Workshop on Discrete Choice Models
Lausanne, June 22nd 2017

Modelling Choices of Control Transitions and Speed Regulations in Full-Range Adaptive Cruise Control

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1. Introduction

Control transitions between ACC and manual driving

Driver switches off | System switches off

↓

Microscopic traffic flow models

Control transitions are not modelled

↓

ACC vehicles have an effect on traffic flow efficiency (?)

(Klunder, et al. 2009; Van Driel & Van Arem 2010)

2. Literature review

Xiong and Boyle (2012), Varotto et al. (2017)

DIDC to *Inactive*	DIDC to *Active and accelerate*
Leader speed & acceleration	Acceleration
Cut-in anticipation	Time after activation
Ramps & exits	Ramps
Driver heterogeneity	Driver heterogeneity

3. Research objectives

Develop an empirically underpinned modelling framework

In which conditions do drivers transfer control?

How does driver behaviour change during these transitions?

Estimate a driver behaviour model

Predict the effects of control transitions on traffic flow

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4. Data collection

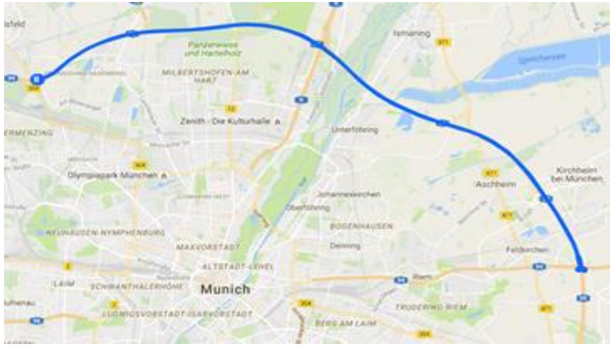
Controlled on-road experiment

Drive as you do in real life and use the system only when you think it is appropriate

BMW 5 series with full range ACC

Peak hours, A99 ~ 35.5 km

23 participants



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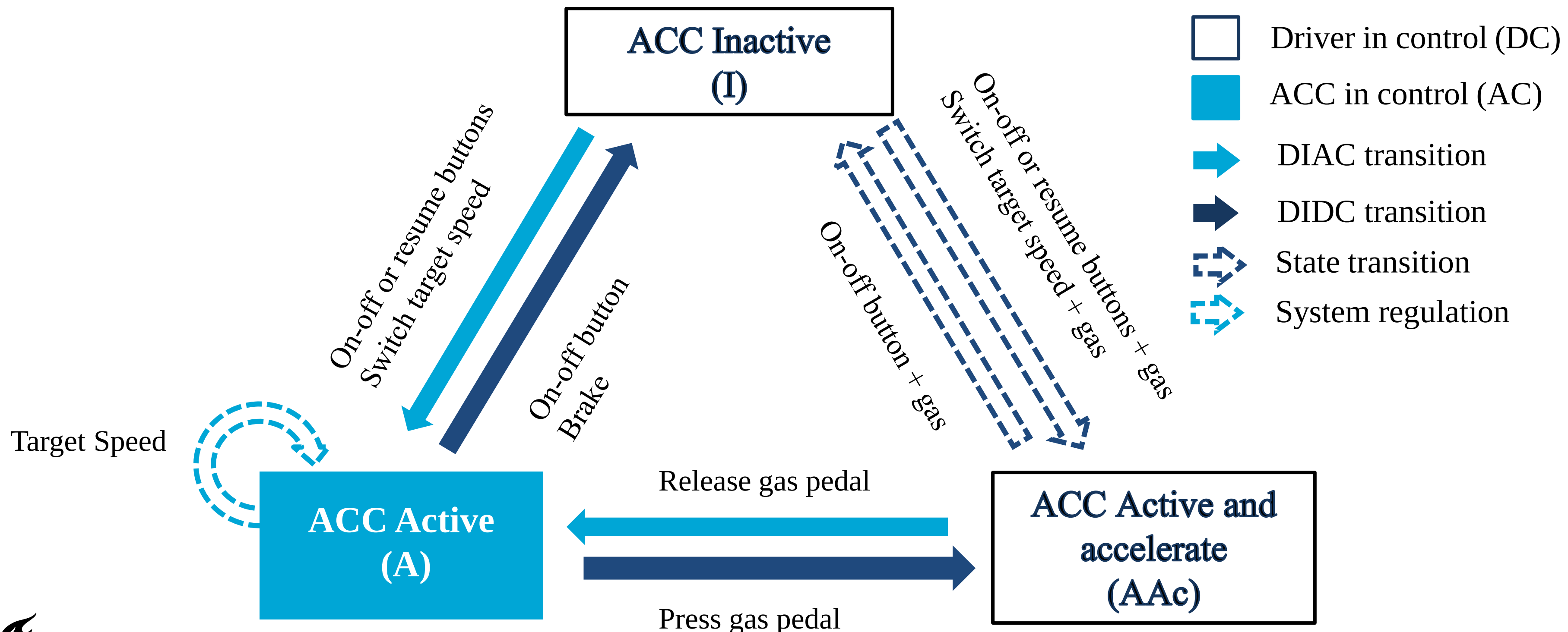
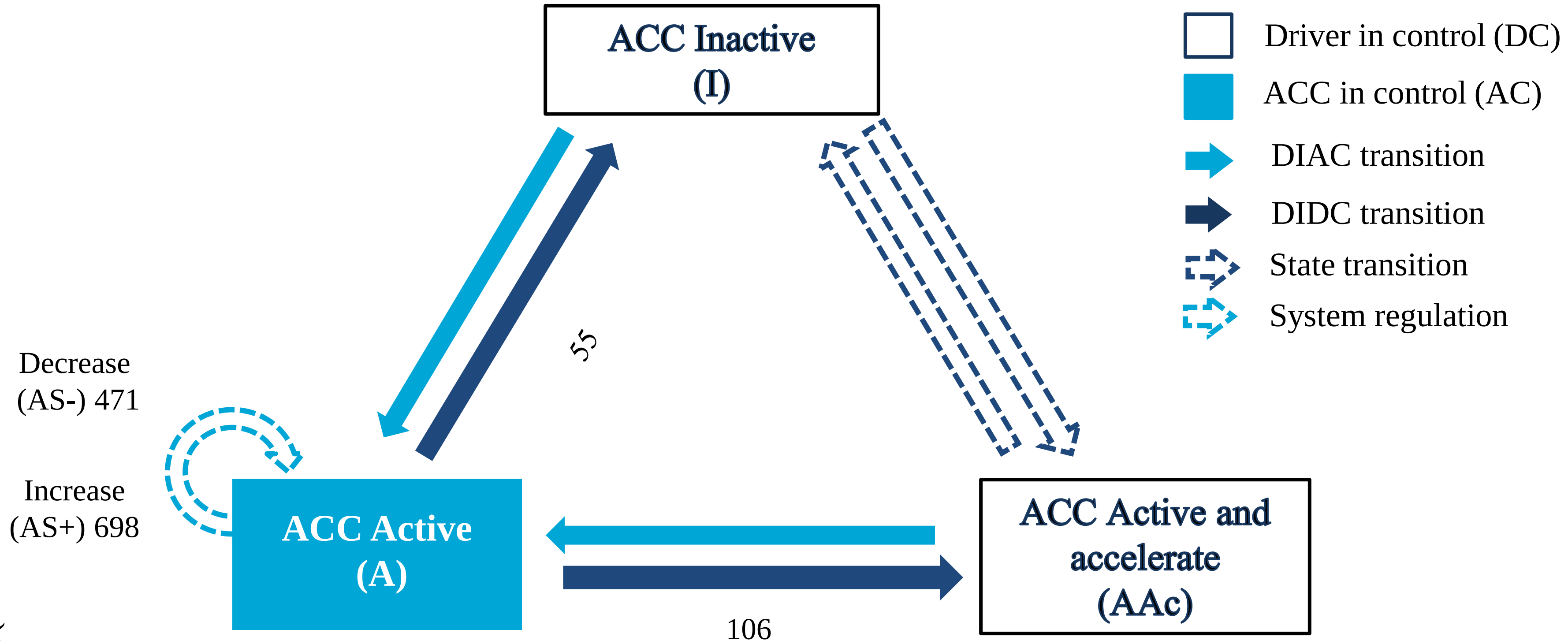
4.1 ACC system specifications



4.2 Dataset



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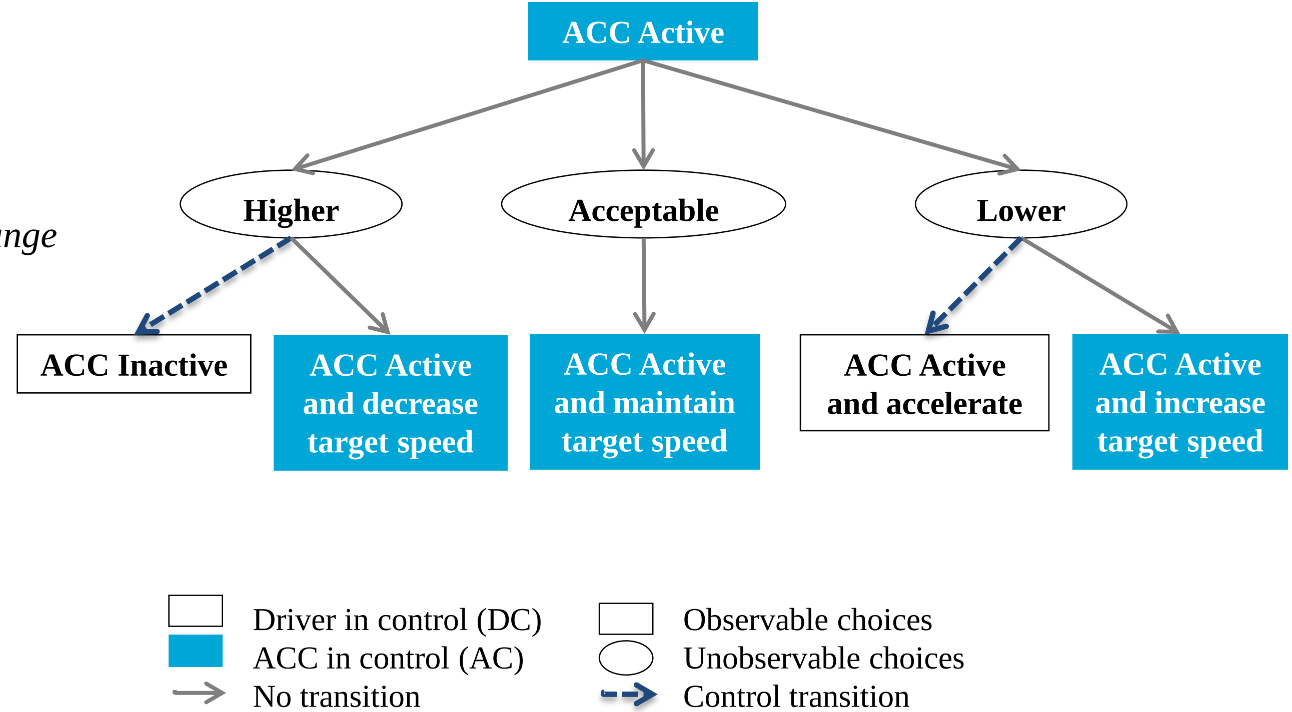
5. Choice model to manual control

Feeling of risk and task difficulty evaluation: actual level vs. acceptable range

System state and speed regulation choice



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5.1 Risk feeling and task difficulty

Ordered probit model with random thresholds

Latent Regression

$$RFTD_n(t) = \lambda_{DrivBehChar} \cdot DrivBehChar(t) + \sigma \cdot \delta_n(t)$$

Random Thresholds

$$MinAc_n = t^L + \tau^L_{DrivChar} \cdot DrivChar + \rho^L \cdot \ln[\exp(V_n^{AAc}(t)) + \exp(V_n^{AS+}(t))] + \gamma^L \cdot \vartheta_n$$

$$MaxAc_n = t^H + \tau^H_{DrivChar} \cdot DrivChar + \rho^H \cdot \ln[\exp(V_n^{I}(t)) + \exp(V_n^{AS-}(t))] + \gamma^H \cdot \vartheta_n$$

λ and τ are vectors of parameters associated with the explanatory variables;
t^L and t^H are the mean lowest and highest risk acceptable;
ρ^L and ρ^H are parameters associated with the utility of resuming control;
γ^L and γ^H are parameters associated with the individual specific error term $\vartheta_n \sim N(0,1)$;

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5.2 System state and speed regulation

Mixed logit models

High Risk

$$U_n^{AS-}(t) = 0 + \varepsilon_n^{AS-}(t)$$

$$U_n^{I}(t) = \alpha^{I} + \beta^{I} \cdot X(t) + \gamma^{I} \cdot \vartheta_n + \varepsilon_n^{I}(t)$$

Low Risk

$$U_n^{AS+}(t) = 0 + \varepsilon_n^{AS+}(t)$$

$$U_n^{AAc}(t) = \alpha^{AAc} + \beta^{AAc} \cdot X(t) + \gamma^{AAc} \cdot \vartheta_n + \varepsilon_n^{AAc}(t)$$

α^{I} and α^{AAc} are alternative specific constants;
β^{I} and β^{AAc} are vectors of parameters associated with the explanatory variables $X(t)$;
γ^{I} and γ^{AAc} are parameters associated with the individual specific error term $\vartheta_n \sim N(0,1)$;
$\varepsilon_n^{AS-}(t)$, $\varepsilon_n^{I}(t)$, $\varepsilon_n^{AS+}(t)$, and $\varepsilon_n^{AAc}(t)$ are i.i.d. Gumbel – distributed error terms.

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5.3 Estimation results

Statistics	
Number of parameters associated with explanatory variables	23
Number of alternative specific constants and mean thresholds	4
Number of drivers	23
Number of observations	23,568
Final log likelihood	-5878
Constant log likelihood (logit)	-6663

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Parameters	Estimate	t-test	
L_SPEED	0.00127	2.88	
L_ACCEL	-0.164	-3.98	
L_THW30	-0.127	-7.08	
L_DA	-0.29	-7.53	
L_DV	-0.0329	-14.86	
L_ANTCUTIN	0.235	3.63	
t_H	2.07	27.91	
t_L	-2.2	-31.48	
tH_MEDEXPACC	-0.27	-3.09	
tL_NOVICEACC	-0.147	-2.48	
tH_PATIENT	-0.298	-2.29	
tL_PATIENT	0.379	4.36	
tL_RECKLESS	0.219	3.9	
tL_WL	0.00365	1.88	*
RHO_H	0.342	2.23	
RHO_L	3.09	7.32	
GAMMA_H	0.253	5.41	
GAMMA_L	-0.194	-4.52	
ASC_HI	-2.7	-11.78	
ASC_LAAc	-0.184	-1.03	**
B_EXIT_HI	2.79	6.21	
B_OnRAMP_HI	0.85	2.53	
B_FEM_LAAc	-0.223	-1.91	*
B_logTIMEA_LAAc	-0.553	-11.86	
GAMMA_HI	-0.0396	-0.19	**
GAMMA_LAAc	0.19	2.76	

Feeling of risk and task difficulty evaluation

System state and speed regulation choice

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6. Conclusion

Low risk and task difficulty	High risk and task difficulty
No experience with ACC	Experience with ACC
Patient and Reckless	Patient
Driver heterogeneity	Driver heterogeneity
DIDC to Active and accelerate	*DIDC to Inactive*
Time after activation	Ramps & exits
Driver heterogeneity	

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7. Future research

Choice Model	Acceleration model
Transition choice	*Transition period*
Discrete/continuous choice of control transitions and speed regulations	Temporal evolution of driver behaviour characteristics over time

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HUMAN FACTORS OF AUTOMATED DRIVING

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