Measuring driver fatigue based on eyelid opening level

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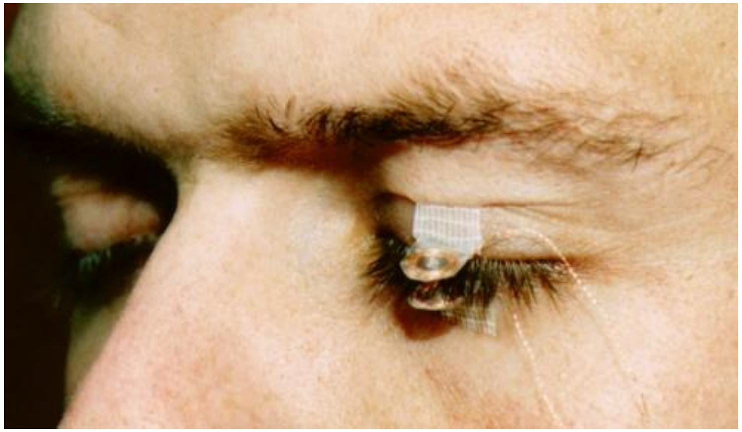
Background

- **In house development of algorithm for measuring driver fatigue in the 90‘s (Drowsiness index).**
  - Focus on detection of early fatigue
- **Due to instable camera based eye tracking at that time, development of own sensor solution.**



Previous Applications

Application in various research projects in the field of driving:

Fatigue in drivers with Parkinson‘s disease

Impact of drugs on driver state

Impact of telephoning on driver‘s state

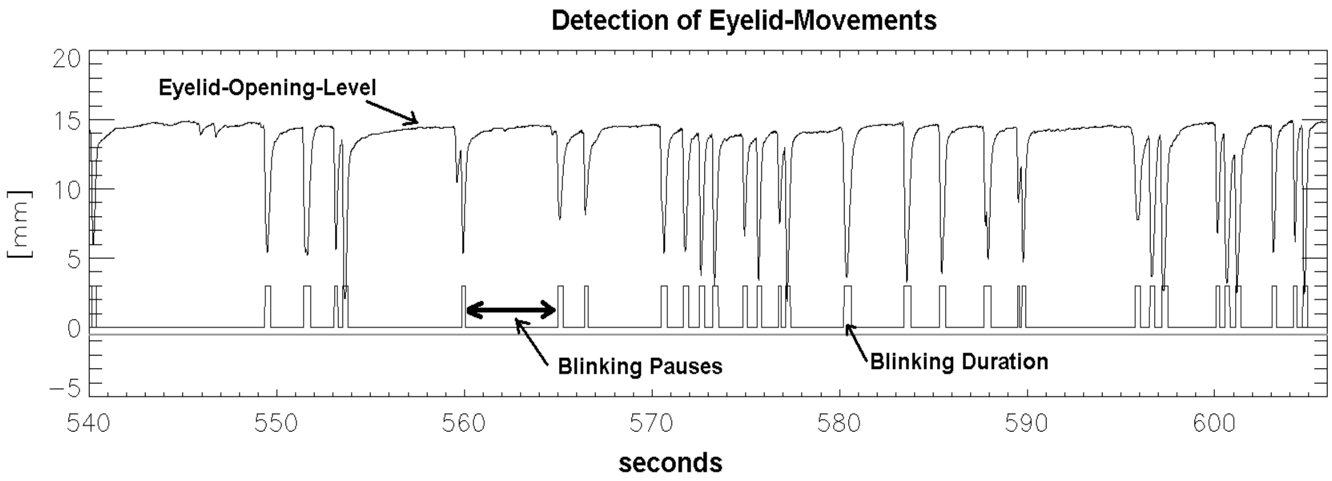
HAVEit

Validation of algorithm using lateral driving behaviour to assess driver‘s state

Impact of automation and distraction on driver‘s state

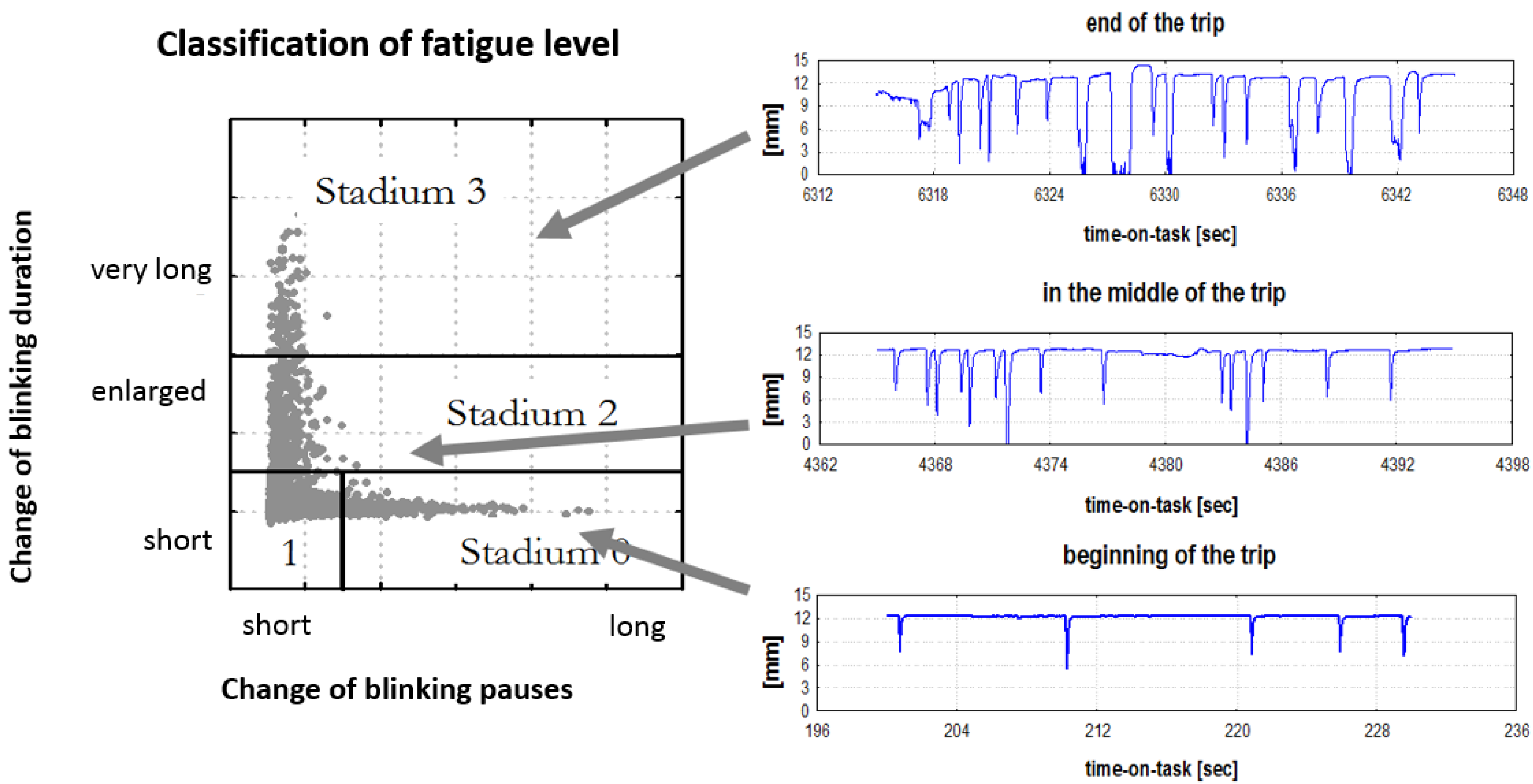
Drowsiness index – basic approach

1. **Identification of blinks in the eyelid-opening level.**
2. **Extraction of parameters for every blink.**



3. **Evaluation of every blink based on these parameters.**
   – Individual baseline information is needed for evaluation.
   – This information is collected in 5 minutes of alert driving.

Drowsiness index- Classification of blinks



Potential for new applications

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Growing need for online assessment of driver‘s state in the vehicle.

Continuous driver monitoring during highly automated driving

- Distraction
- Fatigue

Serial application requires different sensor technique:

– Sensors can no longer be attached to driver‘s lid.
– Contactless measurement of eye-lid opening level is needed.

Does the Drowsiness index work on data provided by a state-of-the-art camera-based eye tracking system?

Experimental set-up

Moving-based driving simulator

Nighttime simulation

Course:

- Start in urban environment
- 2 h of monotonous nighttime driving
- End in urban environment

Repeated rating of driver state

- Karolinska Sleepiness Scale
- Rating by driver every 10 min
- Expert rating every 5 min

Sample N=30

Data logging

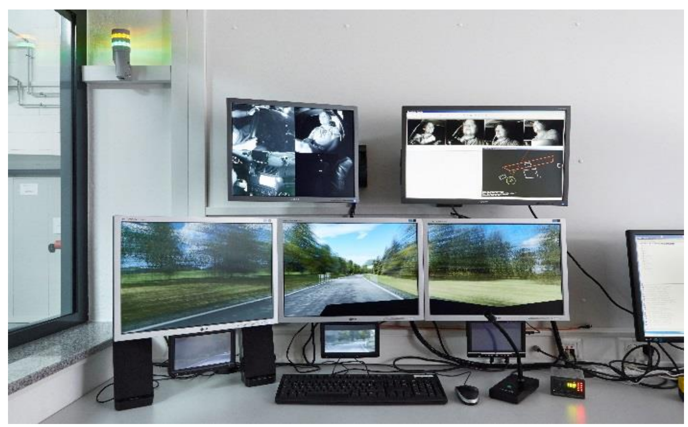
Annotation of symptoms of fatigue

Driving simulator

Expert-rating of driver state with KSS

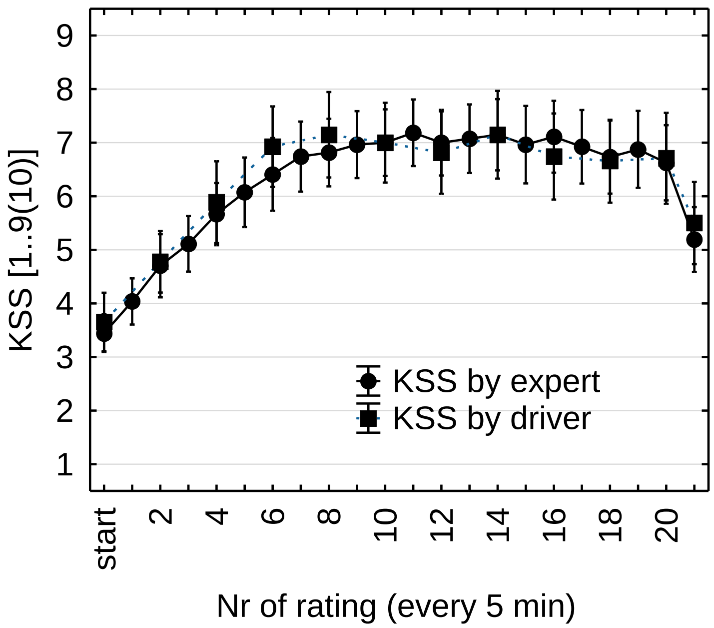
1	Äußerst wach
2	Sehr wach
3	Normal wach
4	Etwas wach
5	Weder wach noch müde
6	Etwas schläfrig
7	Schläfrig, ohne Mühe wach zu bleiben
8	Schläfrig, etwas Mühe wach zu bleiben
9	Sehr schläfrig, große Mühe wach zu bleiben

Eye tracking – SmartEye Pro 6.1

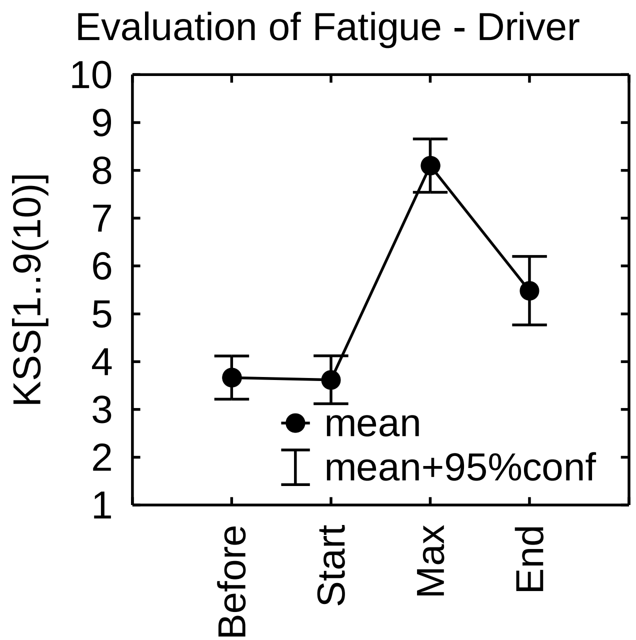


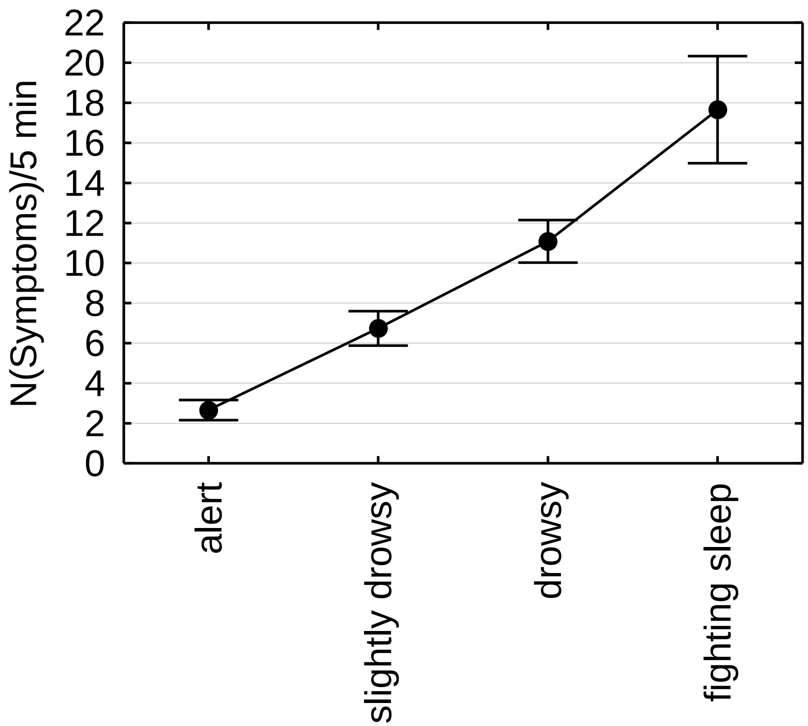
Data analysis

- **Segments with 5-minutes of driving time.**
- **Calculation of parameters for every segment.**
- **Categorization of segments based on following KSS-rating:**
  - Alert: KSS rating <=4
  - Slightly drowsy: KSS>=5 and KSS<=6
  - Drowsy: KSS>=7 and KSS<=8
  - Fighting Sleep: KSS>=9
- **For N=3 drivers, eye tracking was not stable enough to calculate eyelid-based indicators.**



Results – Induced change of state

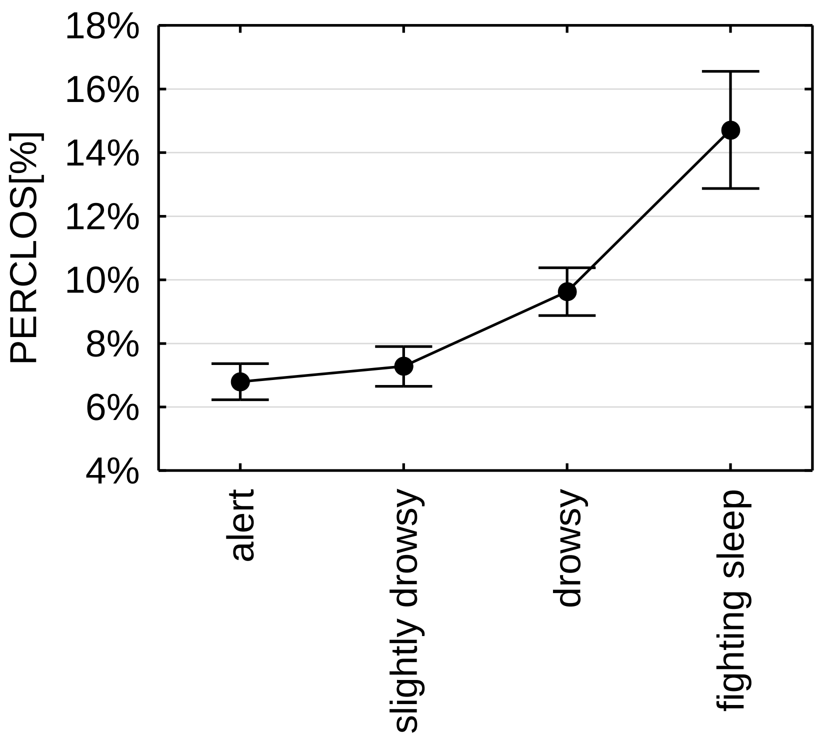




Growing fatigue during the drive. Entering urban environment results in reduced fatigue.

With growing fatigue, number of symptoms rises continuously ($F(3, 587)=78.098$, $p<0.001$).

Results – PERCLOS



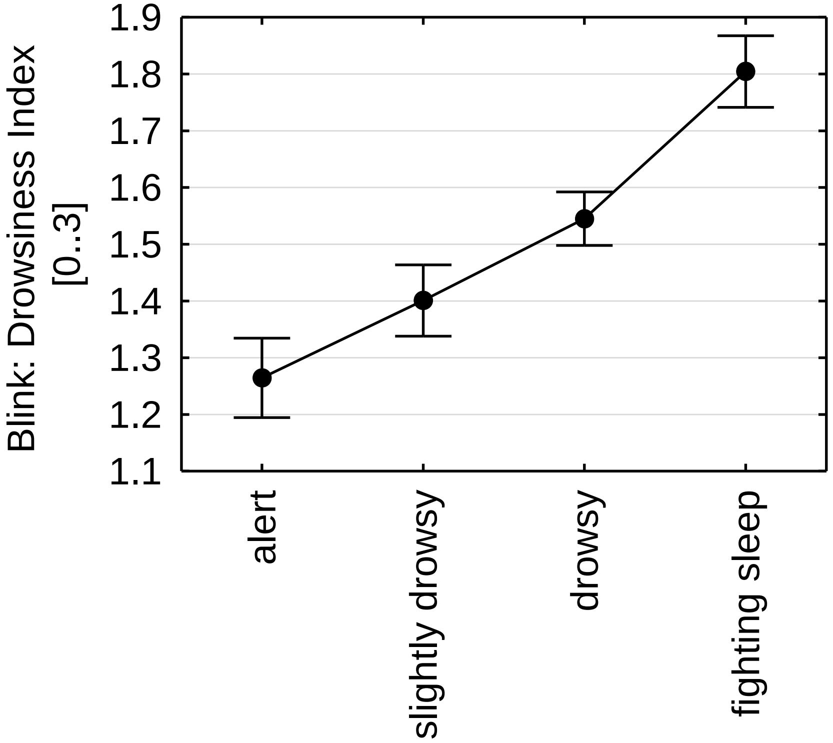
Post-Hoc-Tests

	alert	slightly drowsy	drowsy	fighting sleep
alert		1.0000	0.0003	0.0000
slightly drowsy	1.0000		0.0001	0.0000
drowsy	0.0003	0.0001		0.0000
fighting sleep	0.0000	0.0000	0.0000	

PERCLOS detects growing fatigue ($F(3, 534)=43.228$, $p<0.001$).

'Alert' & 'slightly drowsy' can't be differentiated.

Results – Drowsiness index



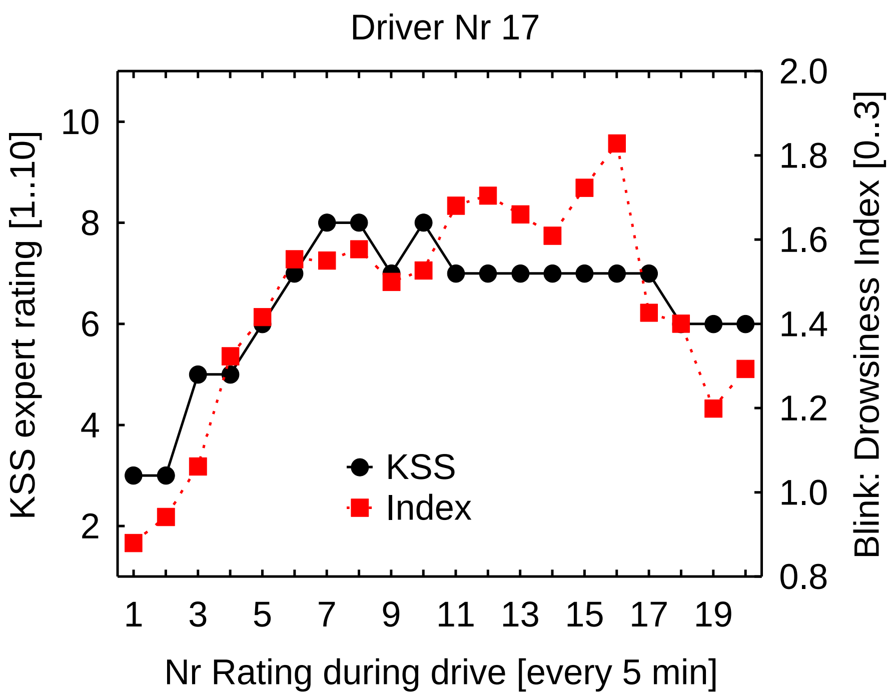
Post-Hoc-Tests

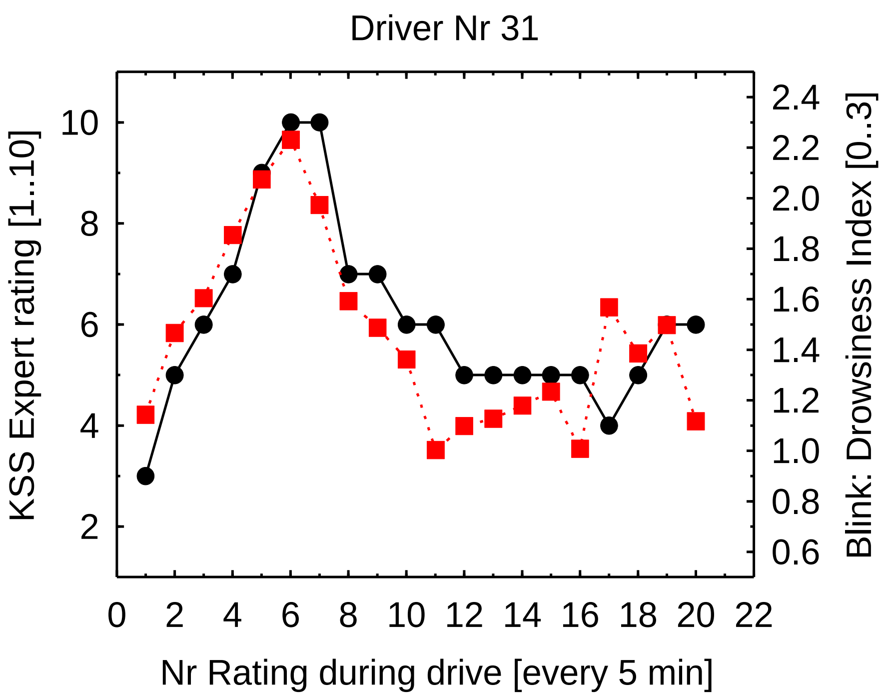
	alert	slightly drowsy	drowsy	fighting sleep
alert		0.0274	0.0000	0.0000
slightly drowsy	0.0274		0.0007	0.0000
drowsy	0.0000	0.0007		0.0000
fighting sleep	0.0000	0.0000	0.0000	

Index detects growing fatigue ($F(3, 534)=36.099$, $p<0.001$).

Already early stages of fatigue can be differentiated.

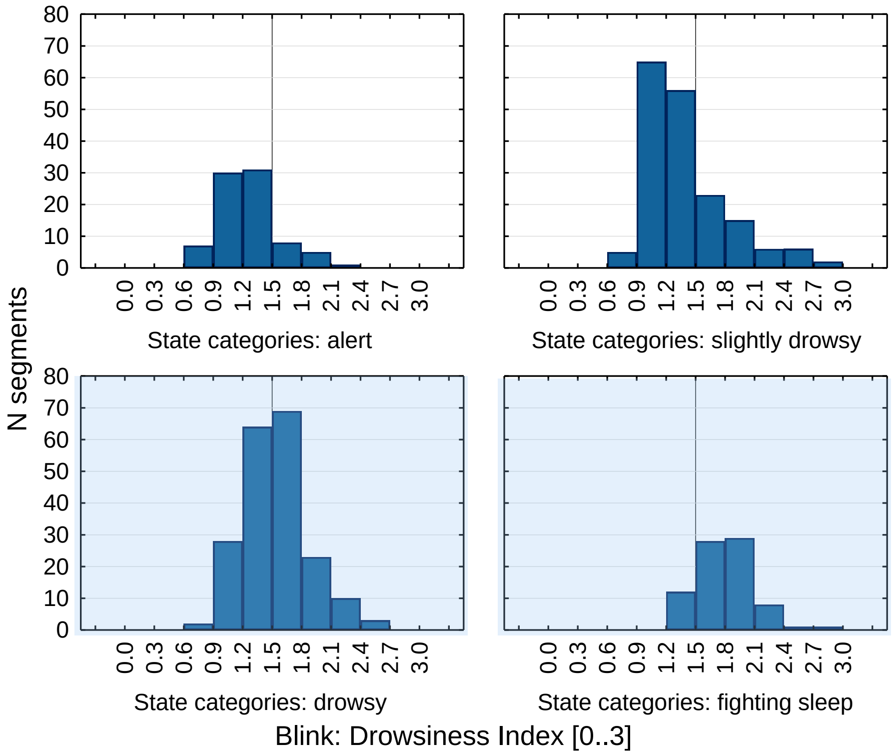
Results – Change over driving time





On individual level, there is a good correlation between KSS-rating and Drowsiness index.

Results – State categories



Index can be used to differentiate state categories:
Example: 2 categories (alert & fatigue)

Sensitivity (true-positive-rate) = 72.3%
Specificity (true-negative-rate) = 74.6%

		Index		**sum**
		alert	drowsy	
KSS	Alert	194	66	260
		36.06%	12.27%	48.33%
	drowsy	106	172	278
		19.70%	31.97%	51.67%
	Sum	300	238	538
		55.76%	44.24%	

Summary

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- Drowsiness index works on camera based eye tracking signal.
- With used hardware, eye tracking was too instable to calculate drowsiness index for about 10% of drivers.

- Drowsiness index measures fatigue in manual driving.
- Focus on detection of beginning fatigue.
- Here, it differentiates better than PERCLOS.

Next steps

Drowsiness index will be adapted to new challenges resulting from automation:

- Highly automated driving changes gaze behavior fundamentally:
  - Attention is not necessarily focused primarily on the road.
  - Drivers may want to use automation to relax (and close their eyes).

- These changes presumably affect indicators assessing driver‘s fatigue based on eyelid opening level.

Thank you

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Annotation of symptoms

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Annotated symptoms are based on ORD Behavior & Mannerism Checklist (Wiegand, McClafferty, McDonald & Hanowski, 2009)