Driver Performance in the Presence of Adaptive Cruise Control Related Failures

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The SHADES project

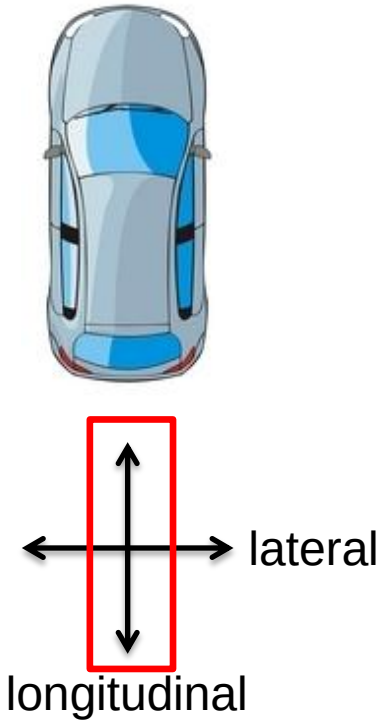
SHADES - **S**ystem safety through combination of **H**MI **a**nd **De**pendable **S**ystems

Budget: 1 MEUR

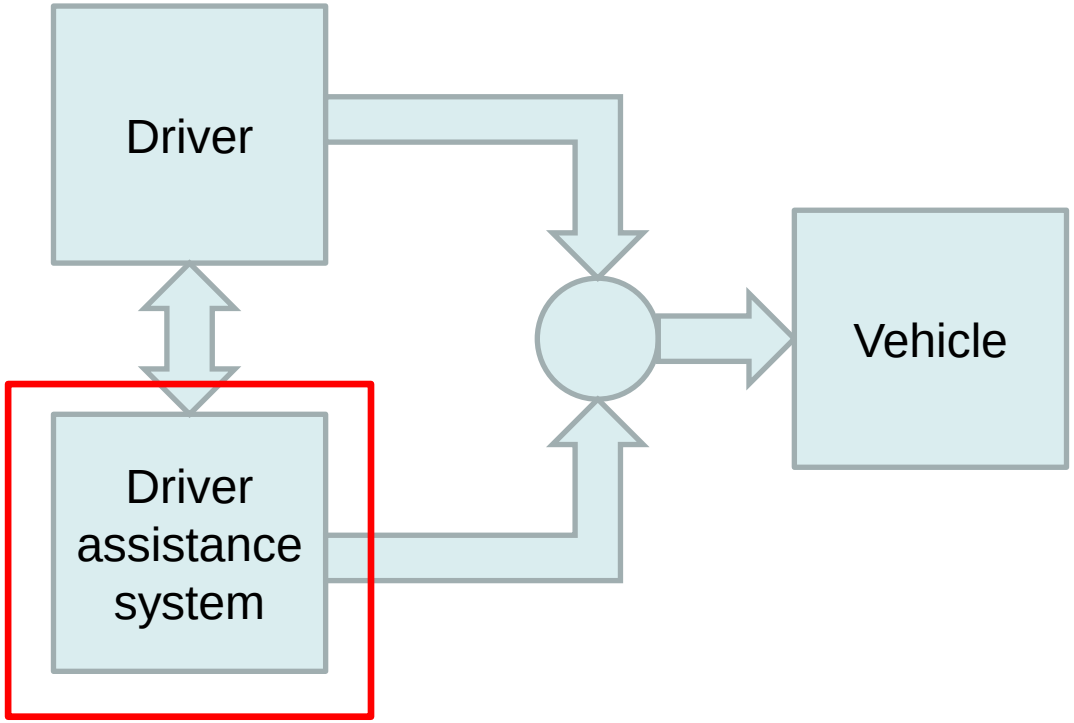
Financed by SAFER

Driver assistance systems

- Information/Warning Systems
  - Forward Collision Warning
  - Lane Departure Warning
  - Blind Spot Monitoring
- Active assistance/Semi automation
  - Collision Avoidance by Braking
  - Lane Keep Assist
  - Adaptive Cruise Control
- Full/High automation
  - Lateral and longitudinal automation
  - Platooning



Focus in this study



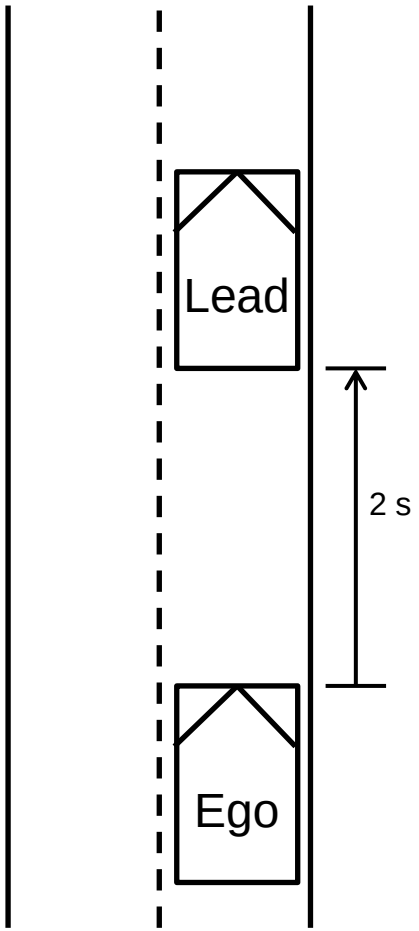
malfunctions that cause hazards

Questions before the study

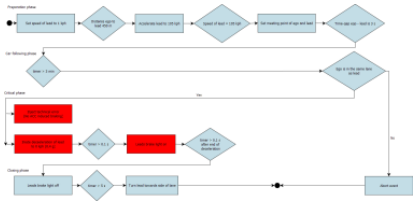
- What are the safety issues considering failures of an adaptive cruise control system (ACC)?
- How do drivers handle failures in an ACC?
- How to develop strategies to improve driver controllability?

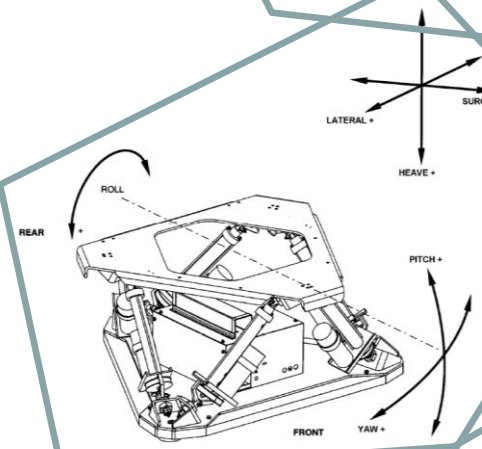
Experimental setup

- Adaptive Cruise Control (ACC)
- Driving simulator study
- Four failure modes
  - Unwanted acceleration
  - Complete brake failure
  - Partial brake failure
  - Speed limit violation
- There was no warning indicating a failure
- All with the same initial settings
  - ACC activated
  - 105 kph (65 mph)
  - Following leader with a 2 second time-gap
  - No vehicle in left lane (free to overtake)



Chalmers driving simulator





Sound system

Visual system

Scenario

Fault injection tool

Motion base

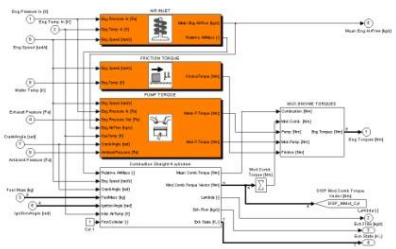
Simulation kernel

Data logging

Driver assistance system

Vehicle model

Cabin



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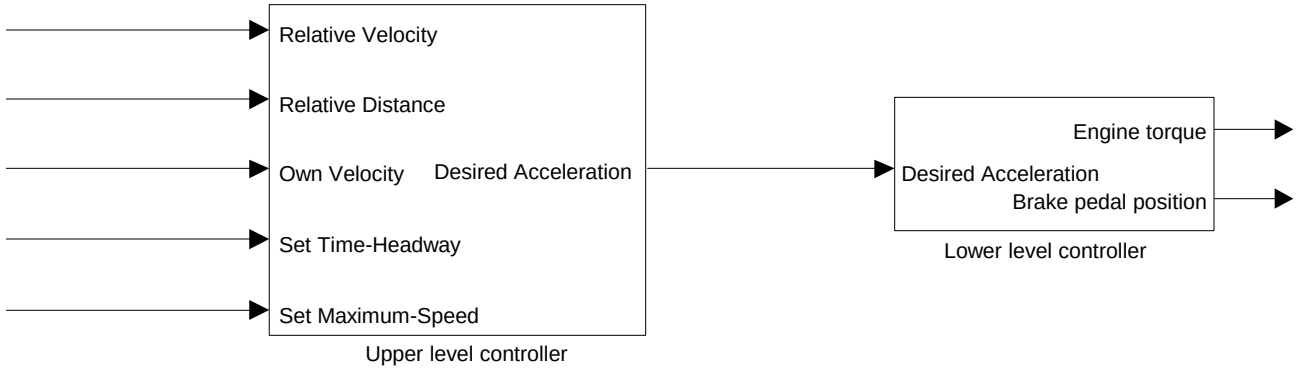
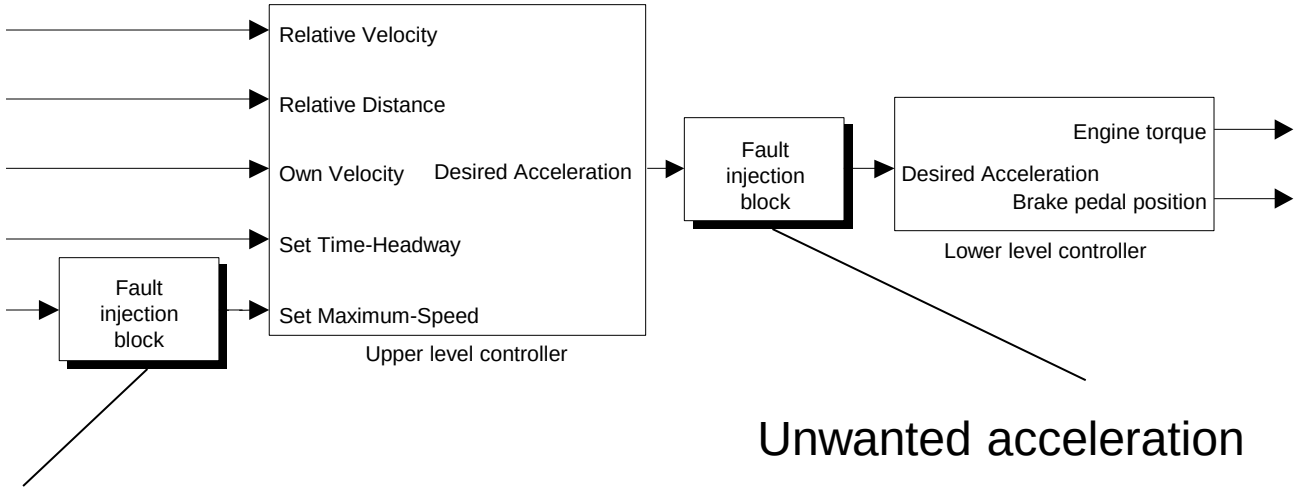
Driving simulator experiment – Fault injection support



Driving simulator experiment – Adaptive cruise control



Speed failure

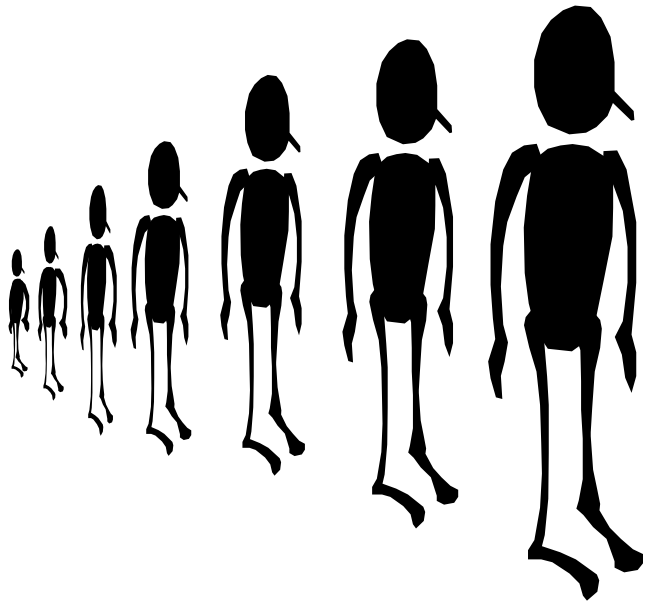
Unwanted acceleration

Complete brake failure

Partial brake failure

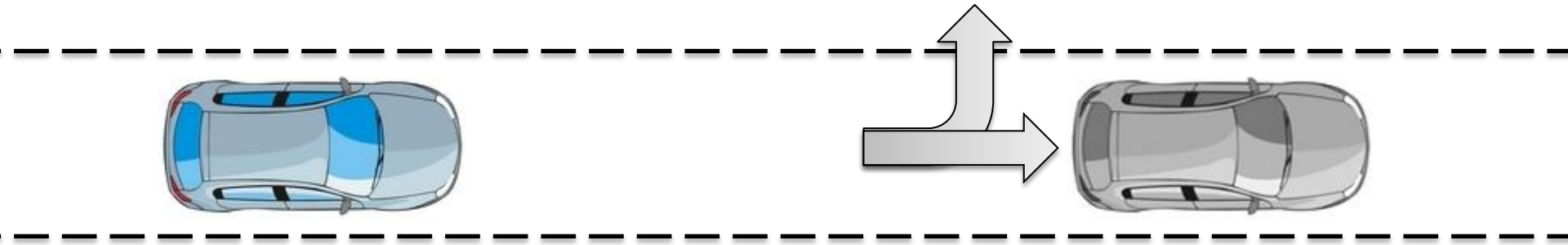
Participants

- 48 participants
  - 33 men and 15 women
  - between 25 and 59 years of age
  - annual driving distance more than 5000 km
  - no experienced ACC users



Scenario A: Unwanted acceleration

Car in front drives at 105 kph (65 mph), ACC in ego car accelerates unintentionally towards vehicle ahead (fails to keep the set distance and speed)



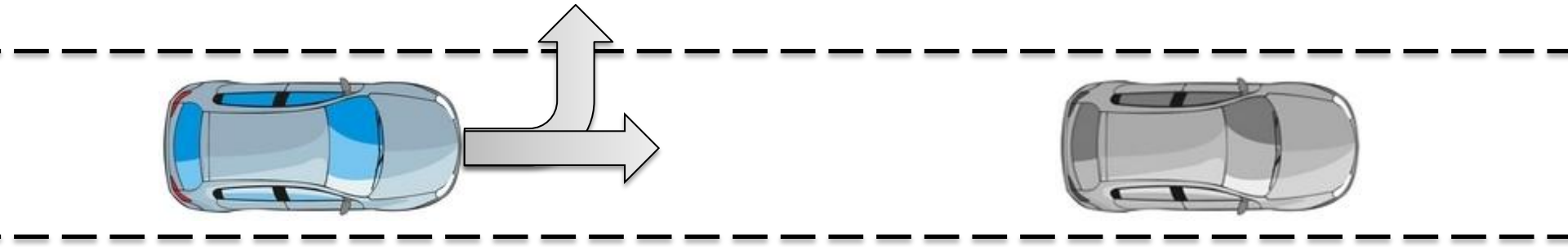
Fails to follow leader with a 2 second time gap

Braking or steering required to avoid collision

Scenario B&C: Complete and partial brake failure

B: Car in front brakes, ACC in ego car does not brake

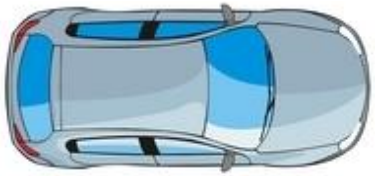
C: Car in front brakes, ACC in ego car brakes less than necessary to avoid a collision

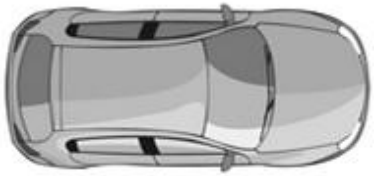


Braking or steering
required to avoid collision

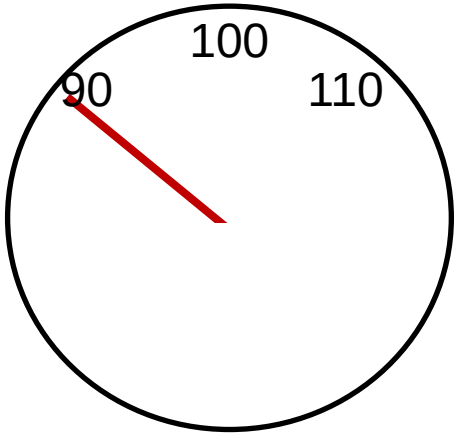
Scenario D: Speed limit violation

Car in front accelerates above speed limit, ACC in ego car also accelerates keeping set distance (2s) but fails to keep set speed limit (110 kph)





Following leader with a
2 second time-gap



Braking required
to avoid speeding

Sweden

Design

	Order of scenarios		
Subjects	**1**	**2**	**3**
n = 4	Practice	**A**	**B**
n = 4	Practice	**B**	**A**
n = 4	Practice	**A**	**C**
n = 4	Practice	**C**	**A**
n = 4	Practice	**A**	**D**
n = 4	Practice	**D**	**A**
n = 4	Practice	**B**	**C**
n = 4	Practice	**C**	**B**
n = 4	Practice	**B**	**D**
n = 4	Practice	**D**	**B**
n = 4	Practice	**C**	**D**
n = 4	Practice	**D**	**C**

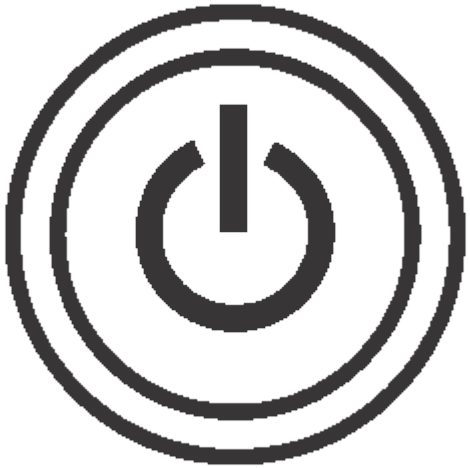
* A=B=C=D=Experimental scenario including experimental situation and preceding baseline

** N = 48

*** n = 24 for each experimental scenario

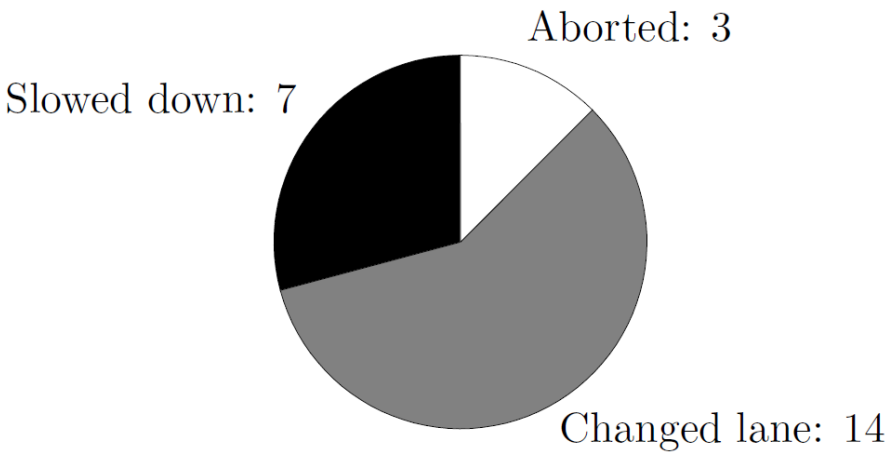
RESULTS

The drivers available strategies when system fails



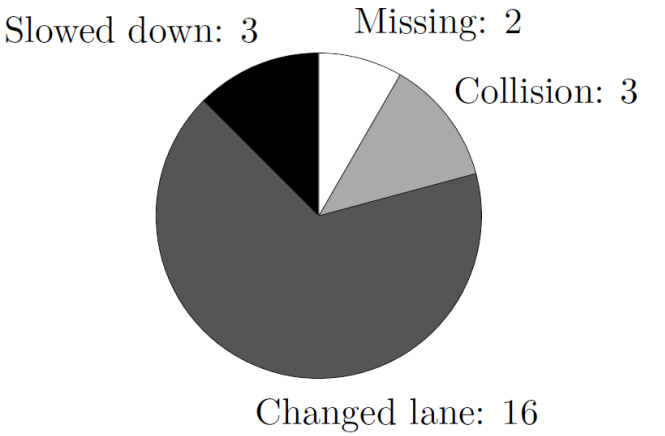
Scenario A: Ego car accelerates unintentionally

- No collisions
- Majority used steering
- One third slowed down
  - Six braked
  - One turned off the ACC using the button
- Three drivers got the vehicle unstable which automatically aborted the experiment

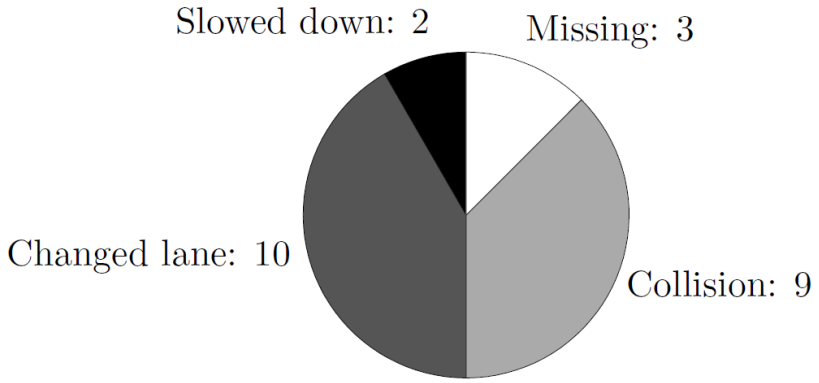


Scenario B&C: Brake failures

- Both brake failures caused collisions
- Partial brake failure caused more collisions than complete failure
  - But with lower impact speed (36 kph vs. 82 kph)!
- Changing lane most common for drivers with successful outcome



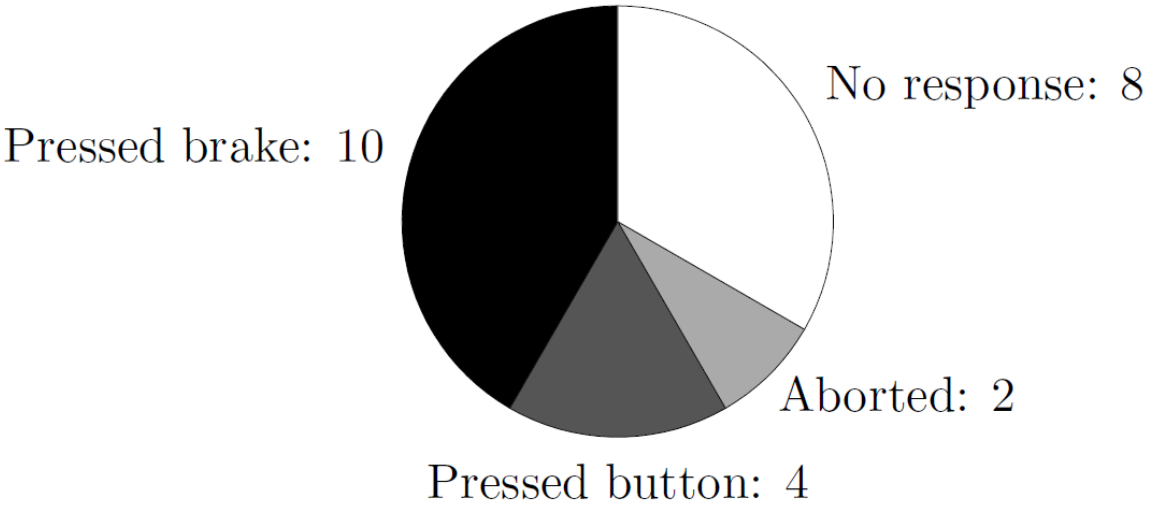
Complete brake failure



Partial brake failure

Scenario D: Ego car accelerates keeping the set distance but fails to keep the set speed limit

- Eight drivers did nothing within 30 seconds of speeds above 110 kph
- Braking more common than pressing the ACC on/off button



Conclusions

- More drivers changed lane than braked to acceleration and brake failures
  - But note that drivers were always free to change lane
- Collisions only occurred in scenarios with brake failures
- More collisions for partial brake failure than for complete brake failure
  - However, impact speed was less for partial brake failure
- Comparing brake failures:
  - Higher controllability for complete brake failure (fewer collisions)
  - Lower severity for partial brake failure (lower impact speed)

Risk = Exposure x Controllability x Severity

Thanks for your kind attention!

Questions?

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