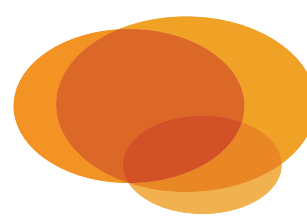


Prerequisites for Adaptive ADAS: Learning from Fatal Crashes in Sweden

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INTRODUCTION

Driver monitoring systems (DMS) have improved considerably in later years, with ever better detection of distraction, and drowsiness (Halin *et al.* 2021), and even alcohol intoxication (Zemblys *et al.* 2024). These systems could be used to adapt intervention of ADAS. If a driver shows signs of impairment, systems could intervene earlier or more forcefully than they would for an alert driver.

The primary aim of the current study was to map scenarios in fatal crashes caused by impaired drivers – to better understand how to intervene close to the crash. The secondary aim was to analyse the possible effects of adaptive interventions.

METHOD

Data: A total of 2708 in-depth studies of fatal crashes collected by the Swedish Transport Administration during the years 2010–2023.

Crashes were classified into two primary patterns of driver degradation: **underperformance** – late or absent maneuvering due to missed hazard detection, itself stemming from distraction, sleepiness, or in some cases visual obstruction – and **overconfidence** – often as excessive speed with respect to present conditions, resulting in loss of vehicle control.

Each case was coded by the author against a structured scheme covering error type (omission or commission), impairment temporality (transient or continuous), relevant ADAS type (lateral, longitudinal or both), and an

RESULTS

Original database coded sleepiness or distraction scenarios as the same type, so the 172 cases in this category were analysed further to assign one primary label. In the revised assignment 45% were interpreted to be related to distraction, 36% to sleepiness, 18% were unclear and the 2% remaining cases were related to substances or illness.

Crashes follow unrecoverable lane deviations/departures or longitudinal mismatches (late braking, early acceleration) which in turn depend on ceased maneuvering due to **unresponsive** drivers (sleep, substance, illness), **missed detections** (distraction, inattention) or **violations** (deliberate rule breaking).

DISCUSSION

The most common suspected driver errors encoded were missed detections or early or late actions, thus mainly errors of omission (Reason 1990) and underperformance. These were often related to distraction, sleepiness, and in some cases alcohol use. These should be contrasted with overconfidence, and errors of commission, such as wrong selection of action or sticking to actions unsuitable to current conditions.

Non-transient impairments such as sleepiness or intoxication show elusive and subtle signs, such as degraded performance, and large intra-individual variation makes them difficult to detect with confidence. Given the detection uncertainty for both driver impairment and conflict detection, intervention adaptation is best confined to situations with large time margins, such as rear-end conflicts, where early and modest deceleration (ACC-style) may be applied with little harm.

CONCLUSIONS

Before DMS output is allowed to modify ADAS behaviour, the benefit-risk balance, failure modes, false-positive rates and driver behavioural adaptation all need to be assessed. Many of the crashes analysed were in principle preventable by ADAS. Still, many involved vehicles were not equipped with ADAS, meaning a potential first step would be to ensure full fleet cover of basic ADAS functions, such as AEB/LKA.

Selection criteria:

- person: driver
- Vehicle year: 2000 or newer (exclude oldest vehicles)
- Accident types – all except wildlife accidents
- Weather conditions: no precipitation (good visibility)
- Road condition dry or moist roadway (no unfavourable road conditions)
- “suspicion of fatigue-/distraction-related action” OR “alcohol” OR “drugs” = “Yes”

373 cases were selected for analysis, a full review of 224 were completed due to time/budget cap.

assessment of whether timely detection of impaired driver capability was considered feasible.

Note that exact event sequences can't be gathered from post-crash evidence. Driver degradation assessment relies on circumstantial evidence, which may confirm stereotypical patterns – the drowsy driver drifting off the road, for instance. Medical evidence provide stronger grounds for classification in substance related cases, but behavioural inference is necessary throughout.

This uncertainty is not only a methodological inconvenience; it *mirrors the uncertainty faced by real-time monitoring attempting to classify driver state from indirect or proxy signals*.

This generally maps to ADAS as follows: longitudinal continuous support: ACC, longitudinal emergency intervention: AEB, lateral continuous support: TA, lateral intermittent support LKA/ELK.

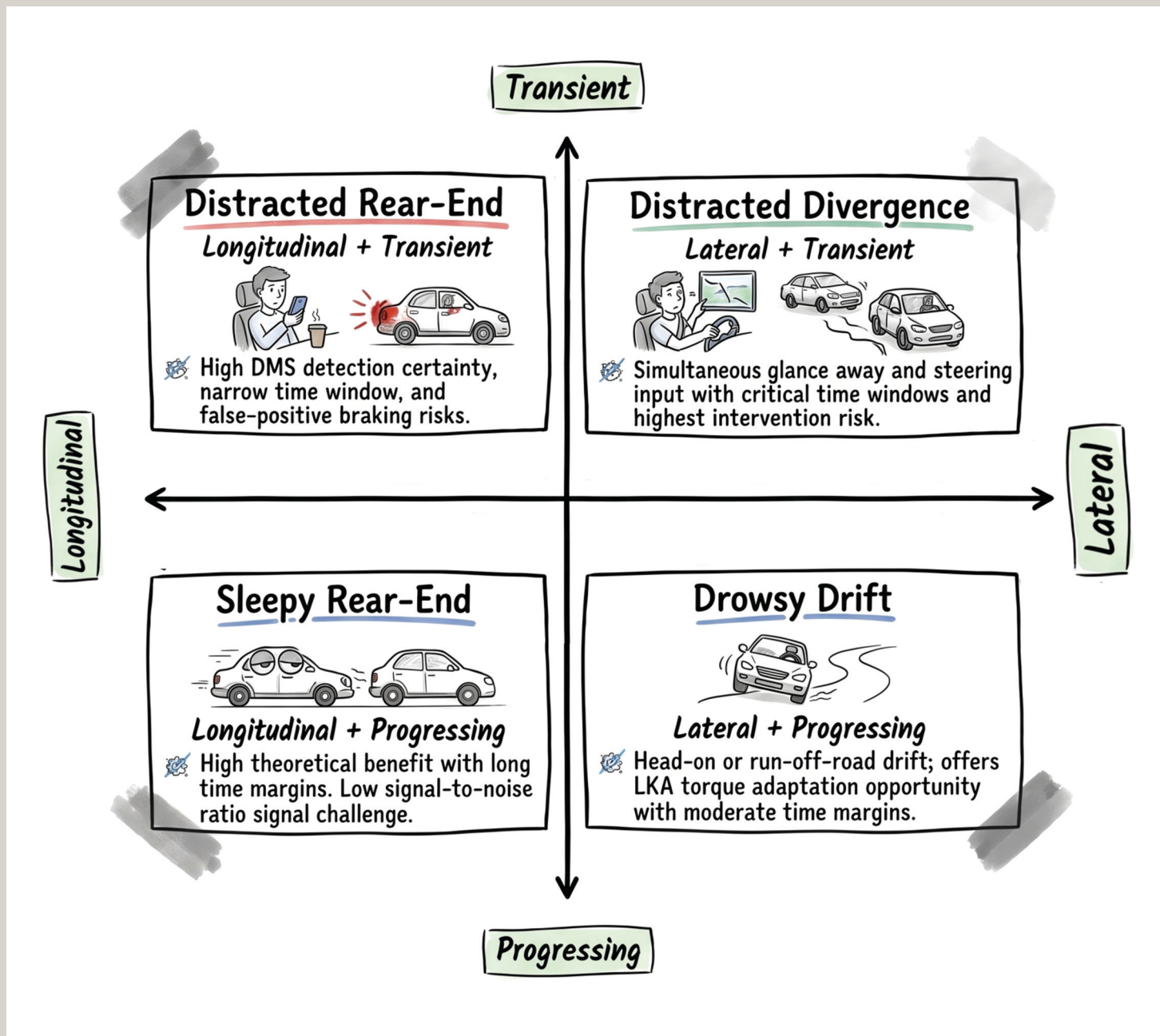
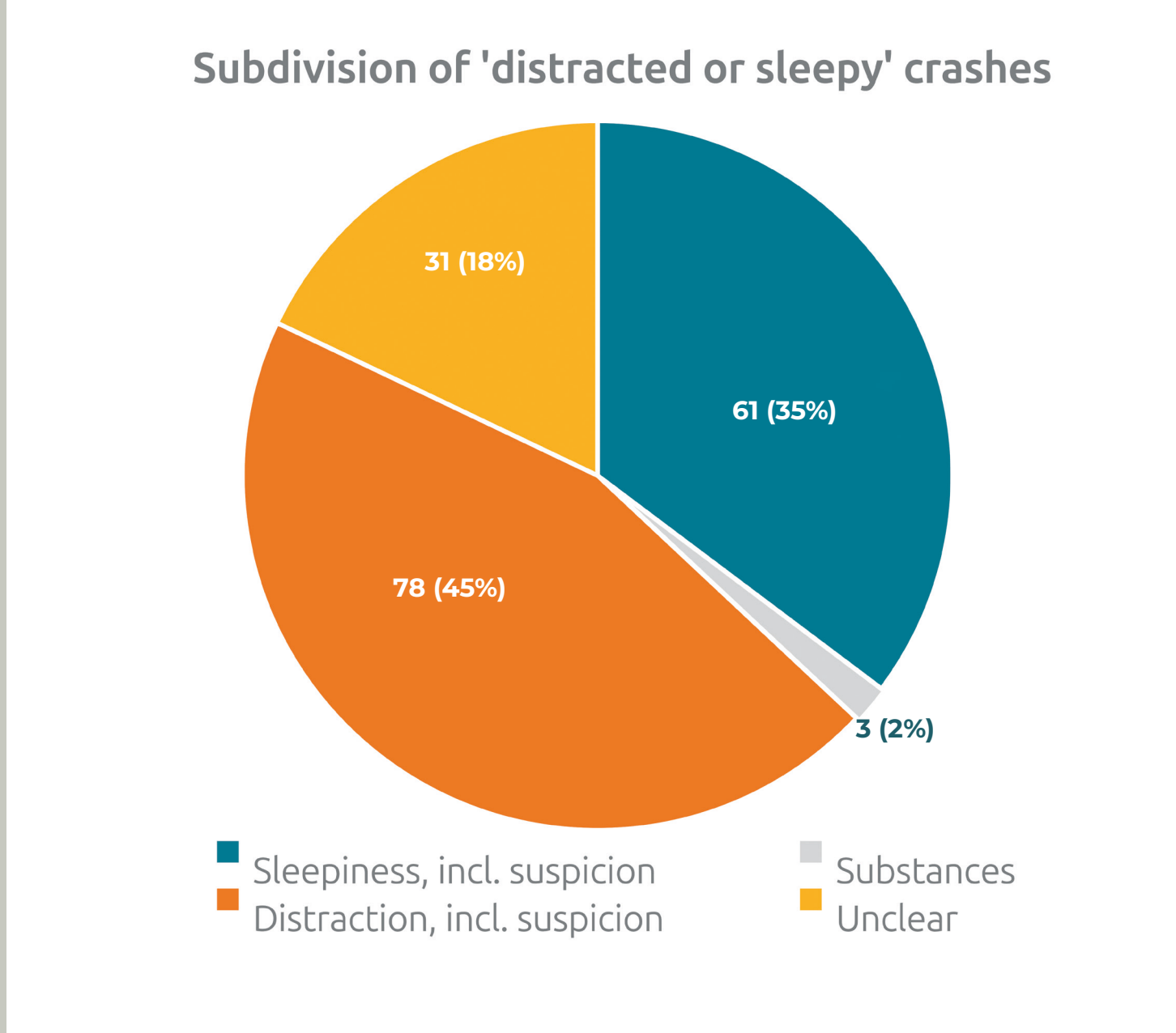
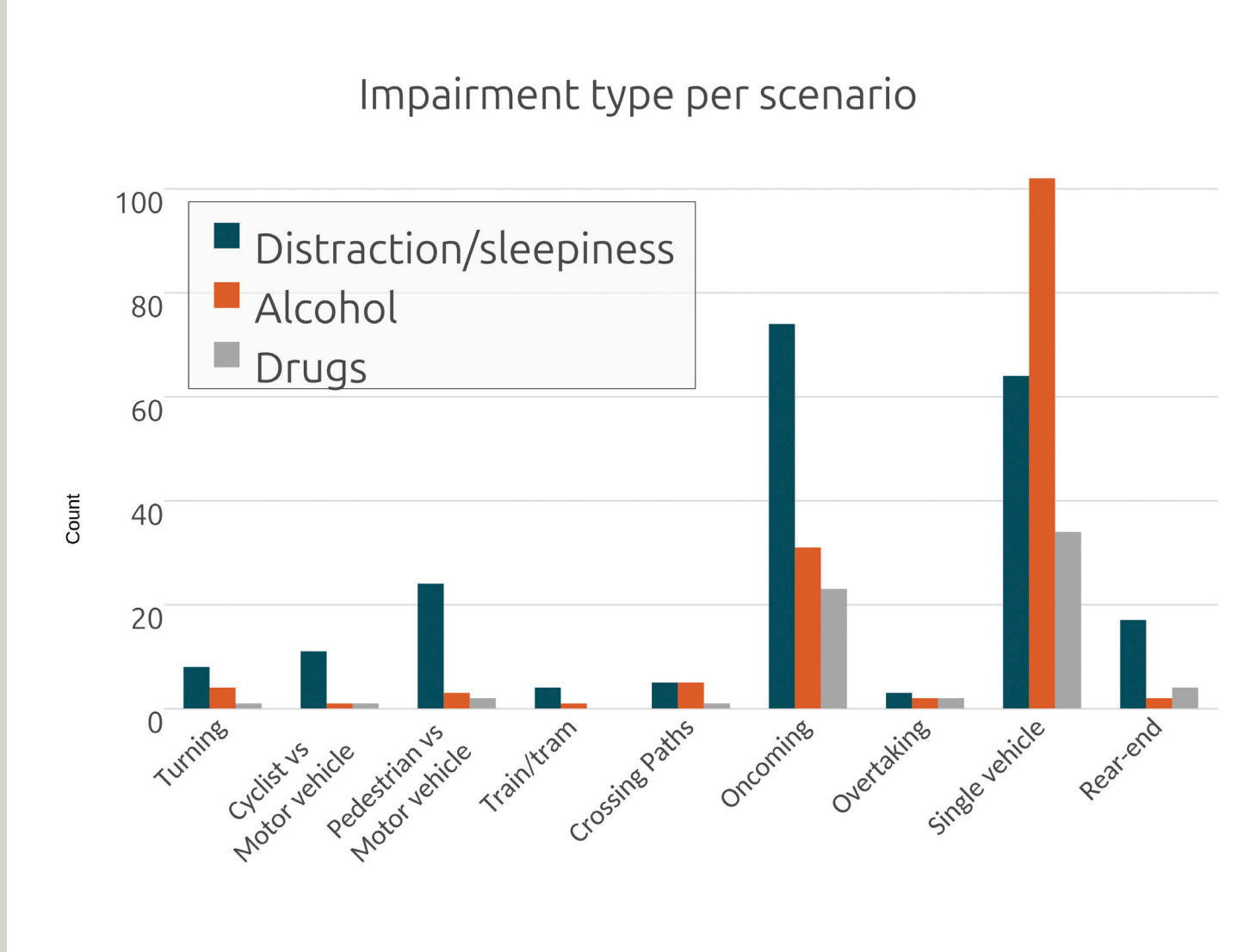
Most crashes were head-on or single vehicle, thus with lateral origin, and the most common impairments are alcohol and sleepiness. Head-on crashes had a higher share of suspected sleepiness while single vehicle crashes had a higher share of confirmed alcohol and drugs.

Note that risk levels for intoxicated drivers at night rise steeply compared to daytime (Forsman 2013), indicating a strong interaction effect between intoxication and circadian sleep drive.

Another adaptation that is, to some extent, defensible from the behavioural data is increased LKA steering torque when impairment is detected, keeping the vehicle in lane until an emergency stop can be performed.

While gaze direction is by no means a complete proxy for attention, some transient states such as visual inattention can be detected quickly. The difficulty lies in combining this uncertain driver state estimate with the uncertainty in conflict detection. For late-stage AEB, and even more for evasive steering, where false activations may become costlier, the compounded uncertainty makes threshold adaptation difficult to justify.

Still, since even modest gains in intervention timing could matter considerably for crash mitigation outcomes, weighing them against the cost of false activations is necessary, and counterfactual simulation starting from a selection of cases from this study could be a next step.



Data:
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Crashes were classified into two primary patterns of driver degradation:
Underperformance
Late or absent maneuvering due to missed hazard detection, itself stemming from distraction, sleepiness, or in some cases visual obstruction.
Overconfidence
Often as excessive speed with respect to present conditions, resulting in loss of vehicle control.

Each case was coded by the author against a structured scheme covering:
Error type
Omission or commission.
Impairment temporality
Transient or continuous.
Relevant ADAS type
Lateral, longitudinal or both.
Feasibility of timely detection
Whether timely detection of impaired driver capability was considered feasible.

ACKNOWLEDGEMENTS

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The premise for this project is that the driver bears primary responsibility for operating the vehicle, whilst collision avoidance systems and driver assistance systems function as complementary protective mechanisms to reduce the risk for or consequences of accidents.

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