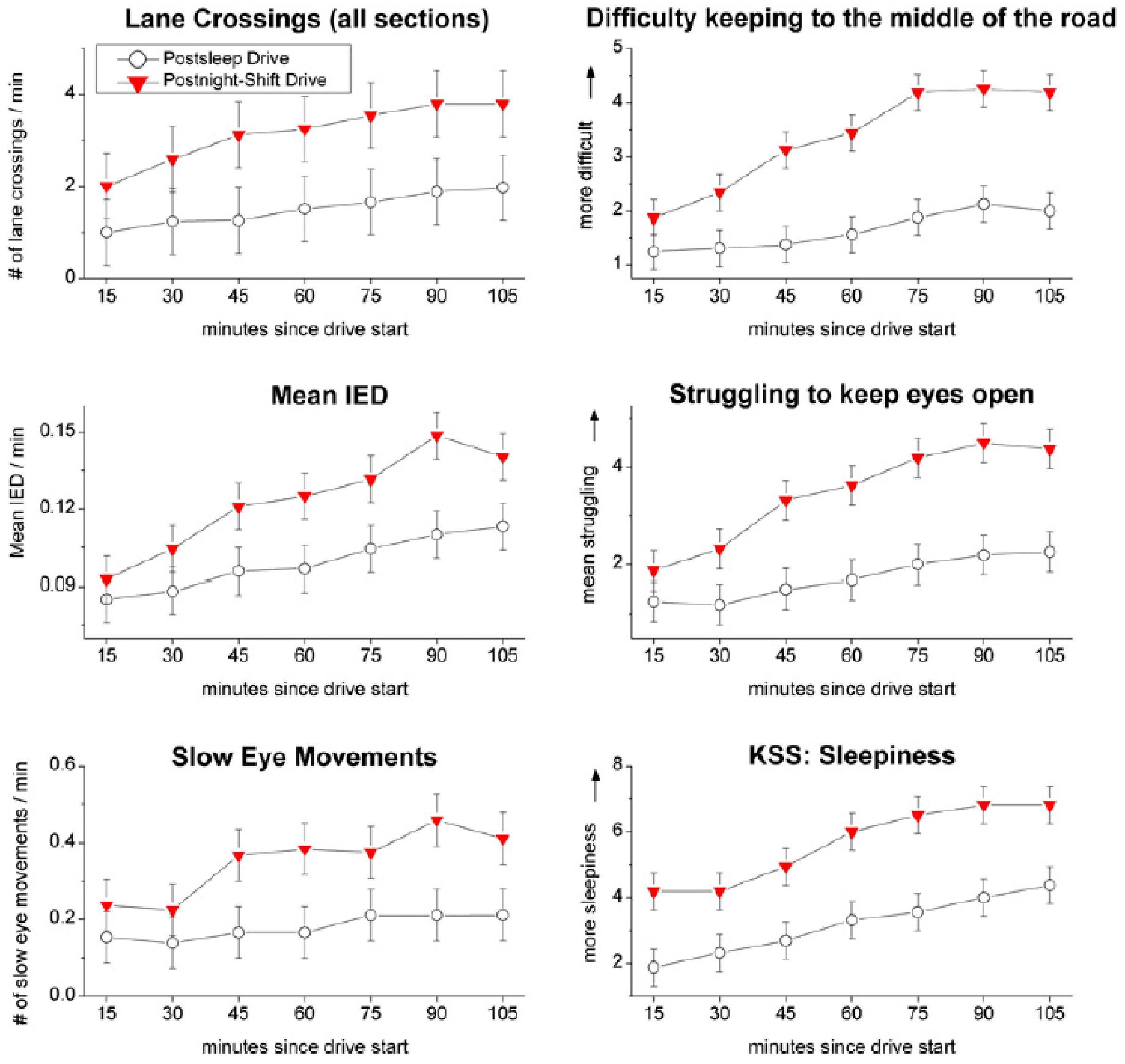
Switching off the system after the first alarm

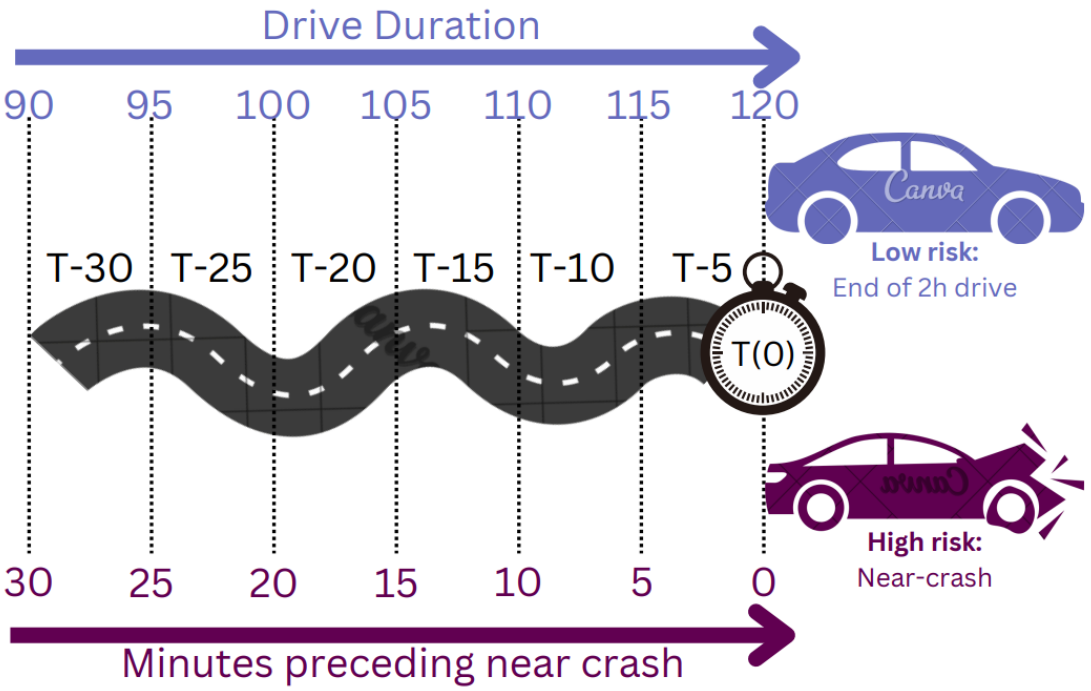
Naturalistic/track study of drowsy driving in shift workers

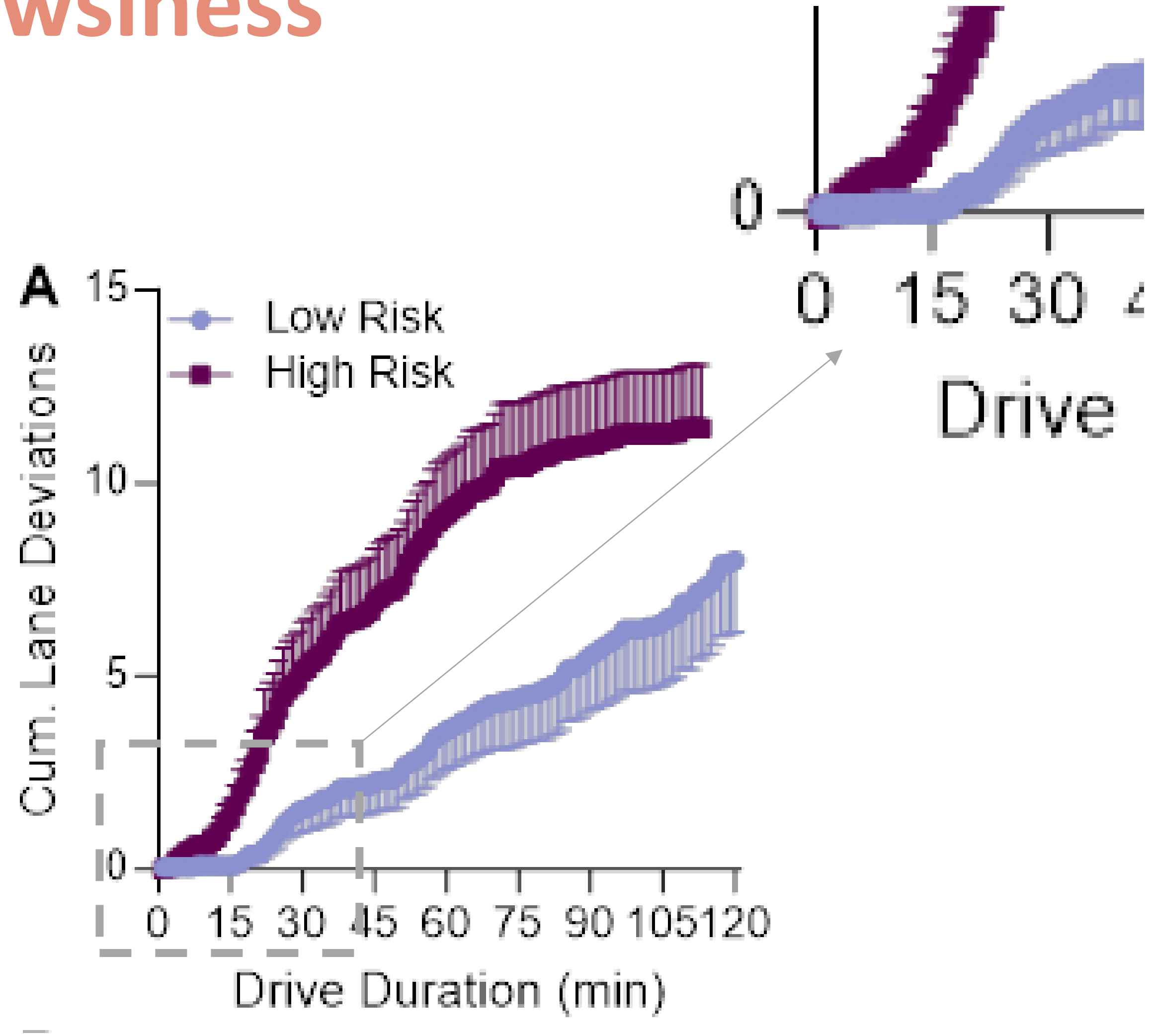
After a night on-shift (limited sleep), evidence of impairment was observed within the first 15minutes, and driving impairment, ocular metrics, and EEG microsleep all increased with drive duration.



Lee et al. 2016. PNAS

Impairment can be observed very early, especially for those most affected by drowsiness





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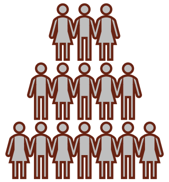
Time Delay KSS versus Driving Outcomes: A KSS of 8 is late in the drowsiness trajectory

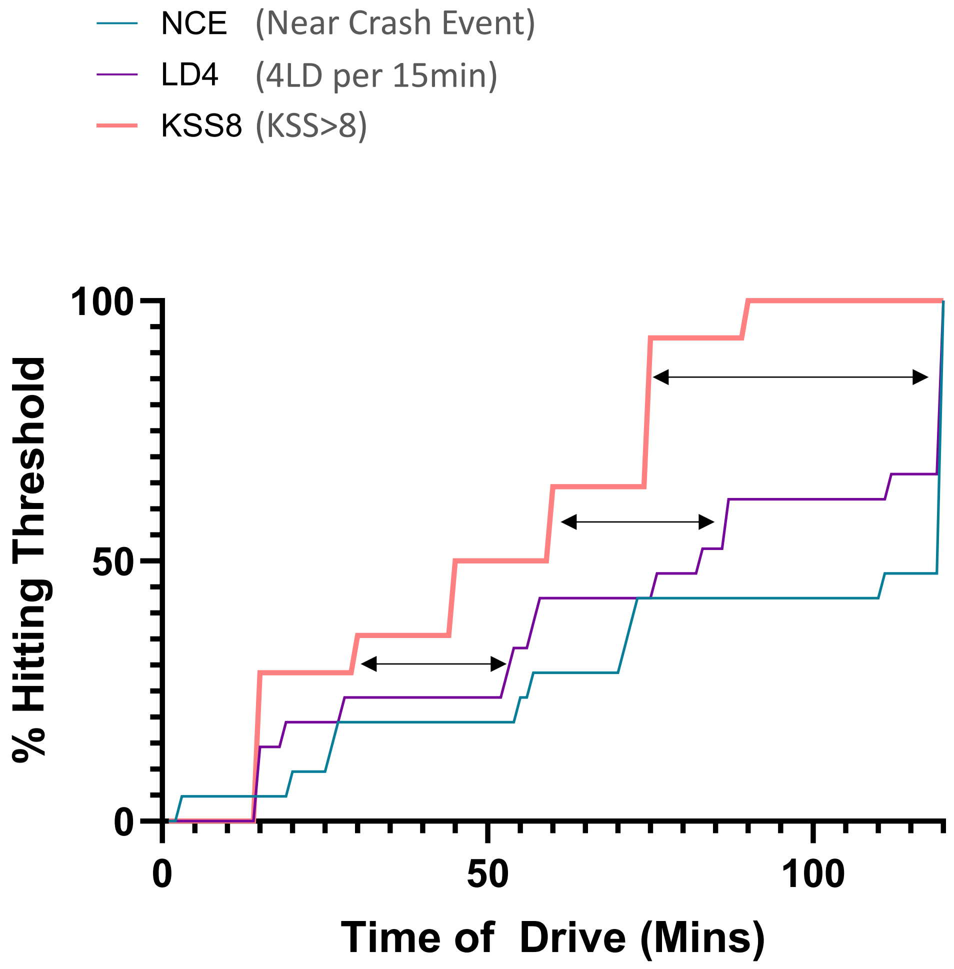


N=21 (12 m)

2520 mins driving (without sleep)

Closed loop track trial

- Subjective Sleepiness (KSS)
- Driving Impairment (Lane Departures)
- Critical Driving Impairment (Emergency Braking)
- ALARMS (Seeing Machines)



On average, KSS 8 is reached:

23mins before a near-crash

6min before a lane departure drowsiness index

PPV = > 80% for LD and NC

Data adapted from Manousakis et al. Evaluation, Validation and Comparison of Fatigued Driving Monitoring Systems Final Report. (https://www.aaa.asn.au/library/evaluation-validation-and-comparison-of-fatigued-driving-monitoring-technologies/, 2024).

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A KSS of 8 is late in the trajectory of drowsiness.

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Watling et al. Examining signs of driver sleepiness, usage of sleepiness countermeasures and the associations with sleepy driving behaviours and individual factors. Accident Analysis and Prevention (2015). 85, 22-29

Acknowledgments

COLLABORATORS AND RESEARCH SUPPORT

Project Leaders/Post Doctoral Fellows

Jessica Manousakis, Ph.D. *
Sophie Mason, Ph.D. *
Katy Jeppe, Ph.D.
Suzanne Ftouni, Ph.D.
Anna Cai, Ph.D.
Charmaine Diep, Ph.D.
Madelaine Sprajcer, Ph.D.
Michael Lee, Ph.D.
Jennifer Cori, Ph.D.

Collaborators

Mark Howard, M.D., Ph.D.
Jim Horne, Ph.D.
Sally Fergusson, Ph.D.
Anjam Naweed, Ph.D.
Charles Czeisler, Ph.D.
Bill Horrey, Ph.D.
Mike Lenne, Ph.D.
Shantha Rajaratnam, Ph.D.

All students and research support staff in the Division of Sleep Medicine (Brigham and Women's Hospital), the Monash Sleep and Circadian Laboratory, and the METEC Driver Training Facility.

All the participants who make the work possible.

FUNDING SUPPORT

VICTORIA State Government | Department of Transport and Planning

TAC Transport Accident Commission

Australian Government Australian Research Council

seeing machines

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* Contributed to data analysis contained here

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