The influence of alcohol and automation on drivers' visual behavior during test track driving

Session: 2.2 Understanding and Assessing Visual Attention

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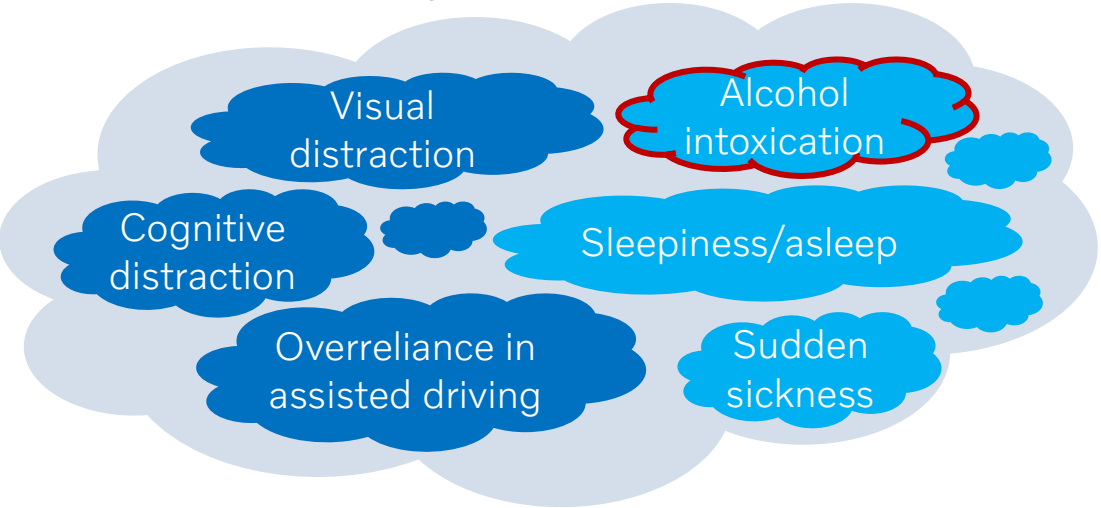
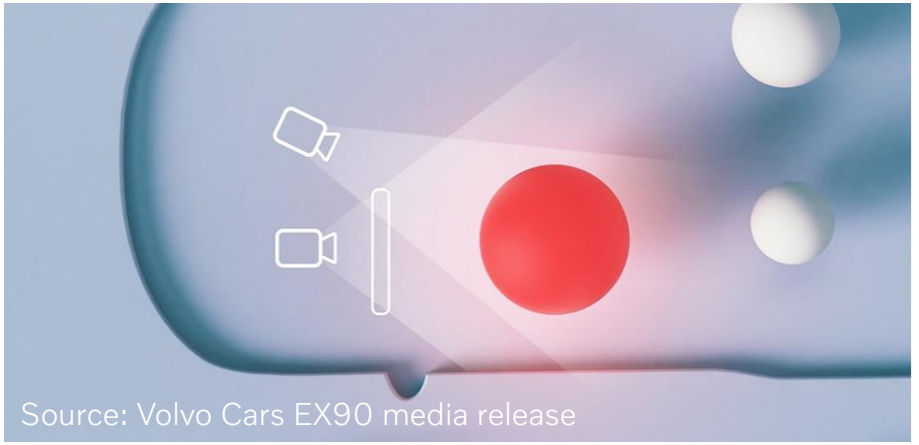
Driver Understanding System (a.k.a. Driver Monitoring System)

Enabler: Understand when the driver is not sufficiently engaged in the driving task (or not available for take-over)

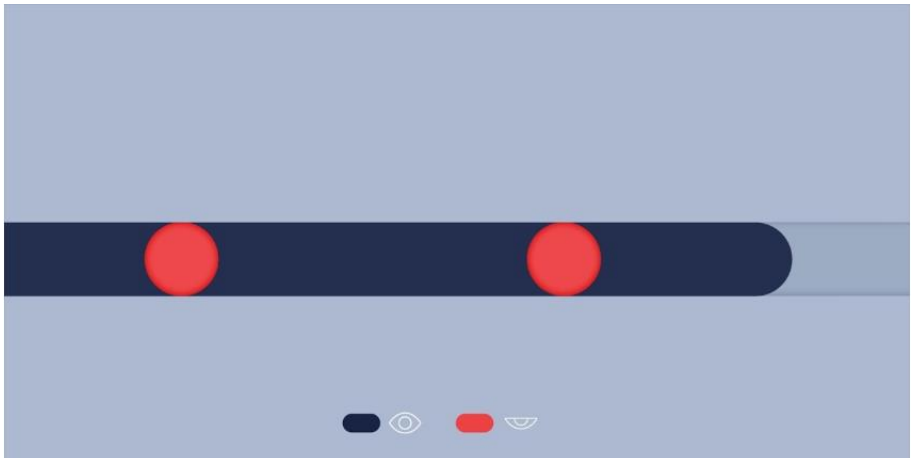
- Patterns deviating from normal routine driving
- Transient states & non-transient states

General driver state detection in all modes (manual, assisted, automated driving)





Source: Volvo Cars EX90 media release



Introduction – size of the problem

Driving under the influence (DUI), fatal crashes:

- **28%** of fatal crashes (19% alcohol only, 9% drugs w/wo alcohol) in Sweden (SNRA, 2020):
- Similar in other countries (NHTSA, 2017; Valen et al., 2019; WHO, 2007)

Driving under the influence (DUI), everyday driving:

- Routine roadside controls in Sweden - about **0.2 %** of the drivers are under the influence of drugs or alcohol above the legal limit of a Blood Alcohol Concentration (BAC) at 0.02% (Jakobsson et al., 2015).

Crash risk increases exponentially for **BAC > 0.1%**

How does alcohol impair driving?

In manual driving, there is a dose-dependent effect of BAC on driving performance:

- **Lane keeping** degrades (e.g., larger SDLP, more lane excursions).
- Longer **response times** to unexpected events
- Reduced **car-following** performance (variation in THW, delayed response times to LV speed changes)
- **Gaze concentration** to the forward roadway & fewer fixations to peripheral areas (Belt, 1969; Moskowitz & Robinson, 1988)
- Longer time to read road signs (Moskowitz and Ziedman ,1979)

Also, when the demand on the driver increases, the effects of alcohol intake become more pronounced (i.e. when driving is challenging or when multitasking, see Garrisson et al., 2021; Martin et al., 2013; Ogden & Moskowitz, 2004)

Research questions for the current study

The **effect of alcohol** on drivers' visual behavior:

1) When just driving
2) When performing a visual-manual NDRT in different driving modes (manual, assisted, AD)

→ Potential value of Driver Understanding system to detect alcohol intoxication

Methods - participants

The participants (N=32)

- Volvo Car employees (practical for insurance reasons), not working as test drivers
- Body Mass Index (BMI) between 19-30
- Regular sleeping pattern
- Mileage ≥ 5000 km/year
- Moderate alcohol intake at least twice a week

Analyzed participants:

- 17 male and 9 female. Total (n=26) in groups:
  - *manual (n=10),*
  - *Assisted, PA (n=8)*
  - *AD (n=8)*

Methods

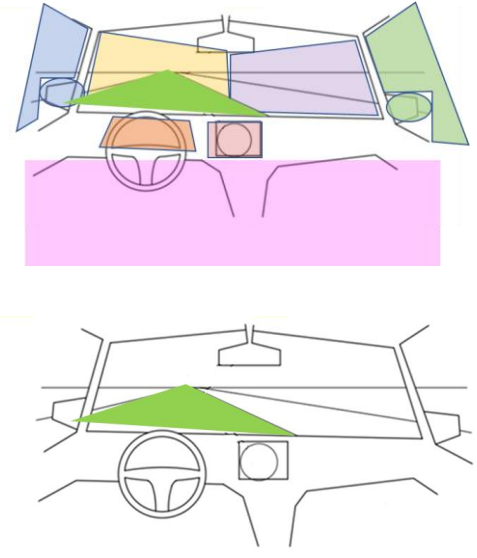
Test setup & timeline (minutes):

1. **Introduction (15)**
   - breath analyzer test
2. **Baseline drive (30)**
   - Manual (5)
   - Man, Assisted, or AD (25)
     - NDRT using the CSD (first 10)
       - Manually tune the radio
       - Manually dial your own phone
       - Set the car temperature
3. **Drinking session (60)**
   - Drinking (45) – Target BAC 0.1%
   - Wait (15)
   - Breath analyzer test
4. **Intoxicated drive (up to 65)**
   - Manual (5)
   - Man, Assisted, or AD (up to 60)
     - NDRT using the CSD (first 10)
5. **Post-drive (30)**
   - Breath analyzer test

Methods – segments for manual annotations

Table 1: *Overview of selected segments included in the analysis from the Baseline (BL) and the intoxicated (IN) drive, including selected driving mode in Manual (M), Assisted (A), or AD.*

Drive	Mode	Segment	NDRT	Duration	Lap
BL	M	S1	-	30 s	1
	M, A, or AD	S2	Radio	12 – 50 s	2
	M, A, or AD	S3	Dialing	13 – 30 s	2
	M, A, or AD	S4	Temperature	5 – 23 s	3
IN	M	S1	-	30 s	1
	M, A, or AD	S2	Radio	13 – 54 s	2
	M, A, or AD	S3	Dialing	11 – 114 s	2
	M, A, or AD	S4	Temperature	6 – 32 s	3



Coded AOI →
Eyes on/off road
timeseries per segment

Methods – metrics

All driving segments:

- **PRC** (percent road center) - percentage of time with eyes on path
- **GF-off** (off-path glance frequency) – number of off-path glances

Segments with visual-manual NDRT:

- **TGT** (total glance time) defined as the sum of all off-path glance durations [s]
- **GD>2s** the percentage of off-path glances longer than 2 seconds [%]
- **MaxGD** the maximum off-path glance duration [s]

Methods – statistical analysis

Non-parametric tests

- Comparing the baseline and the intoxicated drives (within subjects)[1]
- Comparing groups (between subjects) [2]
- Adjustments for multiple testing [3]
- Estimated effect size

1) Wilcoxon signed rank test

2) Kruskal-Wallis + Mann-Whitney U

3) Benjamini-Hochberg false discovery rate + Bonferroni for pos-hoc tests

Results: The effect of alcohol when just driving

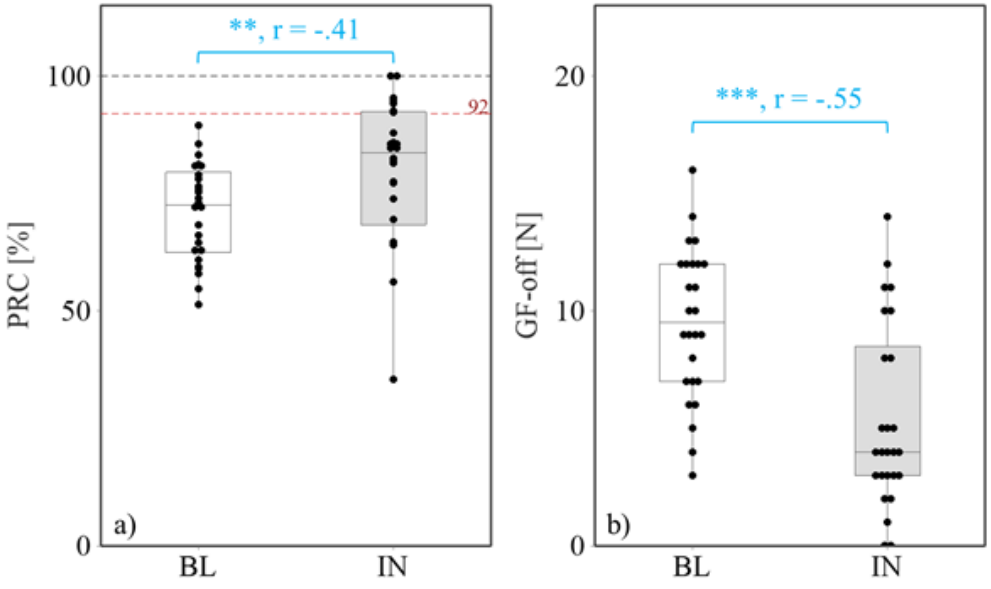


Figure 1: Boxplots of (a) PRC and (b) off-path glance frequency including individual markers for segment S1 (30 seconds, no tasks, manual mode). Each panel includes the repeated drives (BL = sober baseline, IN = intoxicated drive).

Segment S1: 30 seconds, manual driving, no tasks

Intoxication resulted in

- Increased PRC
- Gaze concentration to the road in 27% (n=7/26) participants.
- Fewer off-path glances
- Moderate to strong effect size

Results: The effect of alcohol and mode when doing NDRT

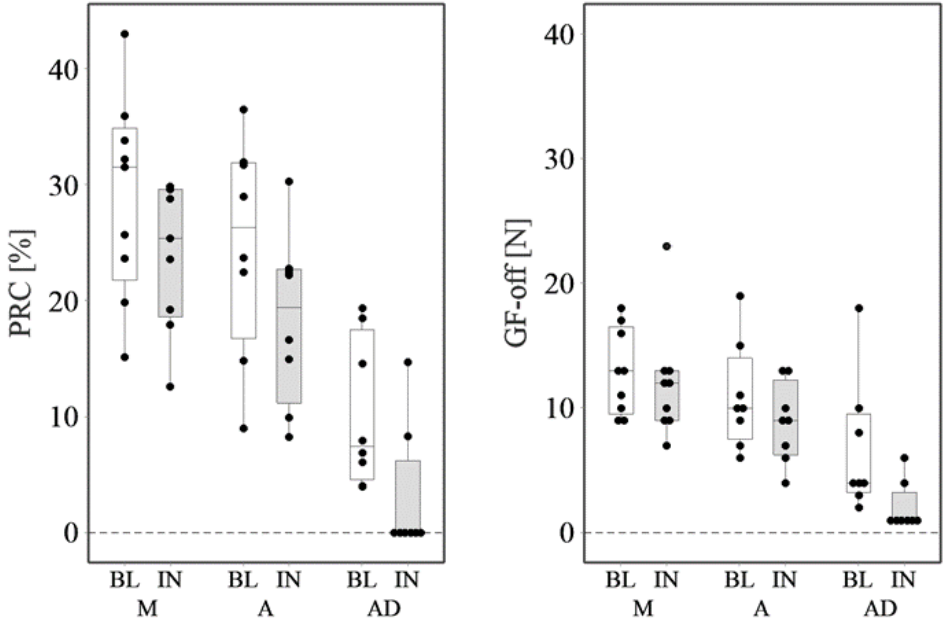


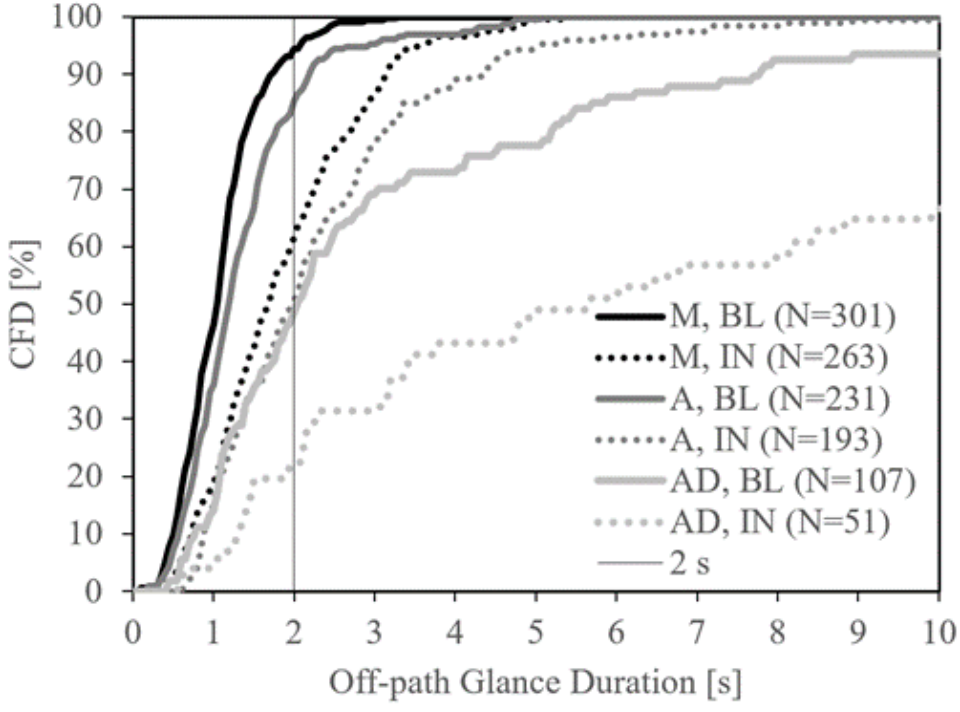
Figure: *Boxplots of (a) PRC and (b) off-path glance frequency including individual markers for segment S2 (radio task). Each panel includes the repeated drives (BL = sober baseline, IN = intoxicated drive).*

Intoxication resulted in:

- lower PRC
- fewer off-path glances

.. in all modes.

Results: The effect of alcohol on off path glance durations (NDRT)



→ Longer off-path glance durations in all modes

Manual (M), Assisted (A), Automated drive (AD)
Baseline (BL), Intoxicated (IN) drive

Results: The effect of alcohol

Table: *Overview of the results showing the comparisons that were statistically significant at 0.05 (*), 0.01(**), and 0.001 (***) level, and indicating the effect sizes that were either moderate (Δ, r = 0.31-0.49) or high (ΔΔ, r ≥ 0.50).*

Metric		Task	Manual	Assisted	AD
PRC	S1	-	** Δ		
[%]	S2	Radio	Δ	ΔΔ	** ΔΔ
	S3	Dial.	Δ	Δ	** ΔΔ
	S4	Temp.			
GF-off	S1	-	*** ΔΔ		
[N]	S2	Radio		Δ	* Δ
	S3	Dial.		Δ	* Δ
	S4	Temp.			
TGT	S2	Radio	**ΔΔ	*ΔΔ	ΔΔ
[s]	S3	Dial.	*ΔΔ	Δ	**ΔΔ
	S4	Temp.	Δ	Δ	Δ
GD>2s	S2	Radio	**ΔΔ	*ΔΔ	**ΔΔ
[%]	S3	Dial.	**ΔΔ	ΔΔ	Δ
	S4	Temp.		* Δ	
MaxGD	S2	Radio	**ΔΔ	**ΔΔ	**ΔΔ
[s]	S3	Dial.	**ΔΔ	*ΔΔ	**ΔΔ
	S4	Temp.	Δ	**ΔΔ	Δ

- The effect of intoxication was most evident during visually demanding tasks (i.e., radio & dialing compared to temperature task).
- Largest effect size for long glance metrics

Conclusions

Drivers glance behavior was influenced by alcohol intoxication in all driving modes.

The effect of intoxication:

- Higher PRC, leading to gaze concentration 27% of the participants when just driving in manual mode.
- Lower PRC, fewer and longer off-path glances, and longer total glance time off-path during visual time-sharing.
- As found in previous studies, the effect of intoxication was most evident when the demand on the driver was high, i.e. during visually demanding tasks.

Discussion/implication & Future work

A more general approach toward detection:

- Gaze concentration – ideally 60 second moving window over several minutes of driving instead of a fixed 30 second window
- Moving towards buffer metrics including ≥ 8 minutes of driving data or more as in Lee et al. (2010) - similar to multi-distraction detection algo (Victor & Larsson, 2004).
- Identify extreme off-path glances (number of extreme glances per hour)
- Limitations in AD mode when drivers decide to almost only look away from the road

Future work:

- Continuously recorded eye tracker data from complete drives
- Refined gaze concentration metrics, blink metrics etc.

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Thank you!

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