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Conflict response after assisted driving with hands on or off wheel and different steering wheel torque settings

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Background – Ironies of automation (Bainbridge 1983)

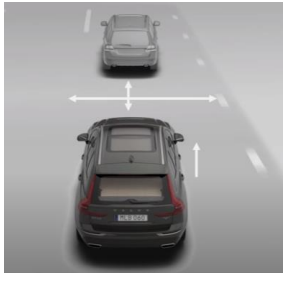
An increase of automation in a process leads to deterioration of control and cognitive skills and a reduction of vigilance if the automation operates acceptably for a long period.

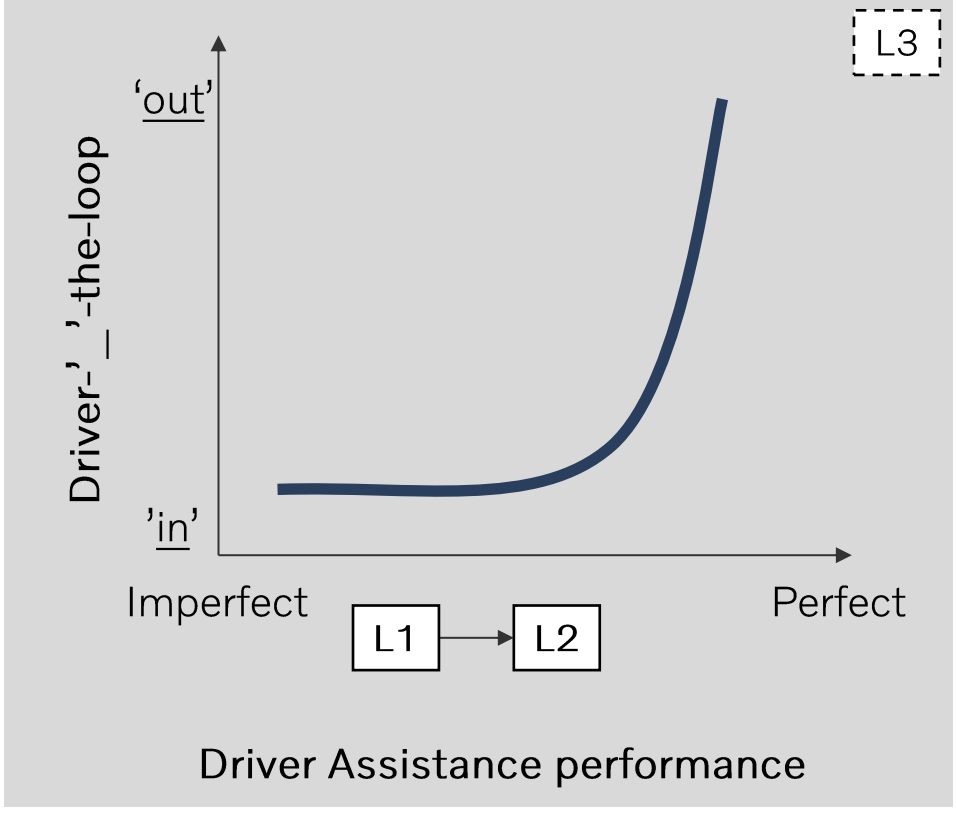
Driver-in-the-loop

- Visual attention
- Control inputs

SAE level 2 automation

- Lateral and longitudinal control
- Driver can override
- Driver in charge





Introduction

What do we know?

In supervised automation (Victor et al. 2018, Gustavsson et al. 2018)

- Some drivers expect system/function to resolve a conflict scenario despite: Introduction of limitations, attention reminders, hands on wheel and eyes on road at conflict approach
- 28% crashed in stationary conflict object and predominantly show high trust in system

Goal

Further investigate impact of system characteristics and introduction on driver disengagement

Research Questions

1) Influence of steering wheel torque setting on drivers' trust and conflict response?
2) Influence of steering reminders on drivers' conflict response?
3) Influence of description of system capabilities and hands on/off wheel requirement on drivers' trust and conflict response?

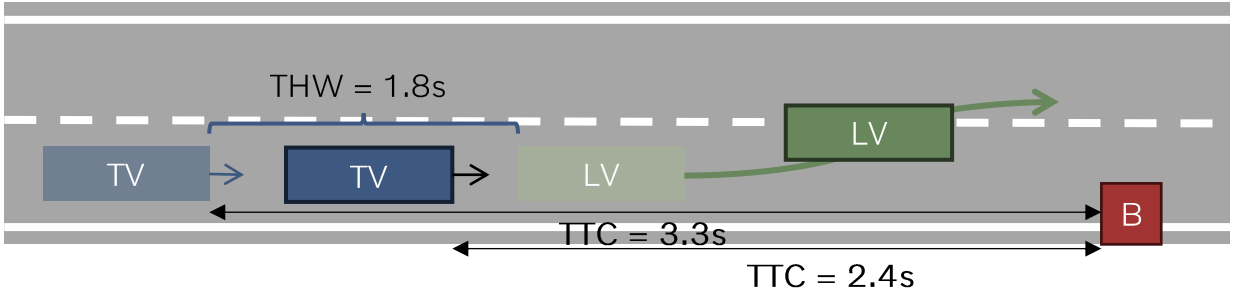
Method - Procedure

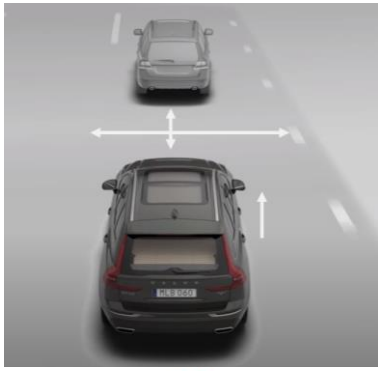
2 Test track study on AstaZero rural road (Hällered, Sweden)

- Test vehicle XC90 with development level 2 system (distance control and lane centering)
- Car following scenario with speeds around 50-70 km/h
- Uneventful driving for 5 laps (30 mins)
- Conflict event : Balloon car partial in lane

E1: 56 participants (13 female) age between 24 and 68

E2: 43 participants (15 female) age between 26 and 65





Method - Design

Experiment	E1			E2		
Group	**1**	**2**	**3**	**1**	**2**	**3**
n	*19*	*18*	*19*	*15*	*15*	*15*
Steering reminders	no	no	no	yes	yes	yes
Torque settings	M	M	M	L	M	H
System information	PAx	L2*	L2*	PAx	PAx	PAx
Hands on wheel instructions	yes	yes	no	yes	yes	yes

Variations

- System introduction:
  - PAx – new PA system
  - L2* - near-perfect level 2

Dependent variables

- Response process
  - Eyes on road
  - Hands on wheel onset
  - Driver braking onset
  - Driver steering onset
- Trust rating 1-100 (per lap)

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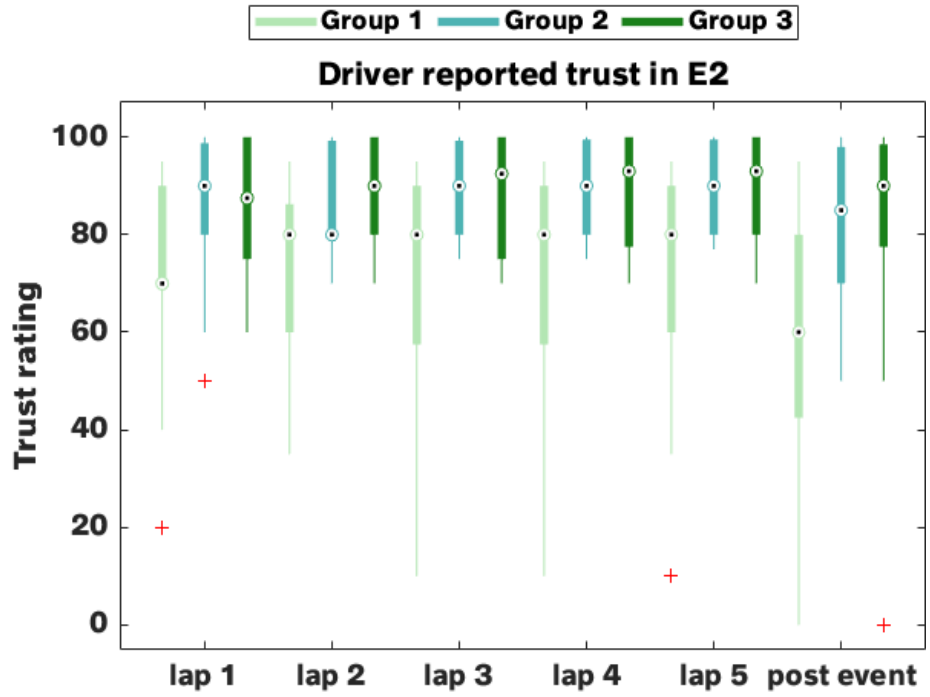
	Exp 2		
N	*15*	*15*	*15*
Torque settings	L	M	H

RQ1: Steering wheel torque influence on trust & conflict response

- Self-reported trust significantly lower in group 1 (low steering wheel torque override) for all ratings except after lap 1
- Conflict response showed no difference between the groups (E2)
  - All drivers eyes on road during approach
  - All drivers hands on wheel during approach
  - All drivers responded by steering



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Experiment	E1		
N	*19*	*18*	*19*
Steering reminders	no	no	no
Hands on wheel instructions	yes	yes	no

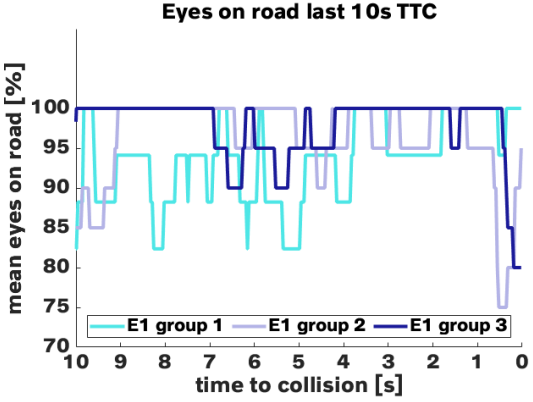
RQ2: Conflict response without steering reminders (E1)

Perception
- Eyes on road

Hands off wheel
- Cut-out onset

Braking
- Braking onset

Steering maneuver
- Steering onset



- 16/56 drivers hands off at LV cut-out start
- 2 drivers no hands-on response

- 11/56 drivers brake (no full brake)

Note:
brake disengages PA

- 5 drivers show no and 1 late steering response resulting in crash

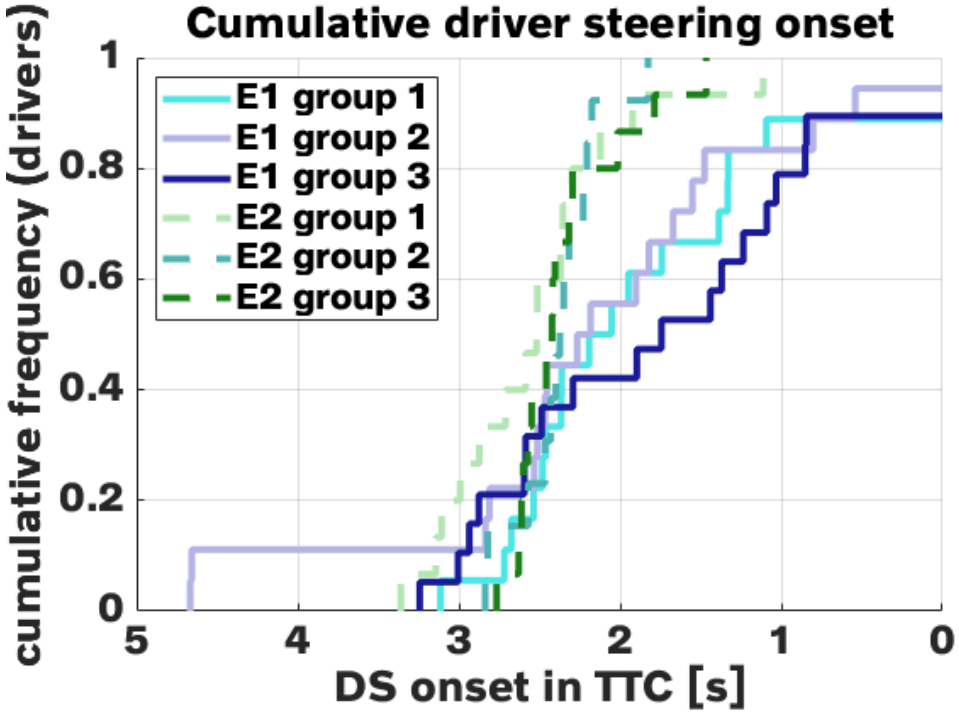
Conflict response: Driver steering (DS) onset

RQ2: No significant difference in DS onset between E1 and E2

- ANOVA: F(5,87) = 1.33, p = 0.26

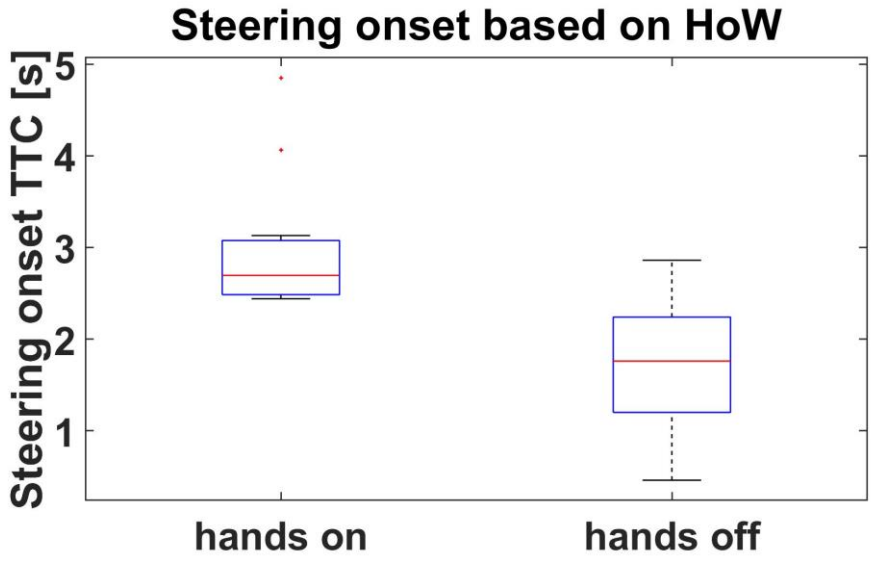
RQ3: Influence of system introduction and hands on wheel instruction on driver response

- No significant difference between groups (E1)
- Allowing hands off wheel visibly later steering response in some drivers (E1 grp3)



RQ3: Influence of hands-on wheel at conflict situation

Experiment 1	On	Off
G1: HoW req	17	2
G2: HoW req	15	3
G3: HoW no req	8	11
Mean DS onset in TTC	2.25s	1.54s
std DS onset in TTC	0.83s	0.69s



$t(52) = -2.92, p < 0.01$

Significant difference in response time between hands on and off at the beginning of the conflict (balloon revelation)

Normal conflict response (E1)

TP gave explicit consent to have this video presented

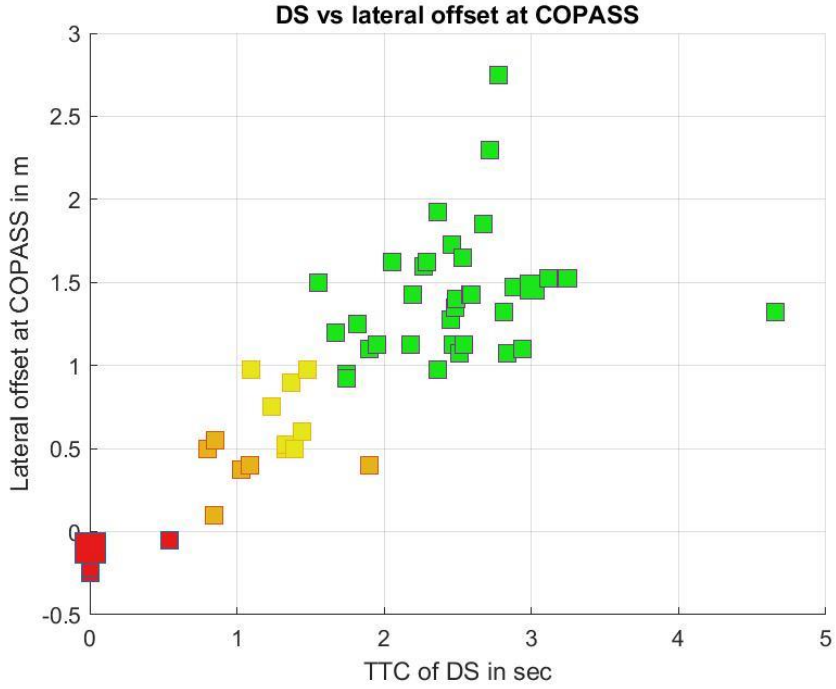
No conflict response resulting in a crash (E1)

TP gave explicit consent to have this video presented

Conflict outcome (E1) – clustering

Clustering based on steering onset, lateral distance to conflict object when passing (COPASS) and steering intensity

- No or too late response (crash) [6]
- Insufficient response (near-crash) [6]
  - Very low lateral offset (< 0.5m) or
  - Late (TTC < 1.1s) & low lateral offset (<0.6m)
- Delayed response (incident) [8]
  - Delayed (1s ≤ TTC ≤ 1.5s) & low lateral offset (<1m)
  - High intensity steering
- Normal response (non-critical interaction) [36]
  - Normal (TTC > 1.5s) & safety boundary (>0.9m)
  - Moderate steering



Experiment	E1		
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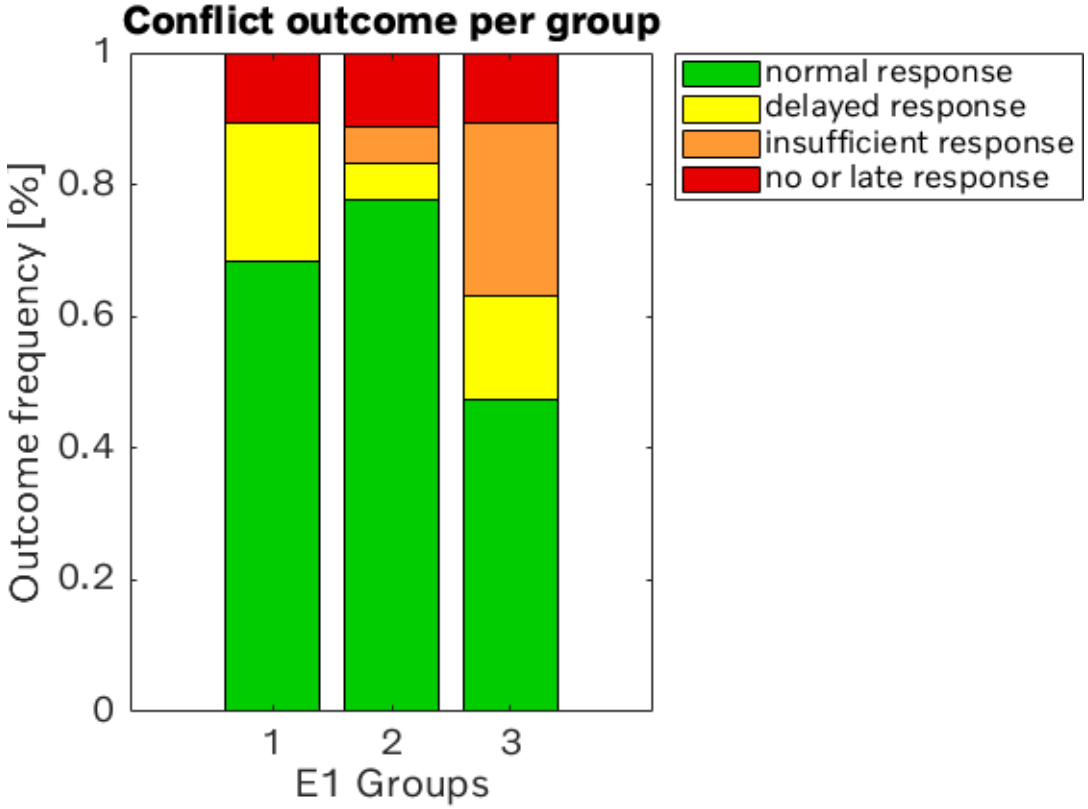
Conflict outcome based on test condition & self-reported data



Test conditions

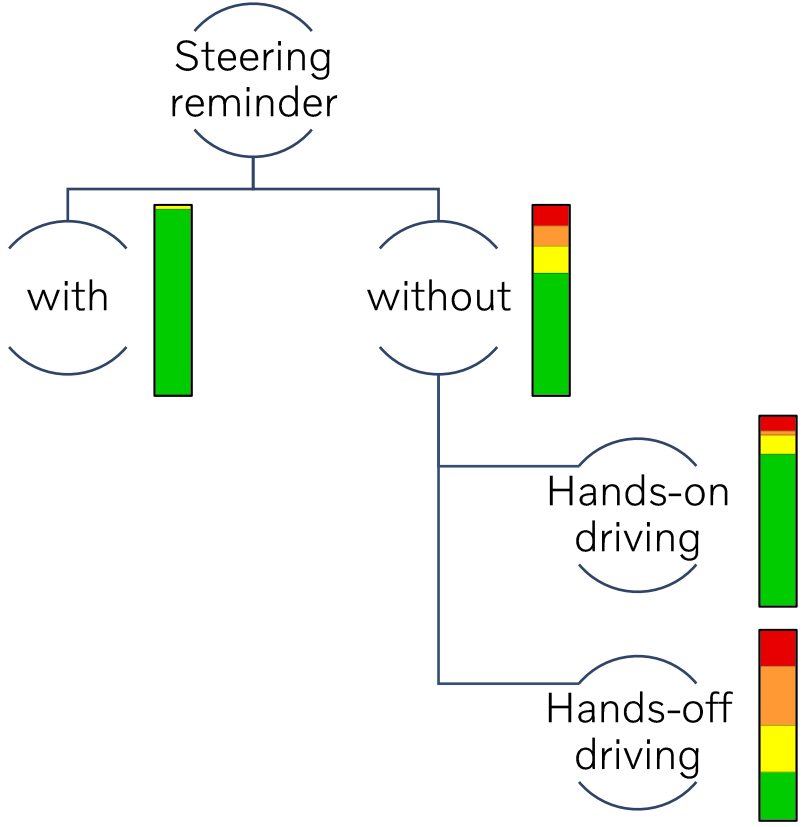
- Crashers equally distributed
- More insufficient response in group 3 (hands off)

No effect on conflict outcome

- Trust during the drive
- experience & usage of ADAS

Conclusions

- Different torque levels to override have no influence on response to conflict (negative influence on trust)
- Steering reminders prevent hands-off driving and resulted in normal response to a conflict
- Without steering reminders some drivers do not act in conflict situation (resulting in crash) or show insufficient or delayed responses
- Hands on wheel instructions does not prevent hands-off driving
- Hands-off driving increases frequency of insufficient response to conflict situation (near-crash)



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Thank you for your attention.