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VEHICLE AND TRAFFIC SAFETY CENTRE AT CHALMERS

Analysis of the role of inattention in road crashes based on naturalistic on-board safety monitoring data

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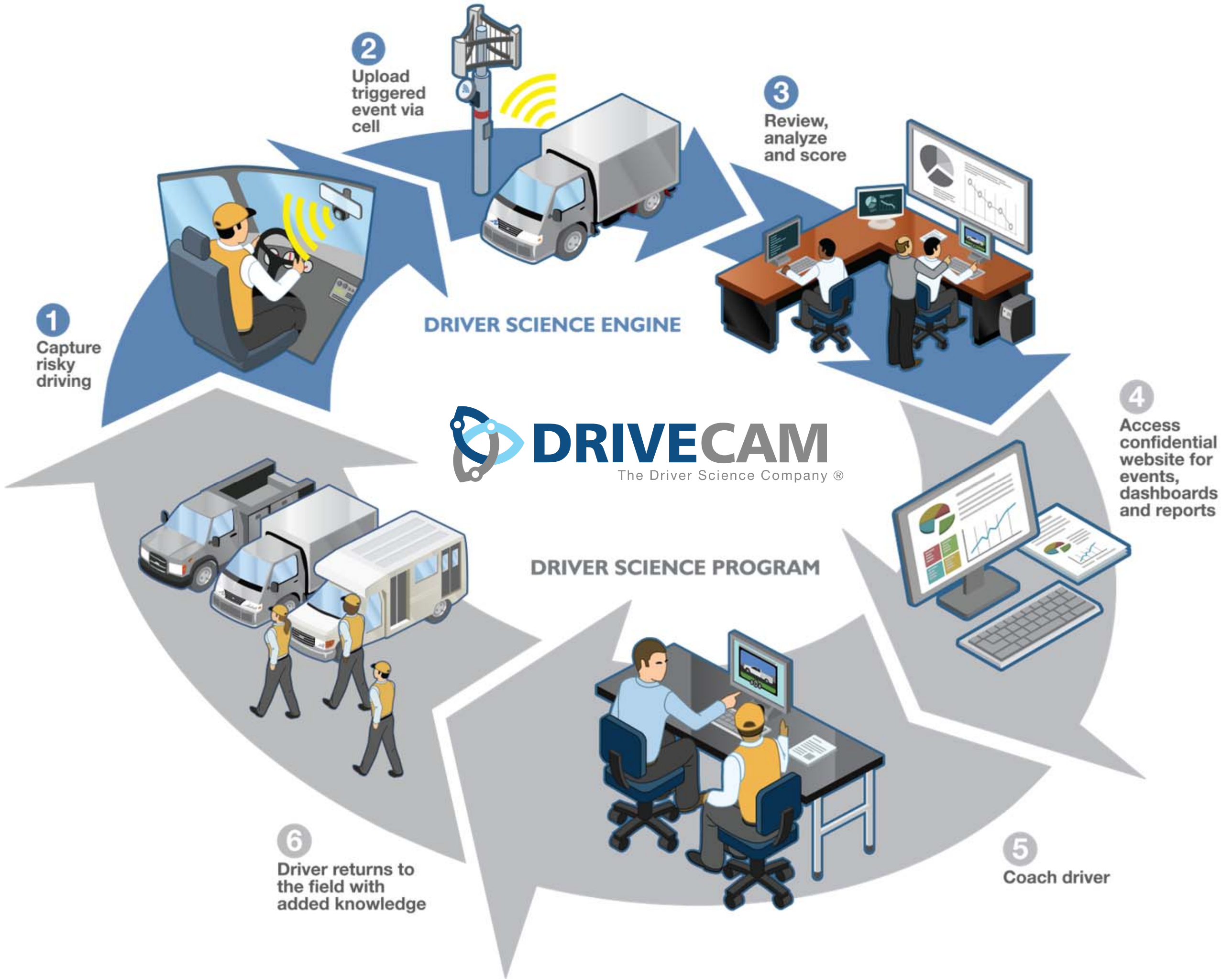
Background

- Driver inattention known as a leading crash-contributing factor
- But *how* does inattention contribute to road crashes?
- Traditional on-site crash investigation (in itself) of little help
- Naturalistic driving (ND) studies provide a more complete picture of pre-crash events, in particular driver inattention
  - However, based on continuous data collection, have generated few crashes (~20-70)
  - Have so far mainly focused on risk estimation based on crashes, near-crashes and incidents
- Alternative: Analyse naturalistic crashes collected by means of event-triggered on-board safety monitoring systems used in commercial safety management programs

The DriveCam risk management program



DriveCam OBSM crash data

- Video...
- Identified through kinematic triggers and manual review
- 8s before and 4s after the trigger point
- Forward and driver video, audio, accelerations (4Hz), global position, speed (1Hz)
- Available in large quantities (+120 000 DriveCam-equipped vehicles)
- Enables focusing the analysis on specific crash types -> aggregation of many crashes to elecit common patterns of contributing factors

Objectives

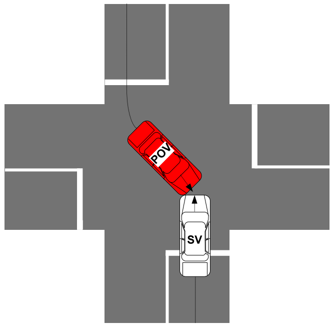
- Based on OBSM crash data, understand to what extent, and how, driver inattention contributes to crash avoidance failures for two crash types:
  - Rear-end crashes with the OBSM-equipped vehicle striking
  - Crossing path crashes in intersections where the monitored driver intended to proceed straight through the intersection and a vehicle encroached into the drivers path
- Specifically, what is the contributing role of
  - …inattention vs. other contributing factors
  - …different *forms* of inattention, in particular driver distraction
  - …driver distraction involving the diversion of gaze vs. non-visual, purely cognitive, distraction.
- Focus on factors **directly contributing to the avoidance failure** – more upstream factors not yet addressed

Methodology

Crash scenarios

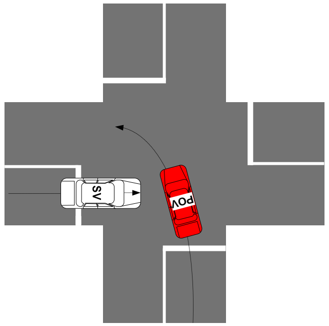
- Rear-end crashes
  - 70 crashes
  - Occurred between October 4, 2011 and March 1, 2012.
  - 53 in the U.S. and 17 in Africa (mainly South Africa)
  - Subject vehicle type: 26 passenger cars,16 buses cases, 28 trucks
- Intersection crashes
  - 63 crashes
  - Occurred between October 26, 2011 and February 28, 2012.
  - 58 in the U.S. and 5 in Africa
  - Subject vehicle type: 32 passenger cars, 19 buses and 12 trucks
  - Distribution of intersection scenario sub-types:

Left Turn Across Path / Opposite Direction (LTAP/OD)



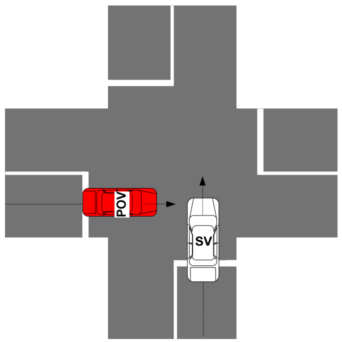
N = 29

Left Turn Across Path / Lateral Direction (LTAP/LD)



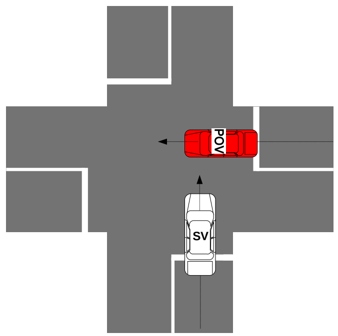
N = 3

Straight Crossing Path / Left (SCP/L)



N = 9

Straight Crossing Path / Right (SCP/R)

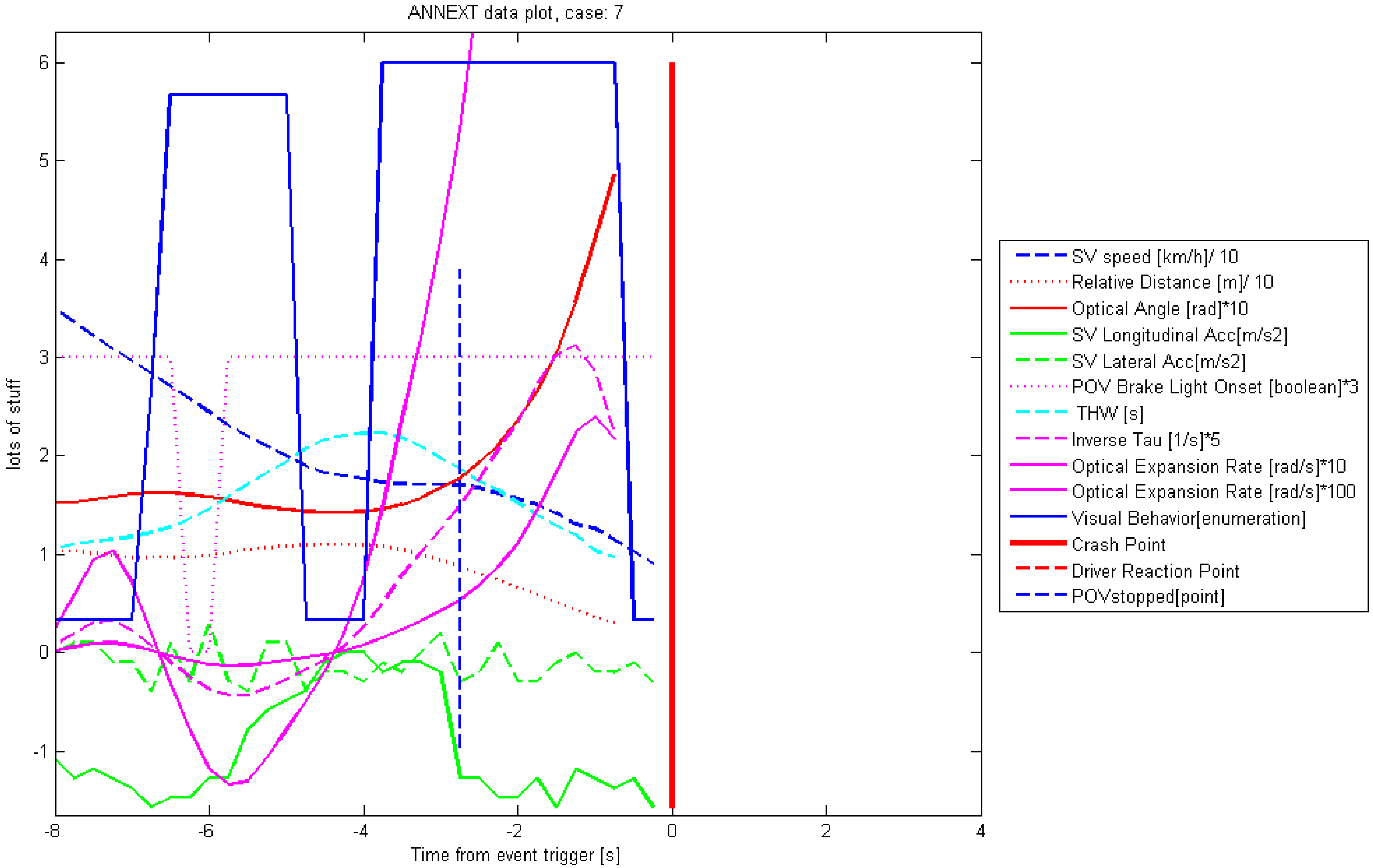


N = 22

Data reduction

- Performed by a trained analyst at DriveCam
- Event coding + manual video annotation of time series data.
- Event coding
  - *Narrative*, describing how the event played out in text along
  - *Other information*: SV and POV vehicle types, road and intersection type, lighting conditions, SV driver gender, driver activity etc.
- Manual time series annotation: Frame-by-frame video analysis of
  - *POV width* on the screen as measured by ruler (using a single computer with a constant image size),
  - *POV turn onset*,
  - *POV brake light onset*,
  - *Visual occlusion of the POV* (three levels: fully occluded, partially occluded or not occluded)
  - *Visual behavior* (including eye closure)
  - *Gaze eccentricity*
  - *The onset of the driver's physical reaction* (when driver reacted to the event by either face or posture changes).
- Further signal processing of time series data
  - Camera calibration, image rectification, smoothing etc. (see Bärgman et al., 2013)
- Video…

Example time series plot



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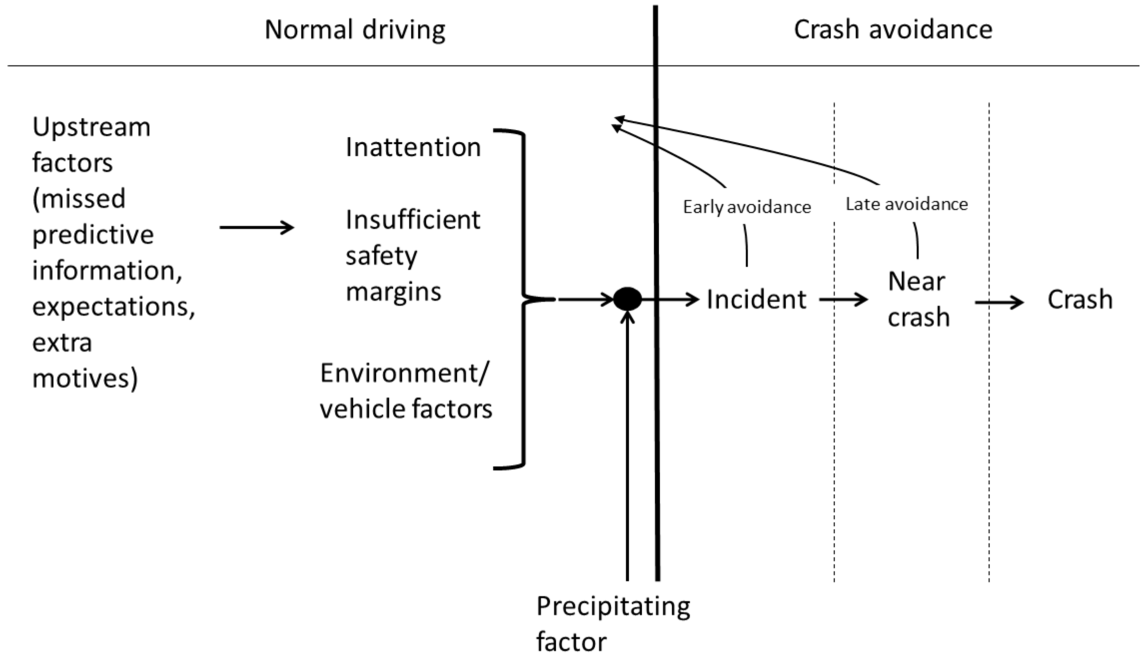
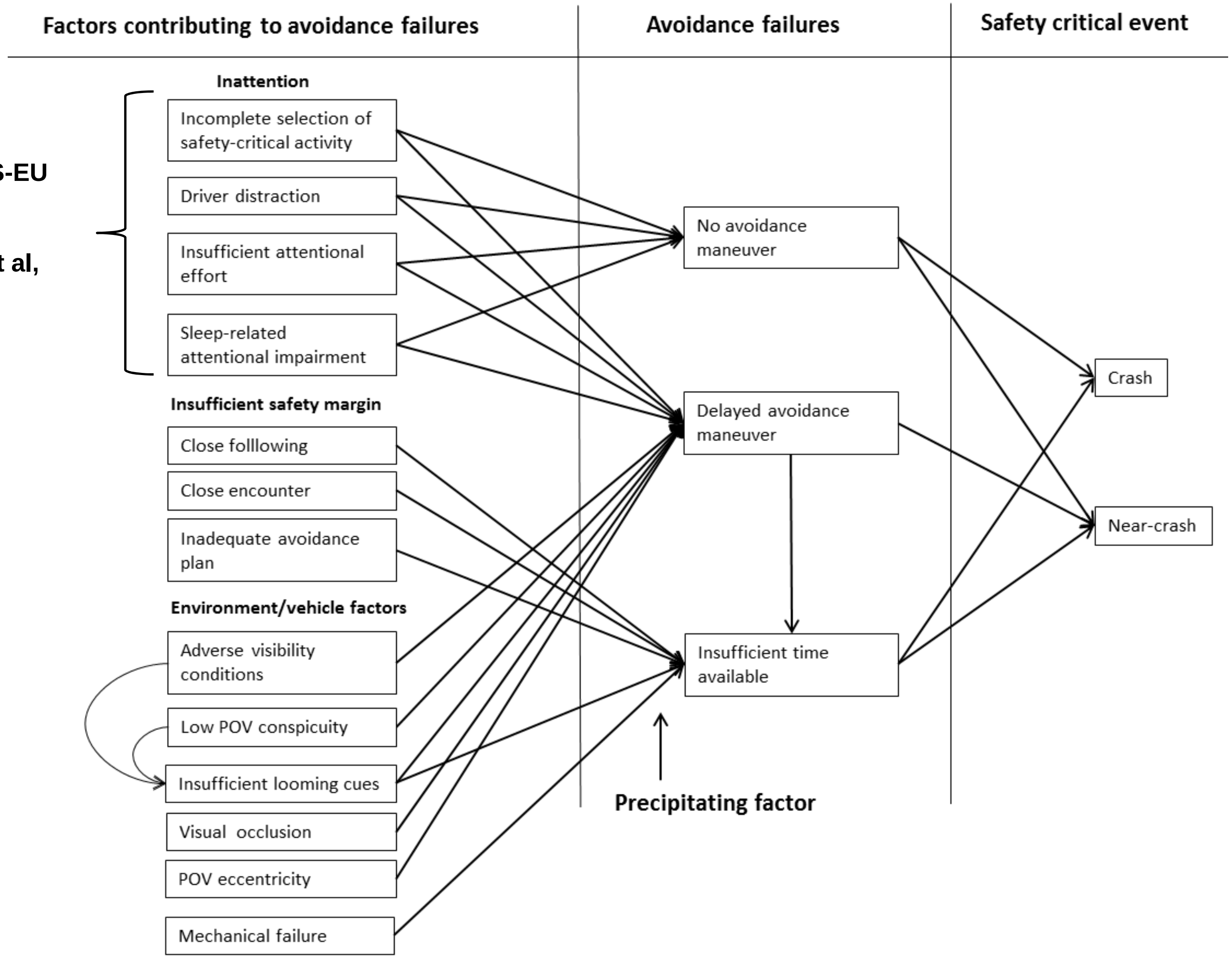
Analysis of crash-contributing factors

- New coding scheme for assigning and aggregrating trees of contributing factors (similar approach as DREAM; Wallén Warner et al., 2008)
- Based on novel accident model:



Coding scheme

Based on US-EU Inattention Taxonomy (Engström et al, 2013)



Coding principles

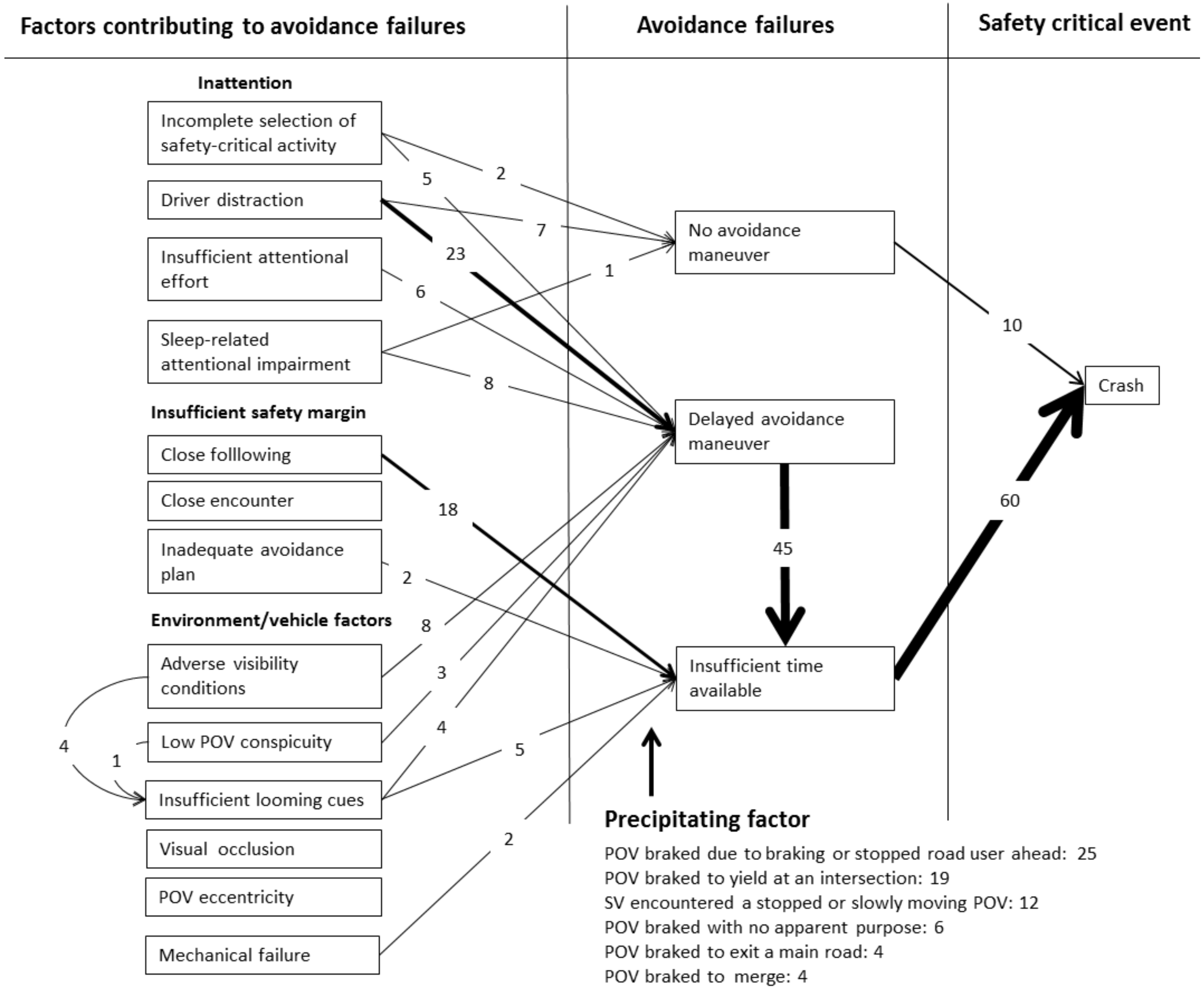
- Only factors judged by the analyst to actually contribute to the crash were coded
- A factor was judged to contribute if the absence of the factor would have led to a different outcome of the event (i.e., crash avoidance or reduced crash impact; the mere presence of a factor did not qualify it as a contributing factor)
- Coding based on the reduced event and time series data + snapshots of the forward road scene obtained from the crash videos.
- Crash video recordings were re-examined in order to resolve remaining open issues
- One analyst (the first author) carried out an initial coding of the rear-end crashes and another analyst (the second author) initially coded the intersection cases.
- The final result was based on consensus

Example screeenshots

Results

SV=Subject vehicle (the OBSM-equipped vehicle)
POV=Principal other vehicle (the vehicle that the SV crashed with)

Aggregated rear-end crashes (N=70)



Main findings, rear-end crashes

- ***Inattention*** was the dominating contributing factor in the rear-end crashes presently analyzed (74% involved at least one form of inattention as a contributing factor)
  - Driver distraction most frequent inattention sub-category (43% of all cases)
  - Attention allocated to other safety critical activities (i.e., incomplete selection of safety critical activities): 10%
  - Sleep-related attentional impairment: 13%
  - Insufficient attentional effort: 9%
- ***Close following*** coded as contributing in 26% of all cases
  - Generally did not co-occur with inattention
  - Almost only involved heavy vehicles (trucks and buses) with limited braking capacity
- ***Environment-related factors*** contributed in 23%
  - Mainly adverse visibility conditions
- ***Mechanical vehicle failures (bad brakes)*** were coded in two cases
- ***Precipitating factors (top 3)***
  - The POV braked in a following situation due to a braking or stopped road user ahead: 36 %
  - The POV braked to yield at an intersection: 27%
  - The SV encountered a stopped or slowly moving POV: 17%

Driver distraction sub-categories, rear-end crashes

Distraction type	Number of crashes	Percentage of distraction crashes
a. Vehicle-external distraction, no gaze diversion	0	0 %
b. Vehicle-external distraction, gaze diversion	9	30 %
c. Vehicle-internal distraction, no gaze diversion	1	3 %
d. Vehicle-internal distraction, gaze diversion	20	67 %
Sum	**30**	**100 %**

Gaze diversion involved in 29/30 distraction cases

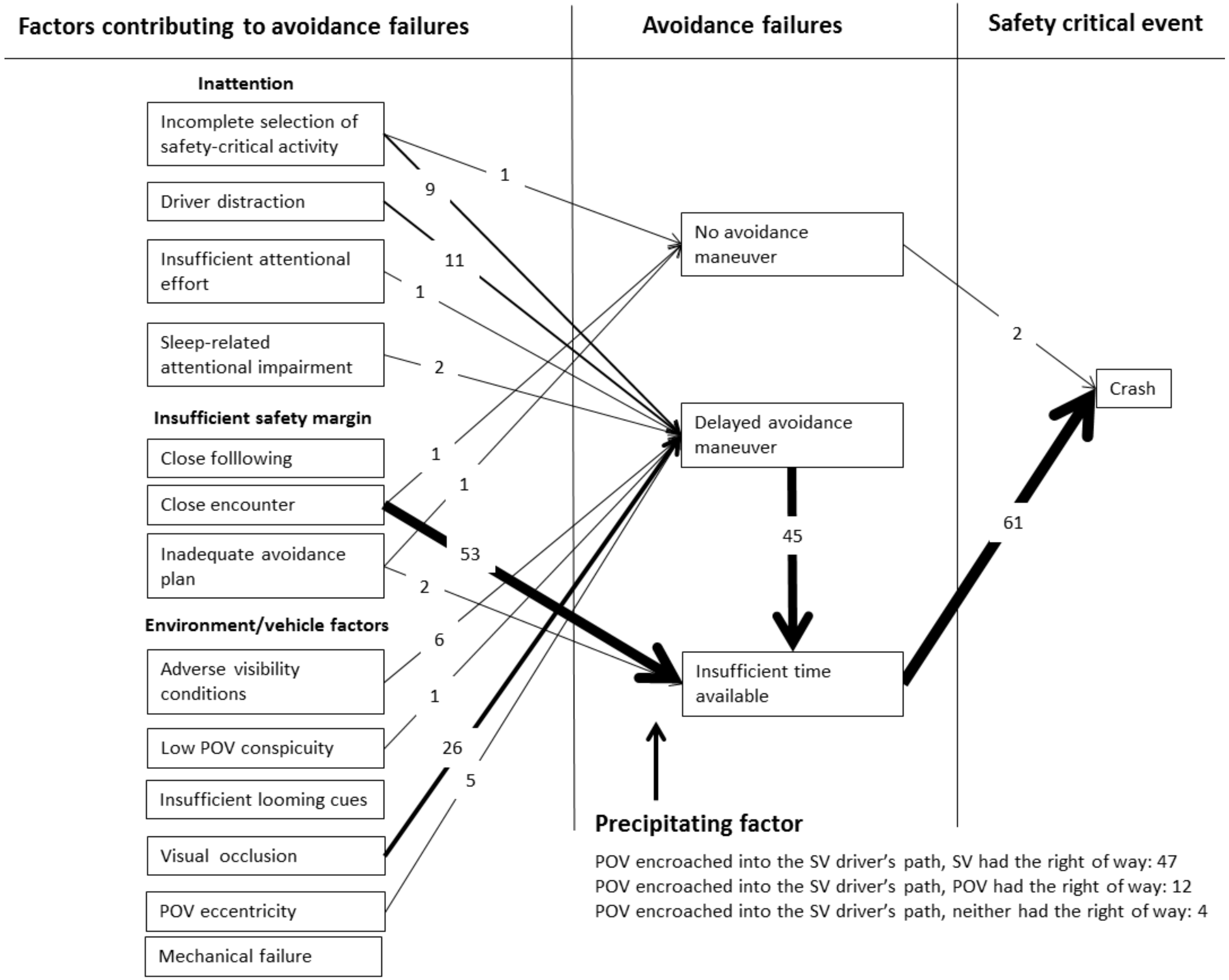
↓

Purely cognitive load (e.g., phone conversation) seems to be a very infrequent factor contributing to avoidance failures in rear-end crashes

A typical rear-end crash

An unexpected event (most often a lead vehicle braking unexpectedly in a following situation) occurs while the driver looks away from the road (most often towards an in-vehicle object). This typically leads to a severe delay in responding to the closing vehicle, thus eventually leaving insufficient time for the avoidance maneuver to be successful.

Aggregated intersection crashes (N=63)



Main findings, intersection crashes

- **Keep in mind: Only the avoidance failure of the driver going straight analysed here!**
- ***Inattention*** contributed in 38% of all intersection crashes - substantially less than for the rear-end crashes
  - Driver distraction:17 % (all involved visual diversion, i.e., no purely cognitive tasks)
  - Incomplete selection of safety critical activities (i.e., attention being allocated to other safety critical activities): 16 %
  - Sleep-related impairments: 3% (two cases)
  - Insufficient attentional effort: 2% (1 case)
- ***Close encounter*** coded as contributing in 84% of all cases
  - The driver intentionally selected and pursued a path that did not leave sufficient room for a successful avoidance of the crash (e.g., the POV suddenly encroaches into the SV's path)
  - Typically occurred in scenarios where the SV driver had (or believed s/he had) the right of way
- ***Visual occlusion*** contributed in 41% of all cases
  - 69 % of these involved visual occlusion by dynamic external objects (e.g., waiting or parked vehicles at the intersection.
  - Visual occlusion due to static external objects (e.g., buildings, hills etc.) was coded in 27 % of the occlusion cases.
- ***Precipitating factors***
  - The POV encroached into the SV driver's path (turning across or entering straight across) road when the SV driver had the right of way: 74 %
  - POV had the right of way:19 %
  - Neither the SV nor POV had the right of way (e.g., both ran a red light): 6%

A typical crossing-path intersection crash

The vehicle that intends to go straight (the SV in the present analysis) has the right of way and enters the intersection based on the assumption that other vehicles will yield. Another vehicle (the POV in the present analysis) fails to yield (for a yet unknown reason) and suddenly encroaches into the SV's path, leaving insufficient time for the SV driver to avoid the crash. In addition, the reaction of the SV driver to the encroaching vehicle is often delayed due to visual occlusion, driver distraction involving gaze diversion or visual scanning of the road scene towards a different location than that of the encroaching vehicle.

Video...

Discussion

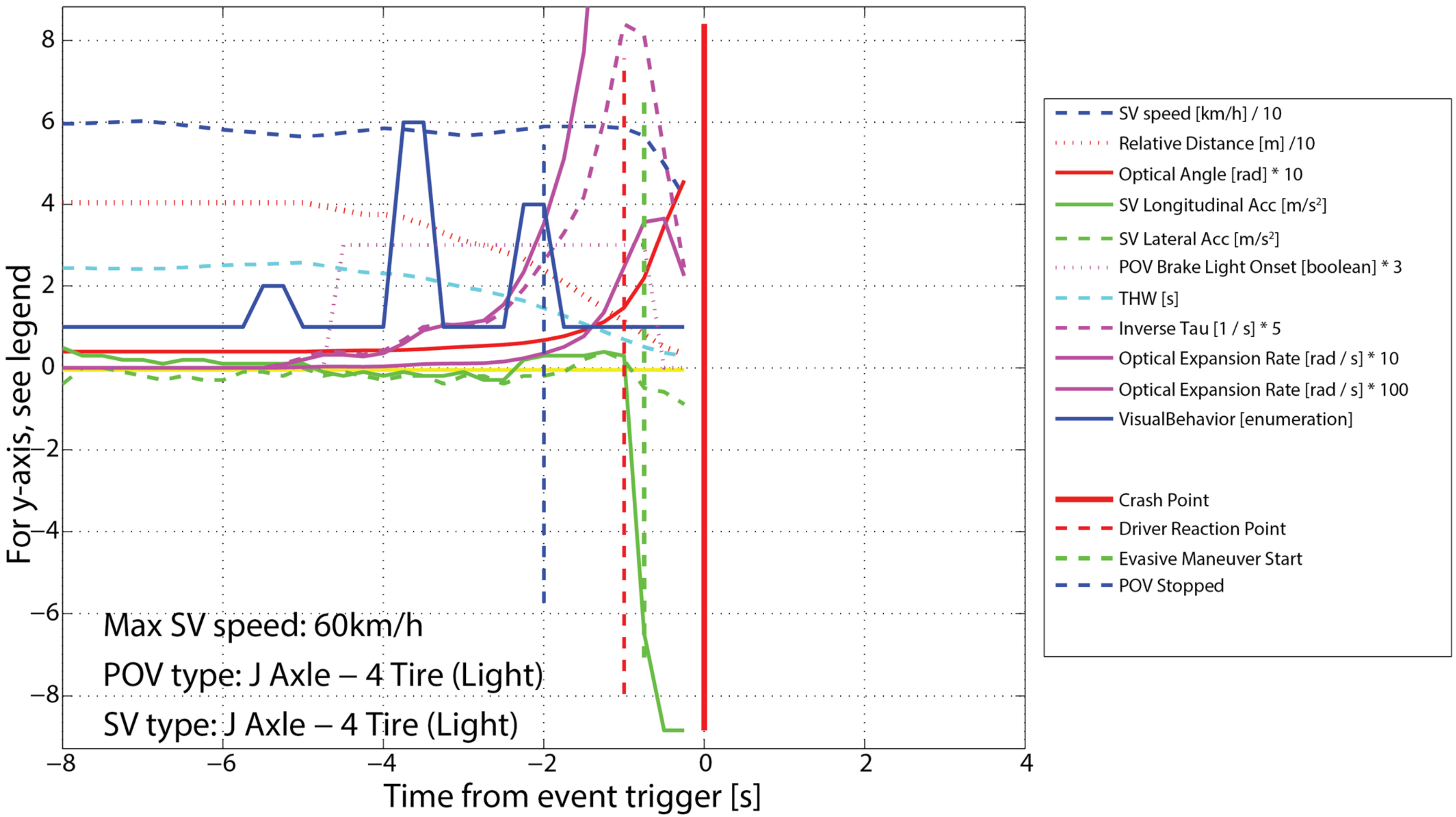
- ”Mental overload” is not the key mechanism whereby inattention leads to crashes – it’s rather drivers ”looking in the wrong way at the wrong moment”
- Results generally support existing naturalistic driving studies
  - Rear-end crashes typically due to the co-occurrence of an off-road glance and an unexpected event (Dingus et al., 2006)
  - Purely cognitive distraction (e.g., phone conversation) does not appear be a prevalent factor contributing to avoidance failures in these crash types
  - While crash risk cannot be accurately estimated here due to a lack of baseline data, it is interesting to note that phone conversation is today very prevalent while driving (5-10%, see Fitch et al., 2013)
  - Cognitive load may play a more important role as an upstream factor (and for the POV driver in the present intersection cases)
- Inattention plays a different role in different crash types, and depending on which driver is analysed (inattention may have been more prevalent for the POV drivers in the present intersection cases)
- Caveats
  - Drivers were commercial drivers participating in a safety management program – may not be representative of general driver population
  - Coding based on consensus between two analysts – no proper reliability analysis performed
  - Influence of substances (e.g., alcohol) difficult to detect from video – most likely underreported

Conclusions

- OBSM crash data offers an extremely rich source of information for studying the detailed mechanisms behind road crashes
- Goes beyond existing ND studies (with continuous data collection) which collected too few crashes for this type of analysis
- The initial results presented here only scratch the surface of what can be analyzed in such datasets
- Future work
  - Further fine-tuning of the analysis methodology (in particular the coding scheme)
  - Analysis of more upstream factors that lead to inattention or insufficient safety margins in the first place (expectations, extra motives and missed predictive information)
  - Explore combinations of factors in further detail.
  - Analyse intersection crashes from the perspective of the driver that failed to yield
  - Compare crashes to near-crashes wrt. patterns of contributing factors
  - Quantitative analysis of drivers' reactions to visual cues such as looming and turn onsets.
  - Collect randomly sampled baseline data to enable quantitative crash risk estimation
  - Combine the present type of analysis with interviews with the crash-involved drivers (as traditionally conducted in in-depth crash analysis (e.g., Wallén-Warner, 2008).

Extra slides

Example time series plot



Inattention categories

- **Insufficient attention**
  - ***Sleep-related attentional impairment*****:** The driver's allocation of resources to activities critical for safe driving does not match the demand of these activities due to factors related to sleep regulation.
  - ***Insufficient attentional effort*****:** The driver's allocation of resources to activities critical for safe driving does not match the demand of these activities due to an inability of the driver to mobilize sufficient attentional effort.
- **Misdirected attention**
  - ***Incomplete selection of safety-critical activity:*** The driver allocates sufficient resources to one or more activities critical for safe driving, or believed by the driver to be critical for safe driving, while the resources allocated to other activities critical for safe driving do not match the demands of these activities.
  - ***Driver distraction:*** The driver allocates resources to a non-safety critical activity while the resources allocated to activities critical for safe driving do not match the demands of these activities.

Based on US-EU Inattention Taxonomy (Engström et al, 2013)