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Modelling human interaction to improve traffic safety and vehicle automation

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Acknowledgments

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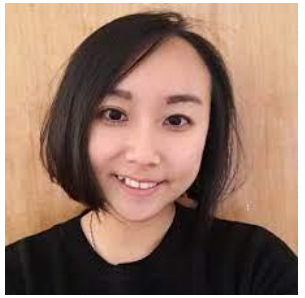
interACT





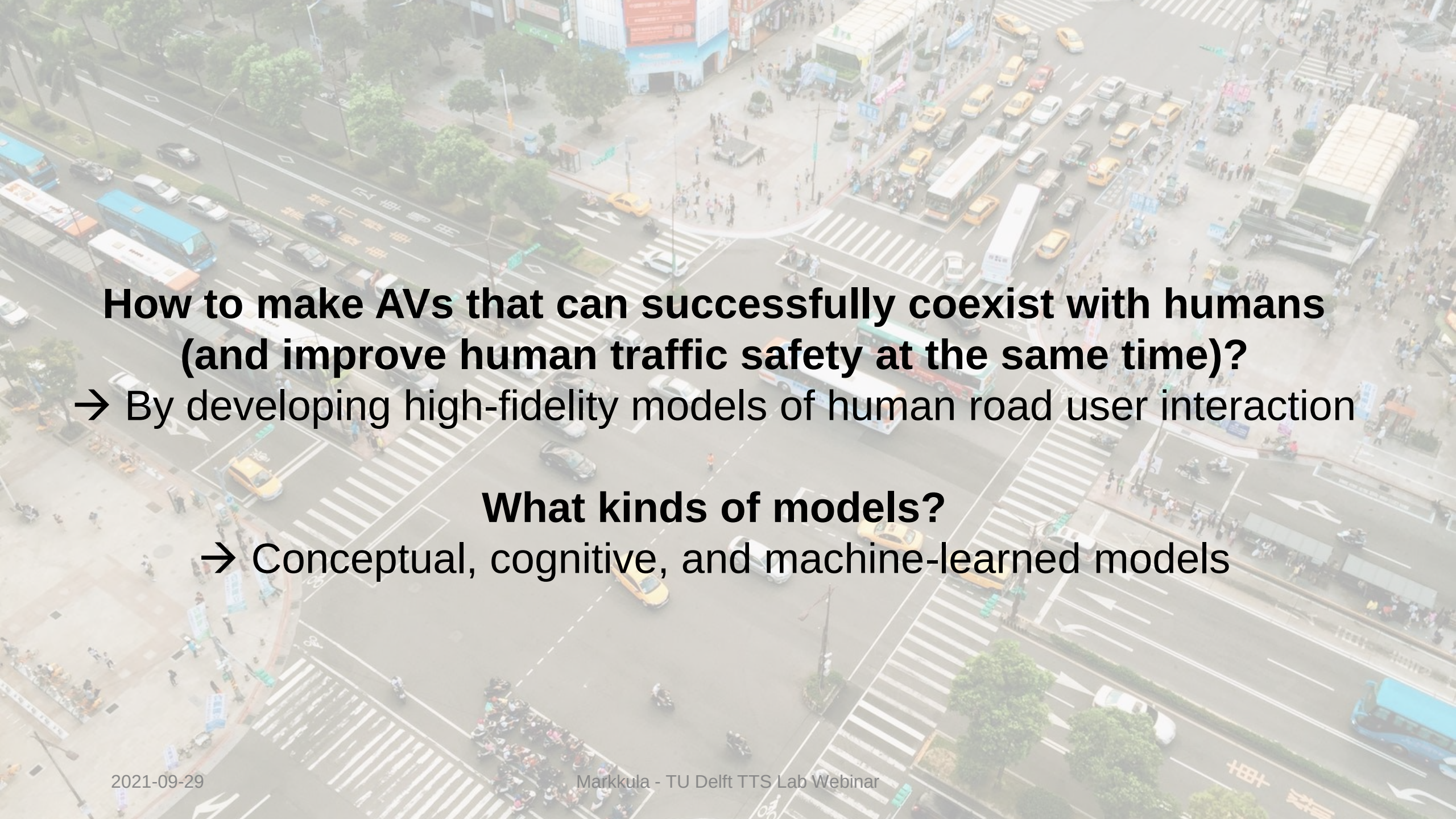


European Commission

COMMOTIONS




UKRI Engineering and Physical Sciences Research Council



How to make AVs that can successfully coexist with humans (and improve human traffic safety at the same time)?

→ By developing high-fidelity models of human road user interaction

What kinds of models?

→ Conceptual, cognitive, and machine-learned models

AV deployment: two main risks

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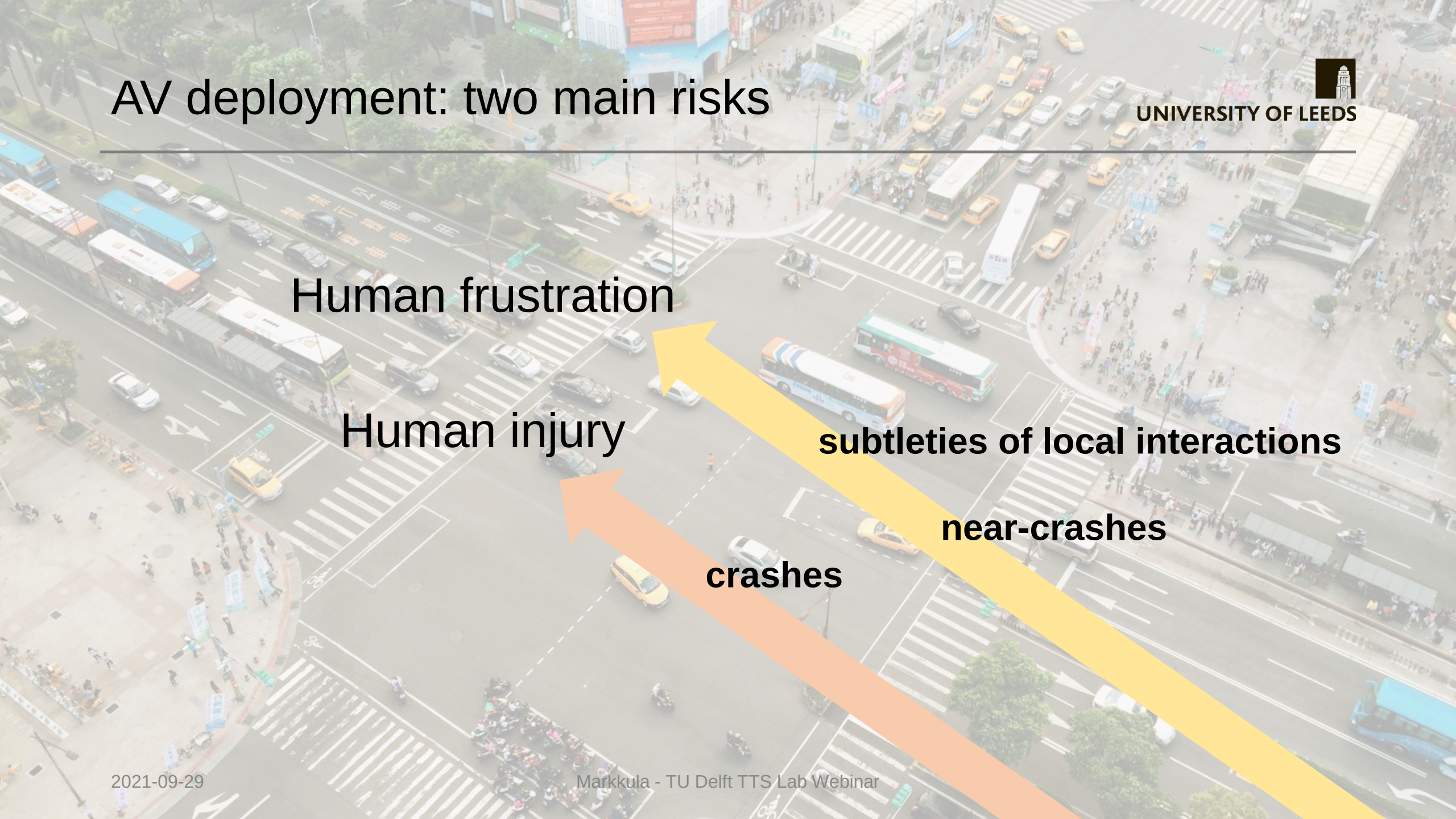

Human-human interaction failures in crashes

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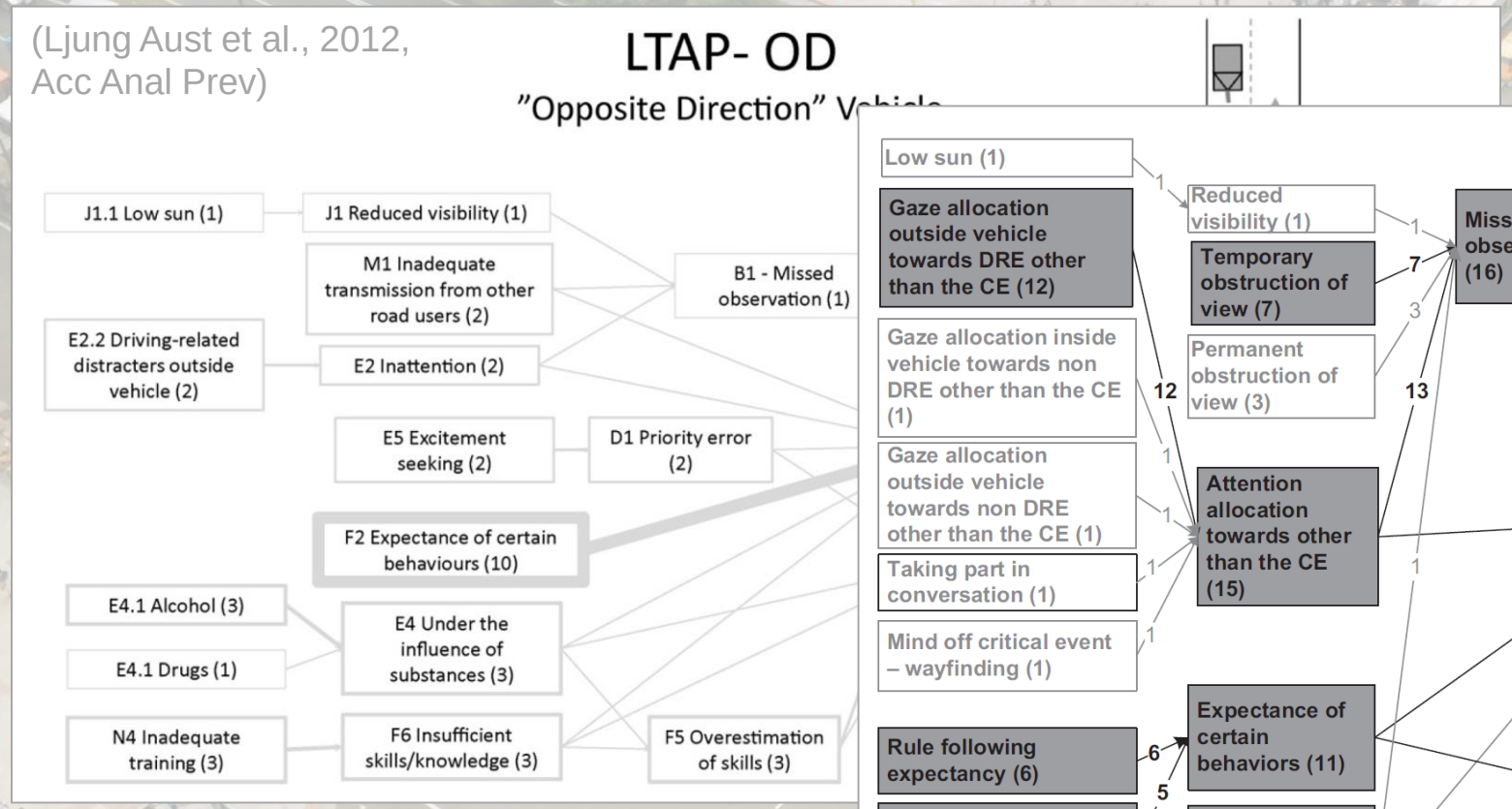
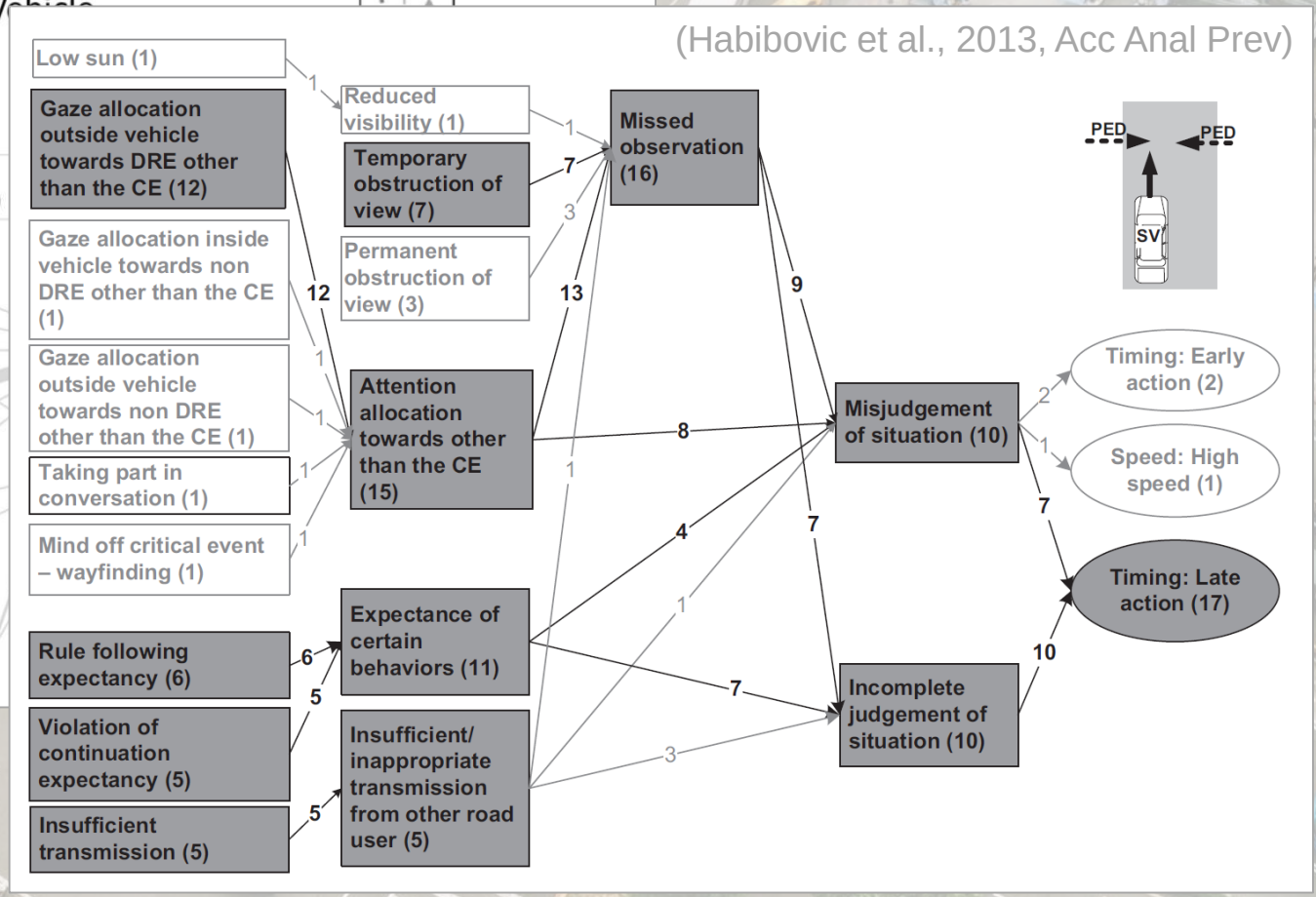
(Ljung Aust et al., 2012, Acc Anal Prev)

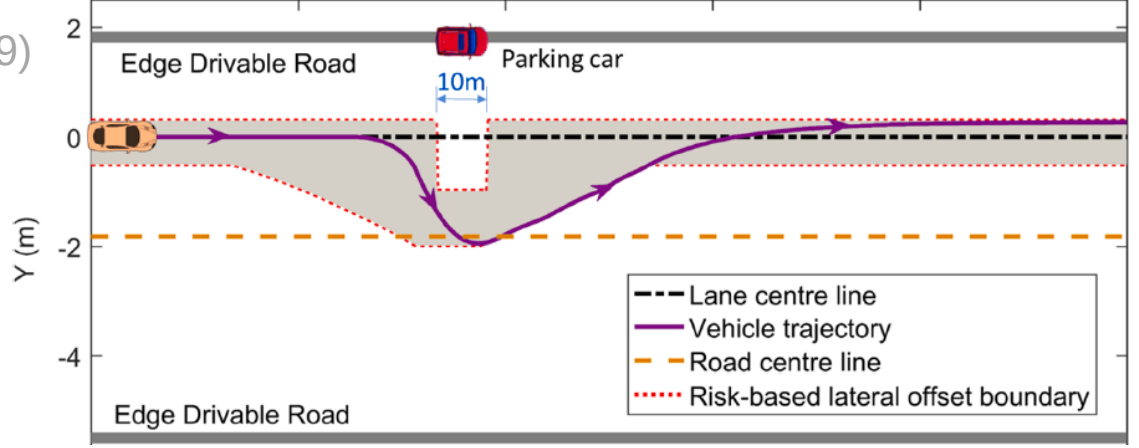


(Habibovic et al., 2013, Acc Anal Prev)

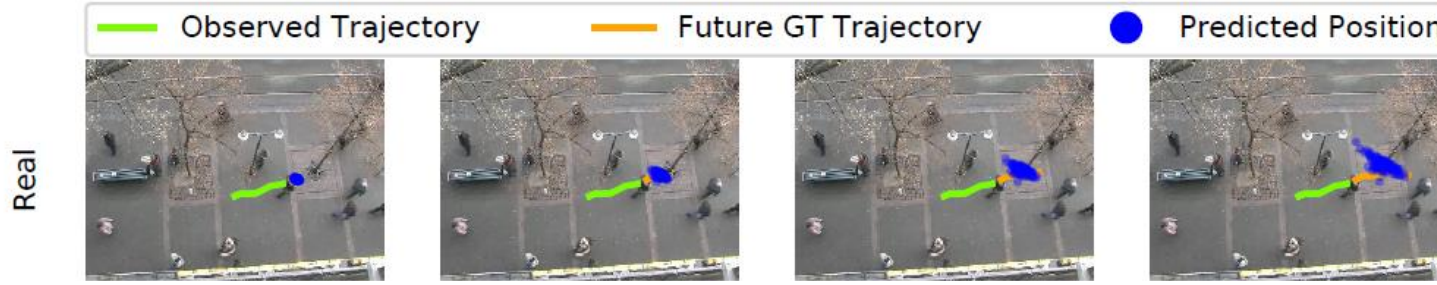


Why high-fidelity models of human interactions for AVs?

(Wei et al., 2019)



(Anderson et al., 2019)



To make...

- ... AVs drive like humans?
- ... online AV predictions about human behaviour
- ... agents for virtual environments, for simulated AV testing

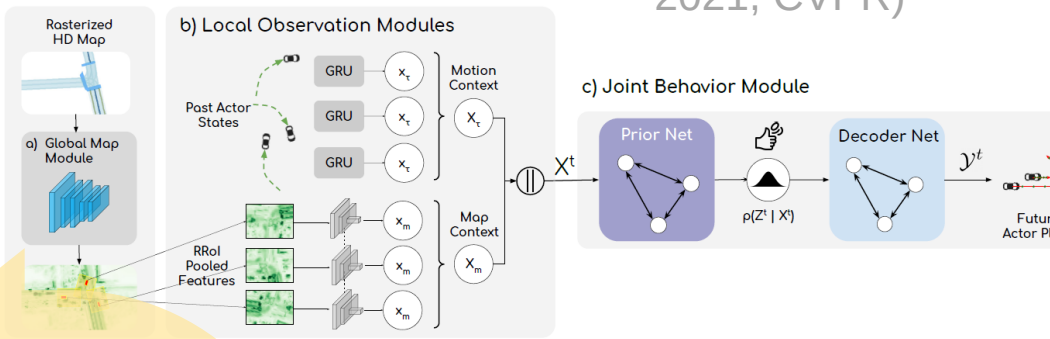
(Waymo Safety Report 2020)

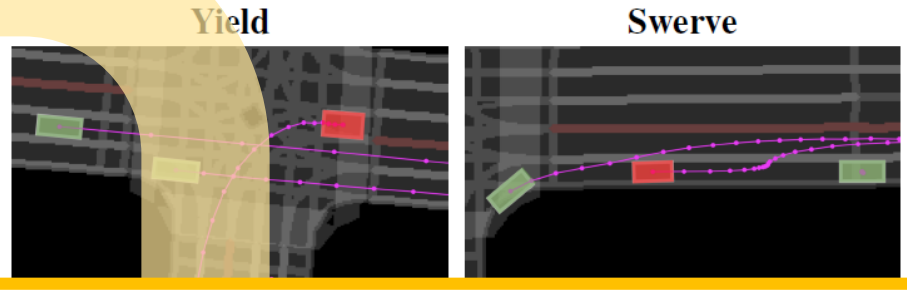
Also clear applied uses in human traffic safety…

Machine-learned (data-driven) models

(Suo et al., 2021, CVPR)

- Achieve realistic-looking routine traffic
- Challenges in relation to ”main risks”:
  - Human behaviour in (near-)crashes
    Very rare in any real-traffic dataset
  - Human behaviour in local interactions
    How do we know models are capturing the important subtleties?

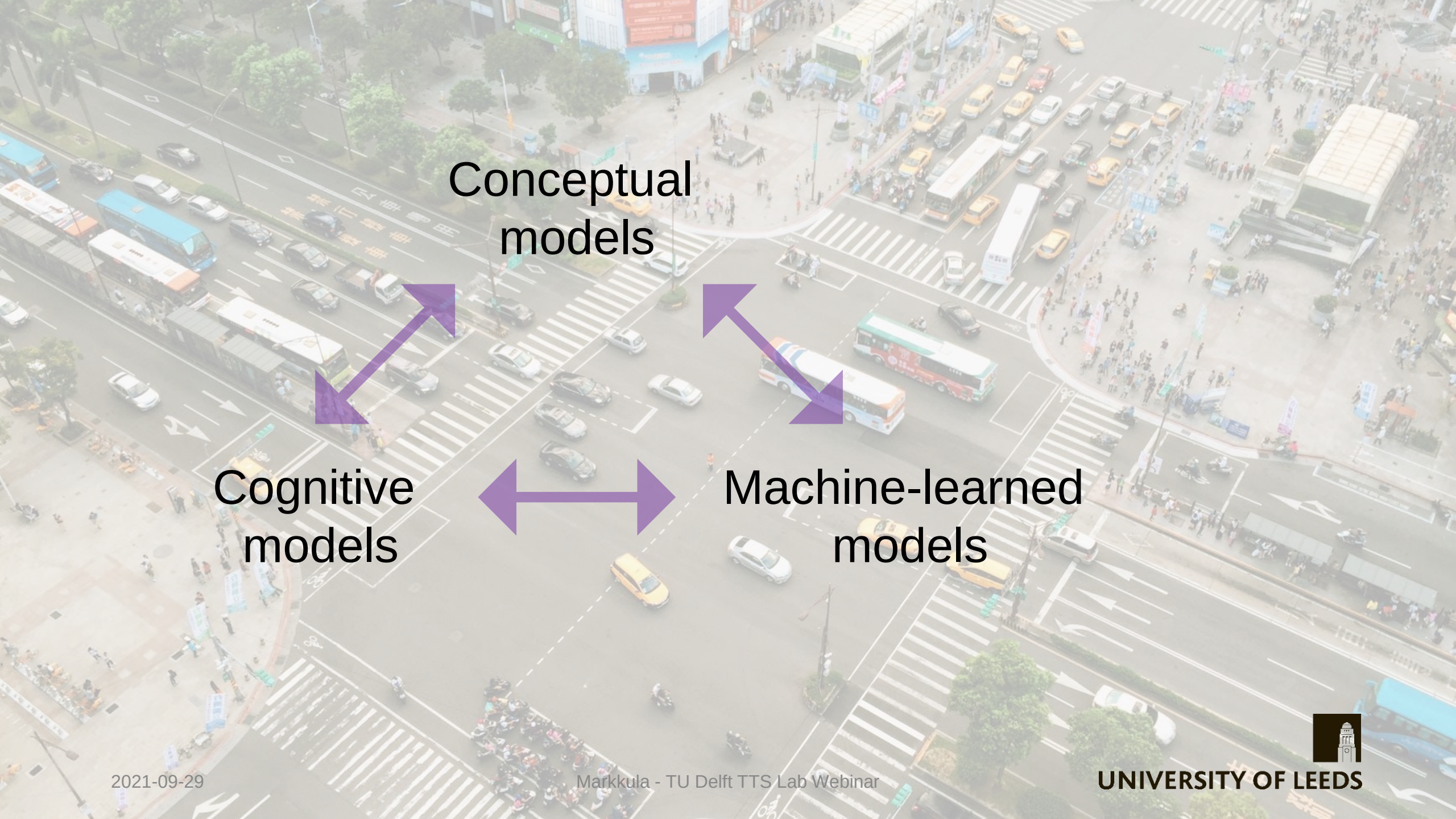




→ **Complement with**
- conceptual models
- cognitive models

Insight into how mechanisms generalise

Model ⇄ Controlled experiment


Conceptual models
Cognitive models
Machine-learned models

Conceptual models

- What is “interaction”?
- What behaviours do human road users exhibit in interactions?
- What factors shape these behaviours, and how?
- …?

Cognitive models

Machine-learned models

Defining interaction

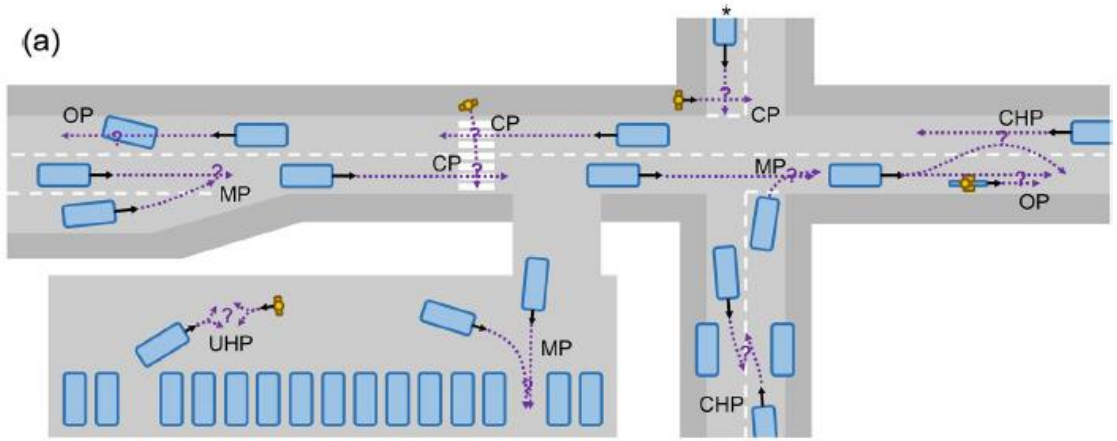
Traffic conflict/safety perspectives

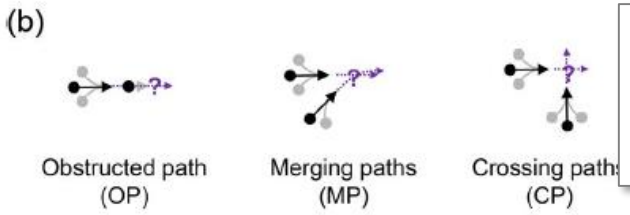
Game-theoretic perspectives

Sociological perspectives

Communication/ linguistics perspectives

Collision avoidance, order of access, reciprocity, coordination, communication



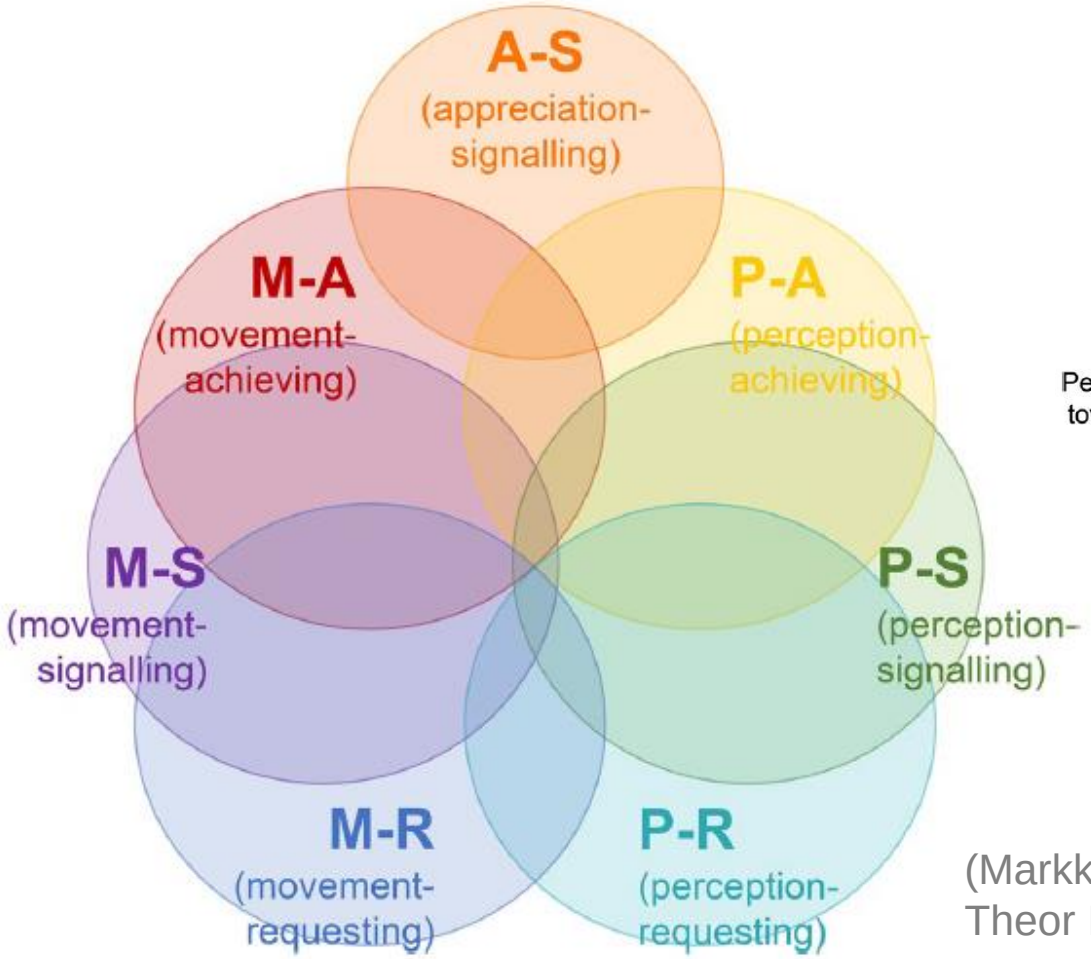


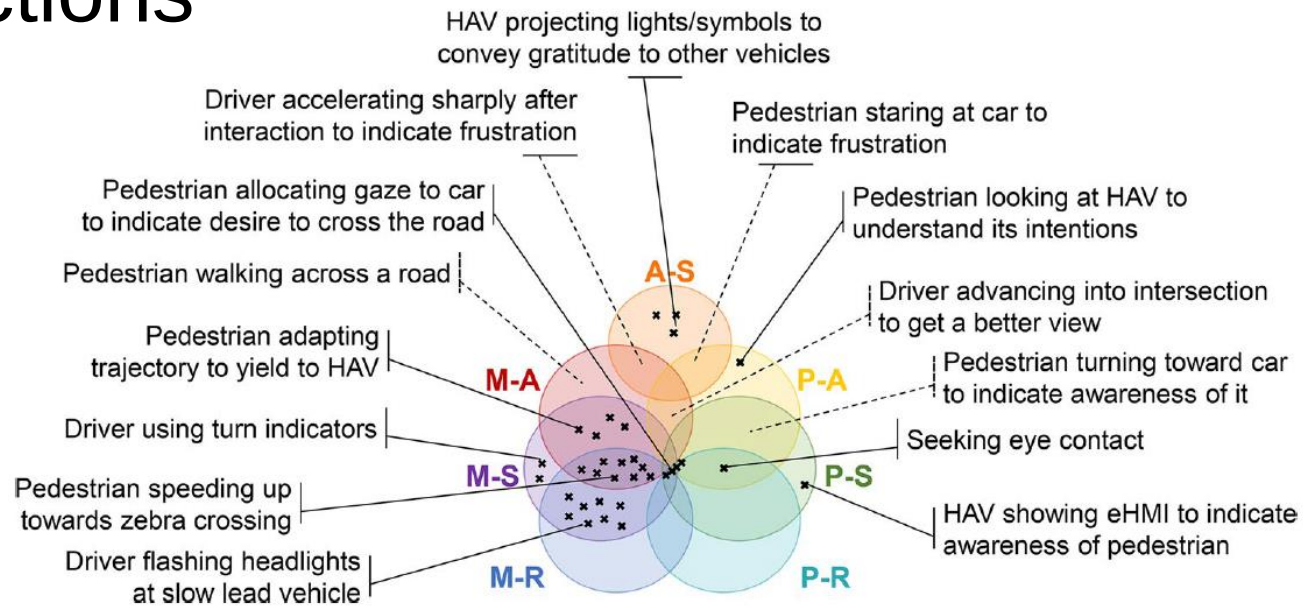
Space-sharing conflict: An observable situation from which it can be reasonably inferred that two or more road users are *intending to occupy the same region of space at the same time* in the near future.

Interaction: A situation where the behaviour of at least two road users can be interpreted as being influenced by a space-sharing conflict between the road users.

(Markkula et al., 2020, Theor Iss Erg Sci; link)

Human behaviour in interactions





(Markkula et al., 2020, Theor Iss Erg Sci)

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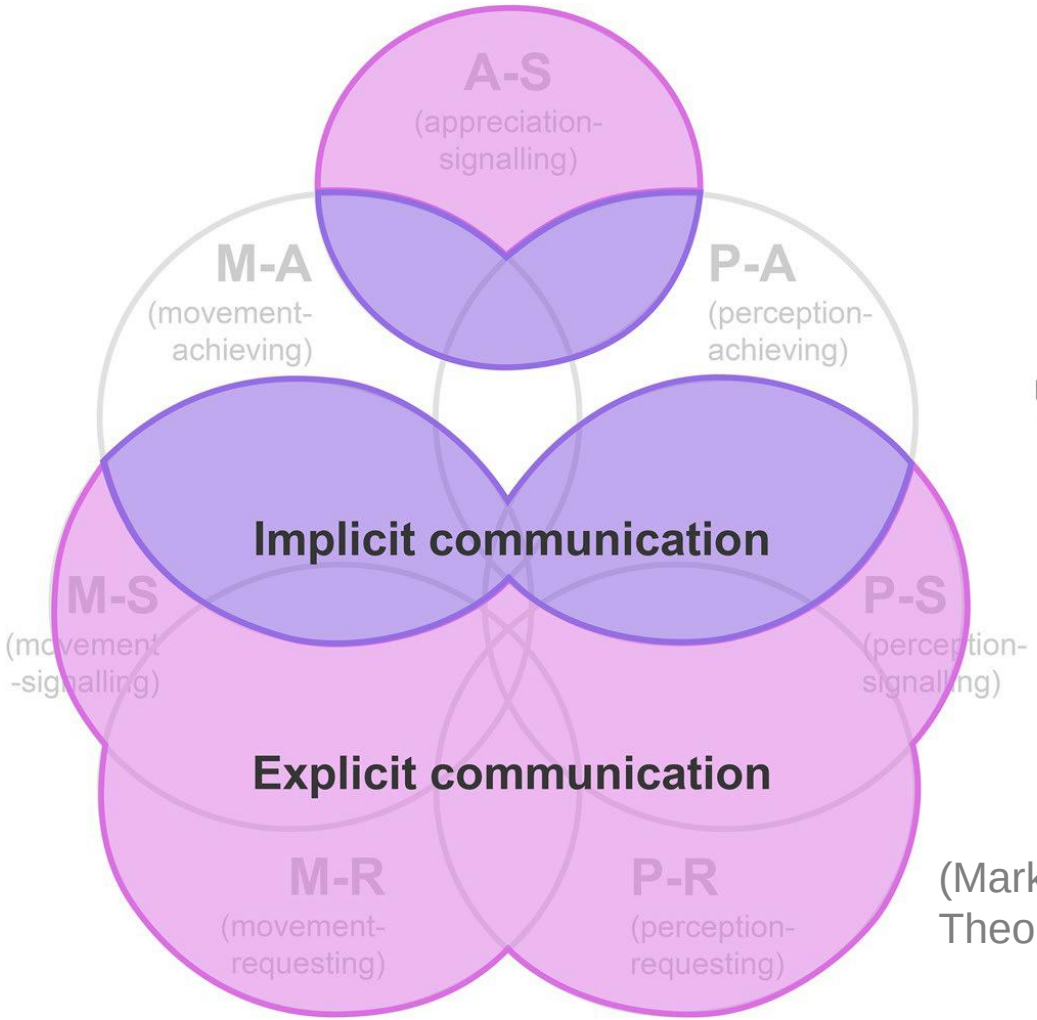
Human behaviour in interactions



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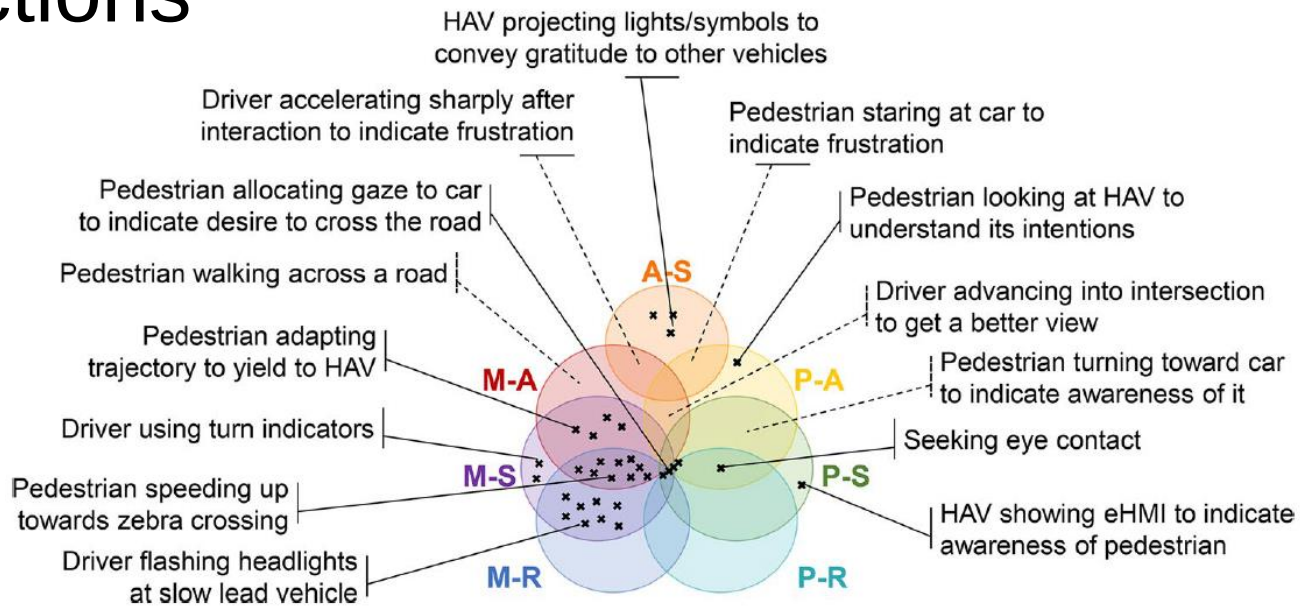
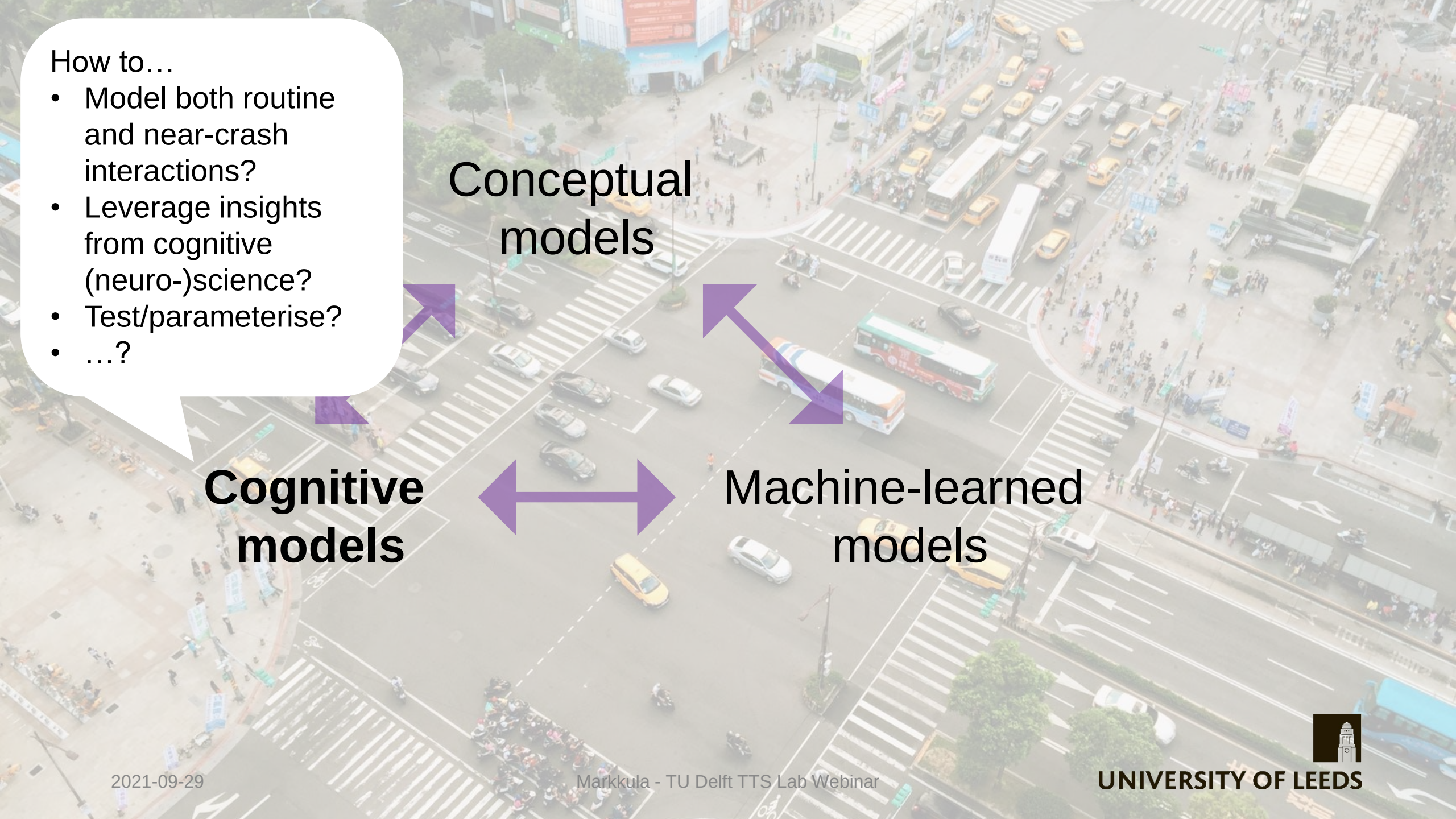


See also:
Domeyer et al. (2020, IEEE Access)
Thalya et al. (2020, Proc TRA)

How to…

- Model both routine and near-crash interactions?
- Leverage insights from cognitive (neuro-)science?
- Test/parameterise?
- …?



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Framework for routine and near-crash driving

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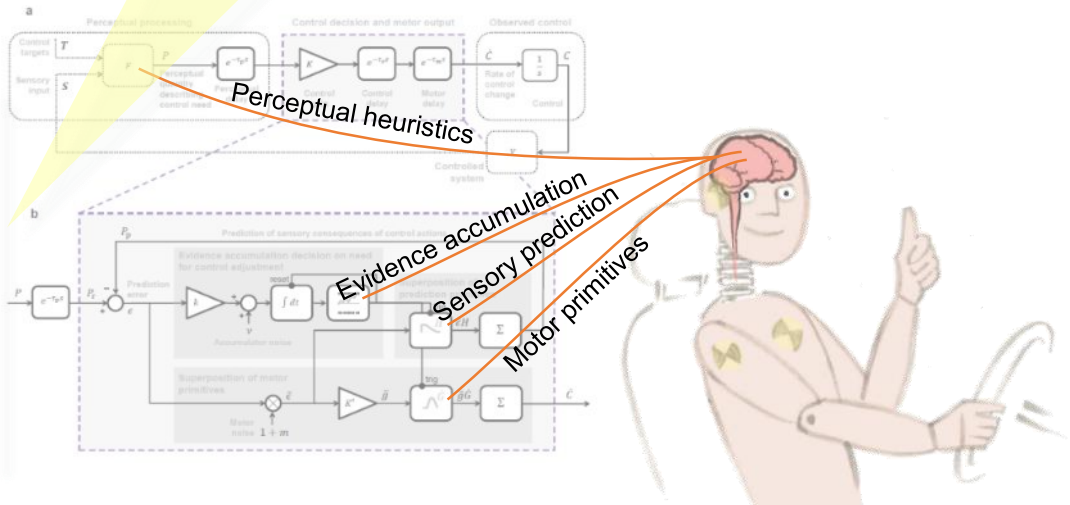
#2. Accumulation of evidence of various kinds

#1. Intermittent (motor primitive) adjustments

#3. Magnitude heuristics tuned to routine driving

#4. Sensory predictions

Routine driving	**Near-crash driving**
Closed-loop	Open-loop
Short delays	Long, random delays
Well-adjusted control	Under- and overreactions



(Markkula, 2014, 2015; Markkula et al, 2018)

Explains behavioural (and neural) responses in routine + near-crash situations

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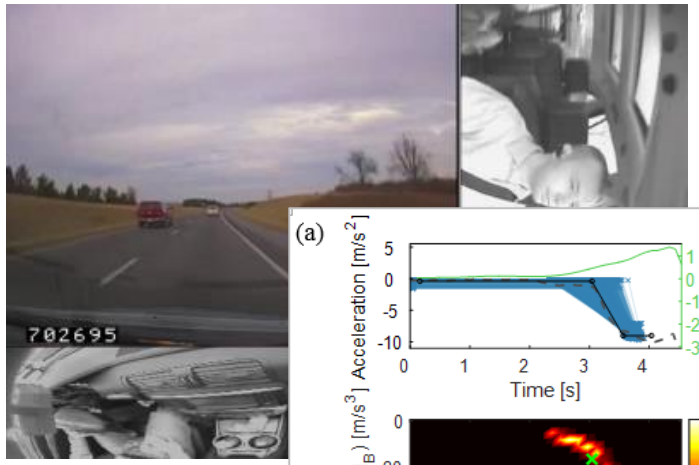
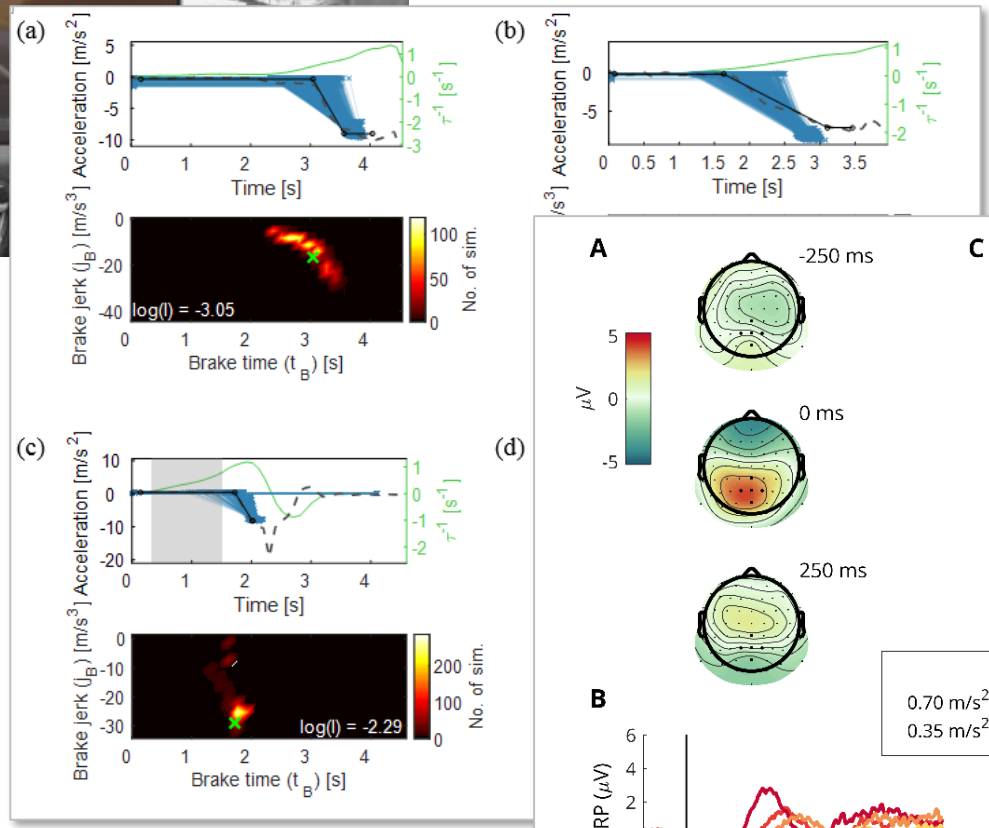
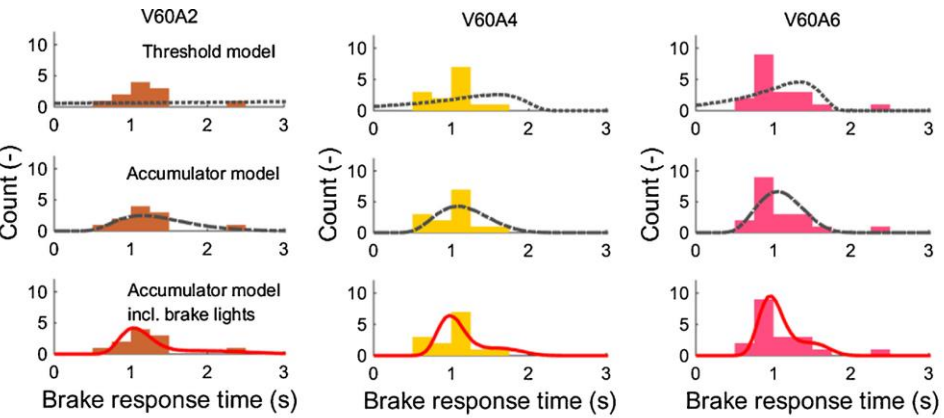


(Victor et al, 2015, SHRP2 report)

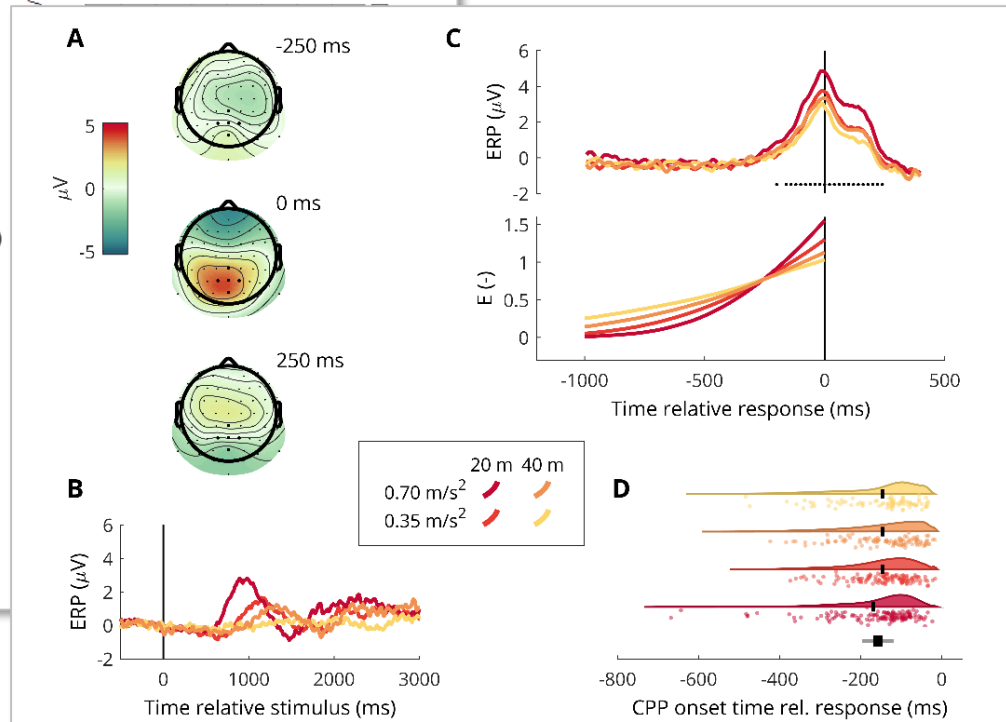
(Svärd et al., accepted, Acc Anal Prev)



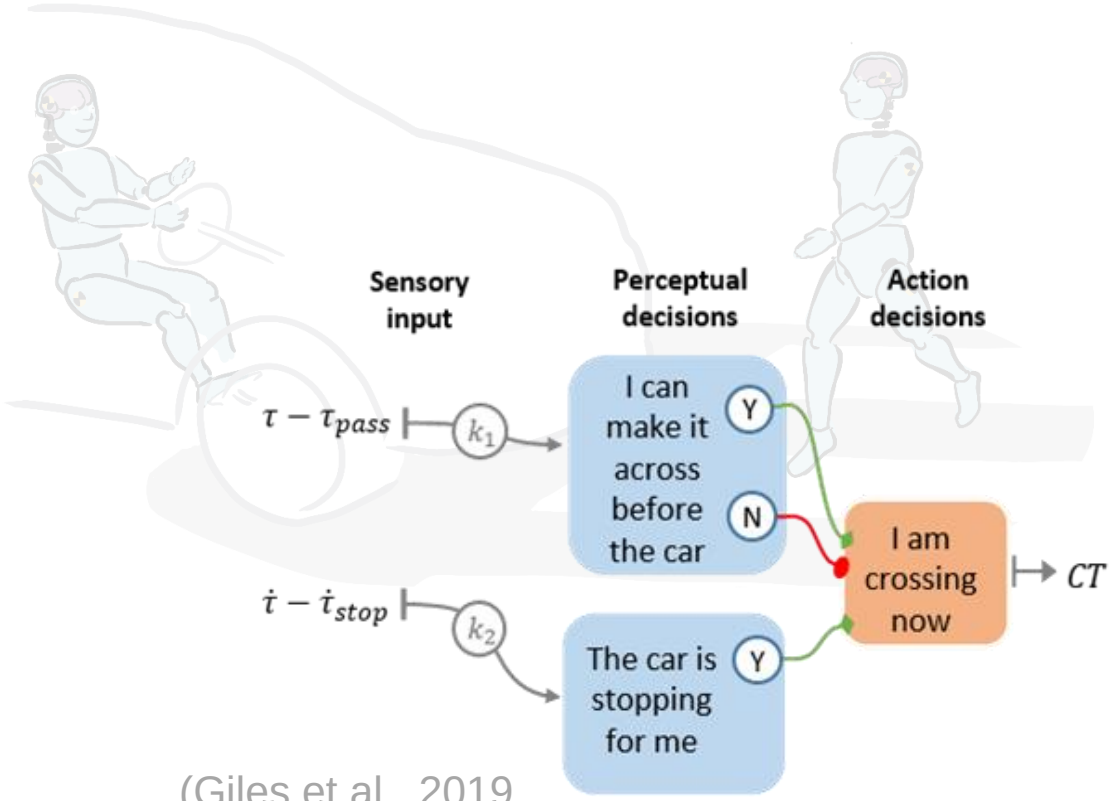
(Markkula et al., 2021, PLOS Comp Biol)



(Xue et al., 2018, Acc Anal Prev)



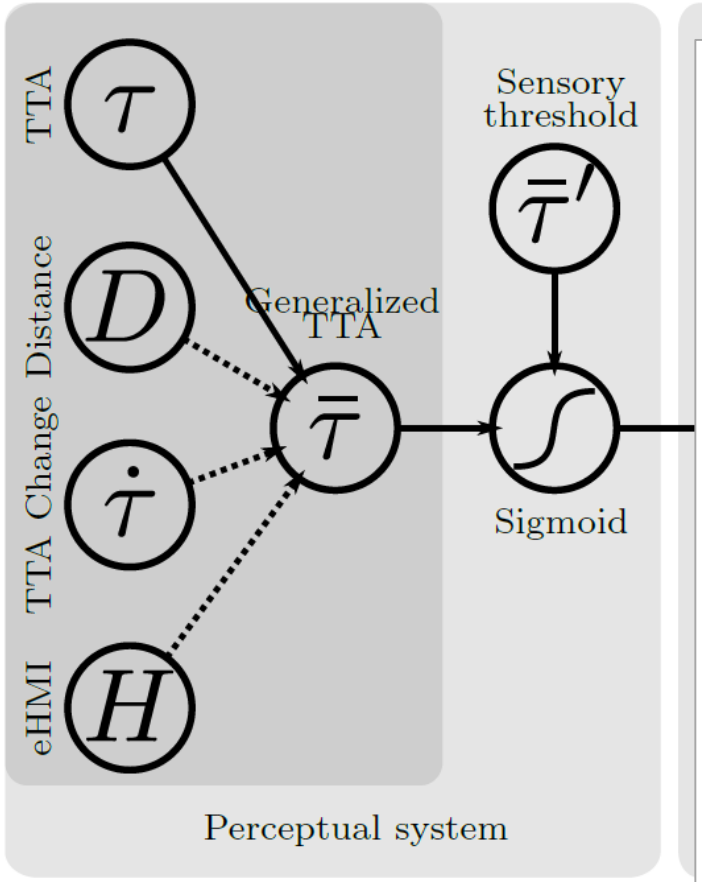
Generalising to road user interactions

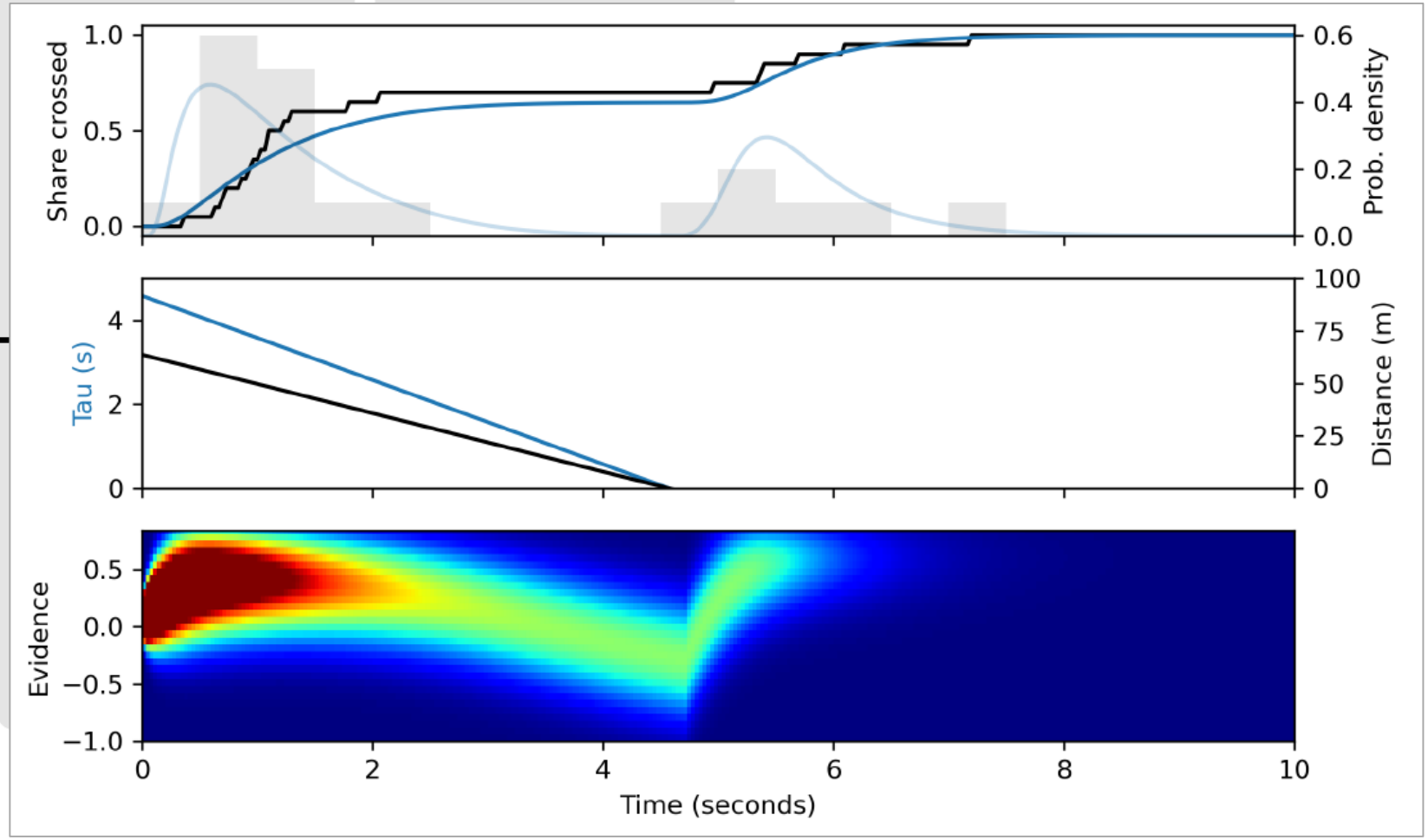


(Giles et al., 2019, Proc CogSci)

(Pekkanen et al., 2021, Comp Brain & Beh, preprint link)

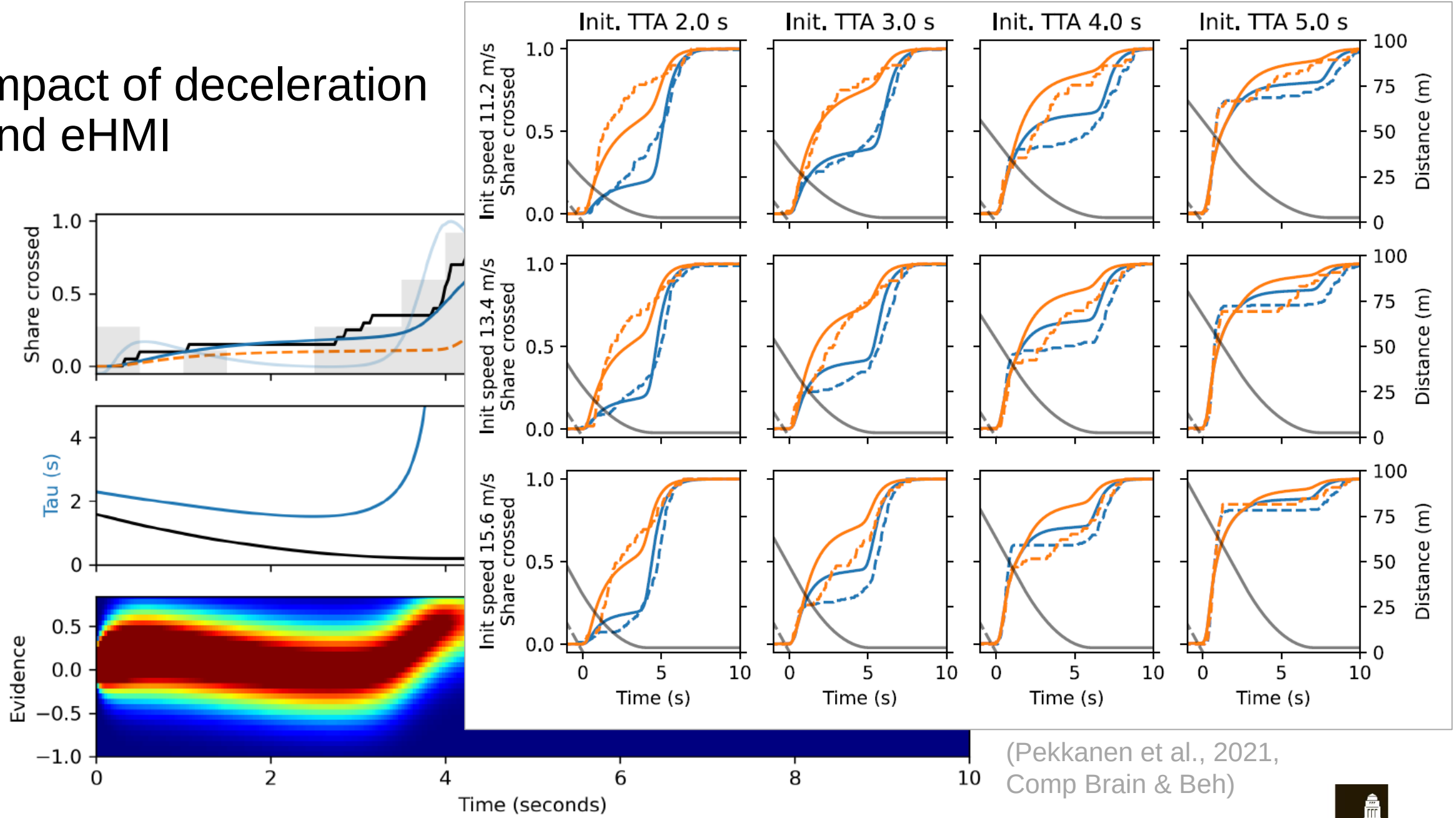
Variable-drift diffusion model





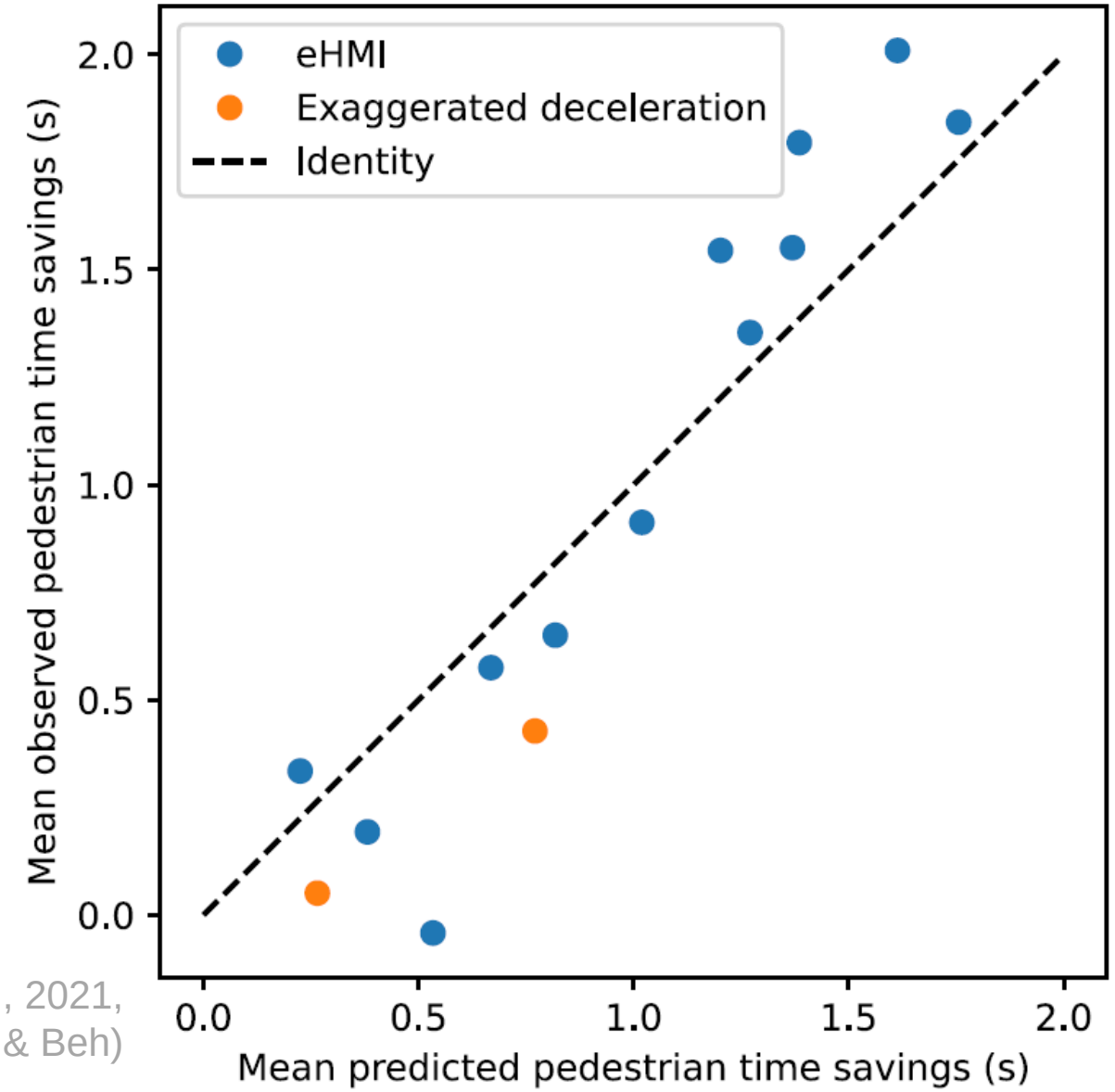
(Pekkanen et al., 2021, Comp Brain & Beh)

Impact of deceleration and eHMI



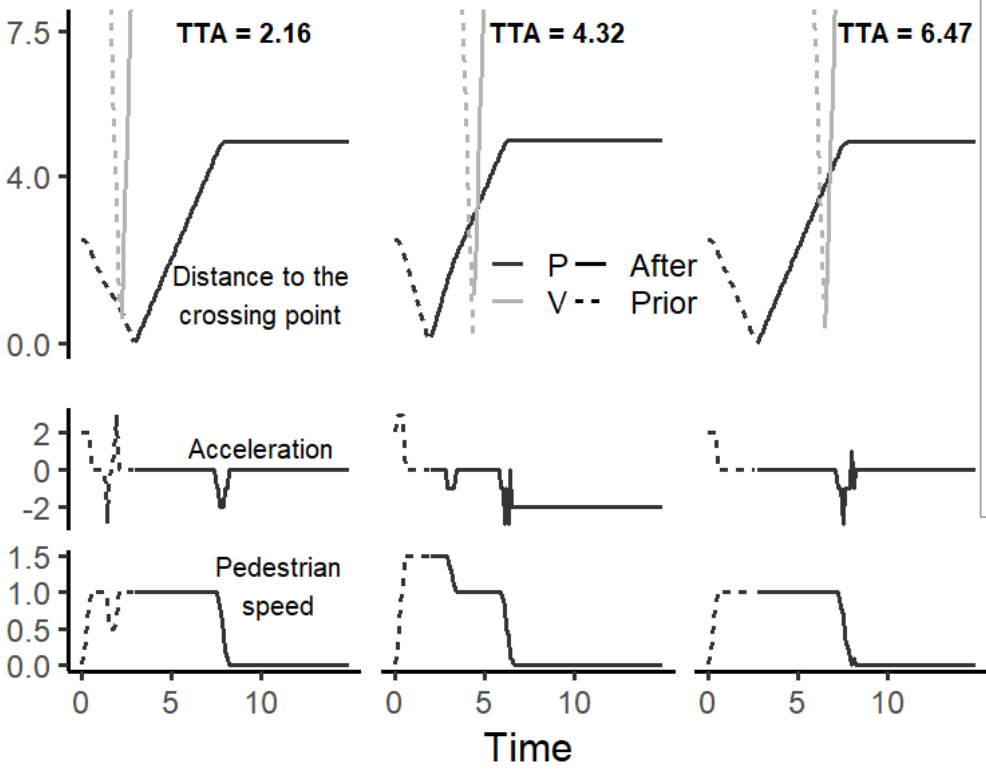
(Pekkanen et al., 2021, Comp Brain & Beh)

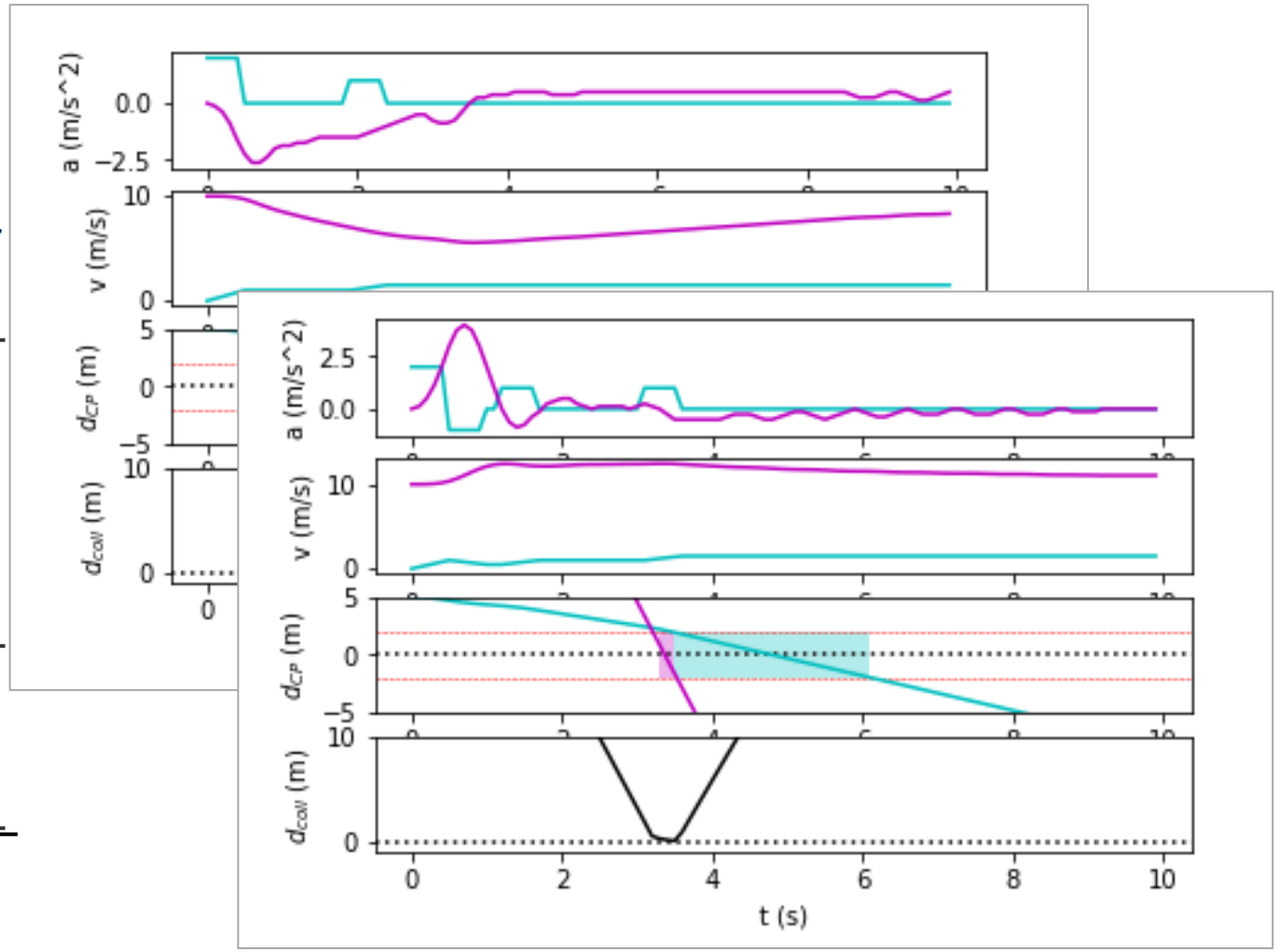
Predicting AV interaction efficiency



(Pekkanen et al., 2021, Comp Brain & Beh)

Beyond single decisions





What model assumptions are needed to achieve what behavioural phenomena?

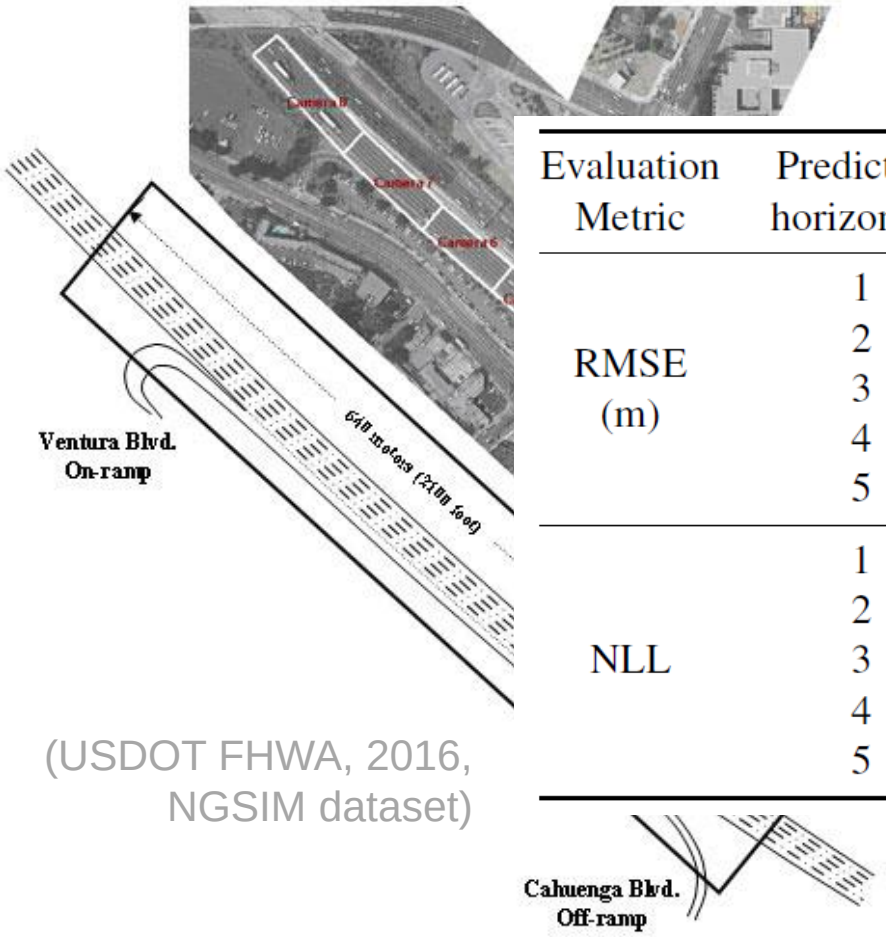
Conceptual models

Cognitive models

Machine-learned models

- Do they generalise to near-crash situations?
- Can we improve them using (insights from) cognitive models?
- Do the models behave like humans in the “important ways”?
- …?

CSP-LSTM prediction of highway driving



(USDOT FHWA, 2016, NGSIM dataset)

Evaluation Metric	Prediction horizon (s)	CV	C-VGMM + VIM [6]	GAIL-GRU [13]	V-LSTM	S-LSTM	CS-LSTM	CS-LSTM(M)
RMSE (m)	1	0.73	0.66	0.69	0.68	0.65	**0.61**	0.62
	2	1.78	1.56	1.51	1.65	1.31	**1.27**	1.29
	3	3.13	2.75	2.55	2.91	2.16	**2.09**	2.13
	4	4.78	4.24	3.65	4.46	3.25	**3.10**	3.20
	5	6.68	5.99	4.71	6.27	4.55	**4.37**	4.52
NLL	1	3.72	2.02	-	1.17	1.01	0.89	**0.58**
	2	5.37	3.63	-	2.85	2.49	2.43	**2.14**
	3	6.40	4.62	-	3.80	3.36	3.30	**3.03**
	4	7.16	5.35	-	4.48	4.01	3.97	**3.68**
	5	7.76	5.93	-	4.99	4.54	4.51	**4.22**

(Deo and Trivedi, 2018, CVPR)

Kinematical lead/lag and order of access

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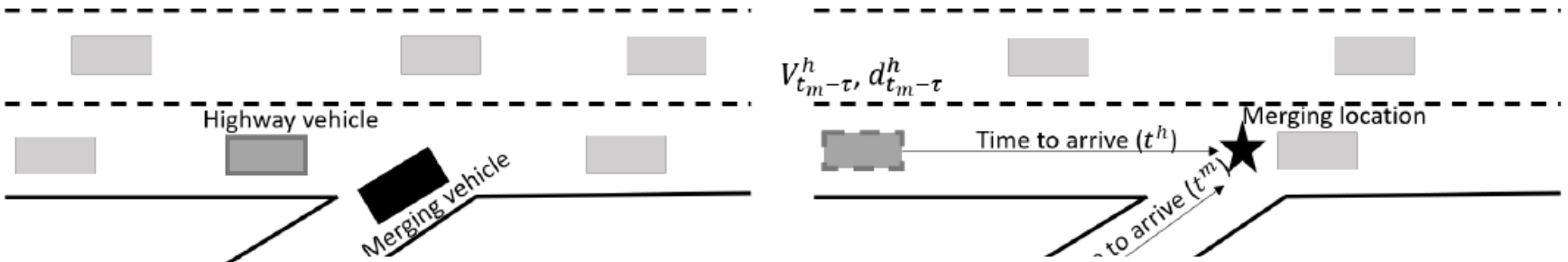
(Srinivasan et al., 2021, Proc IEEE ITSC, preprint link)



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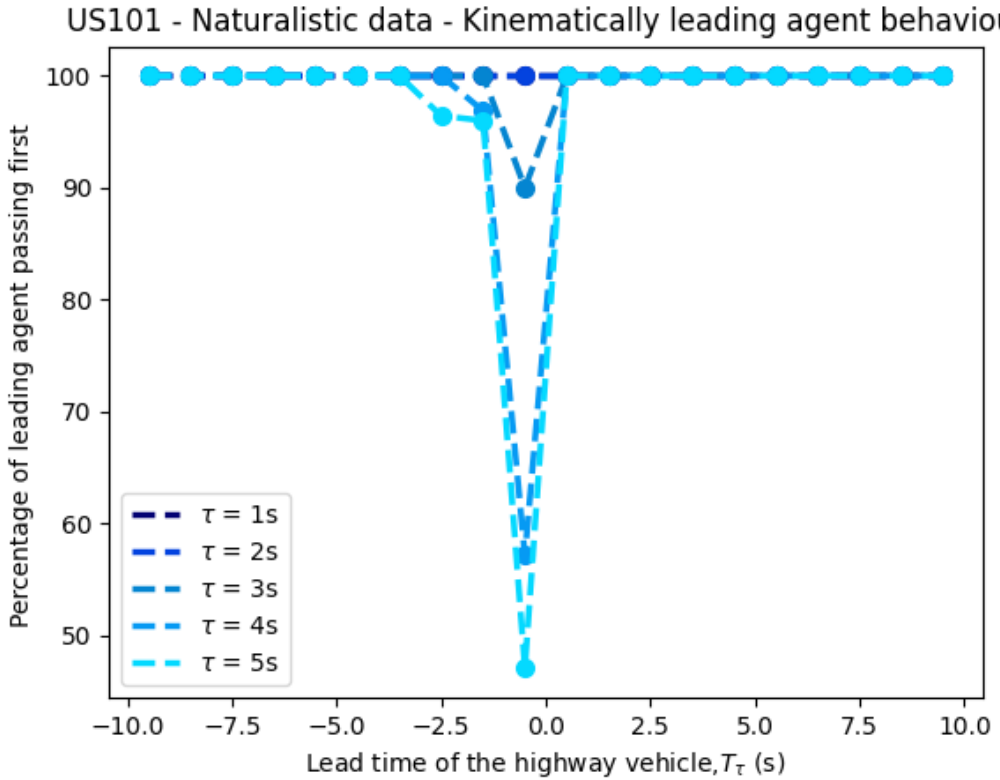

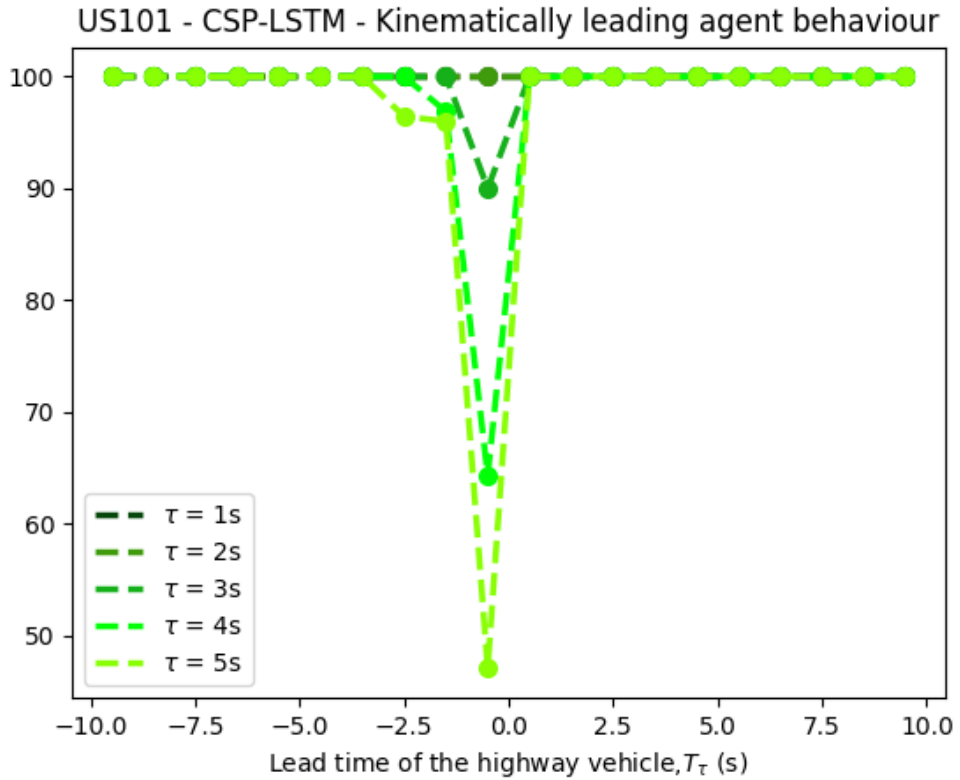

Courtesy lane changes

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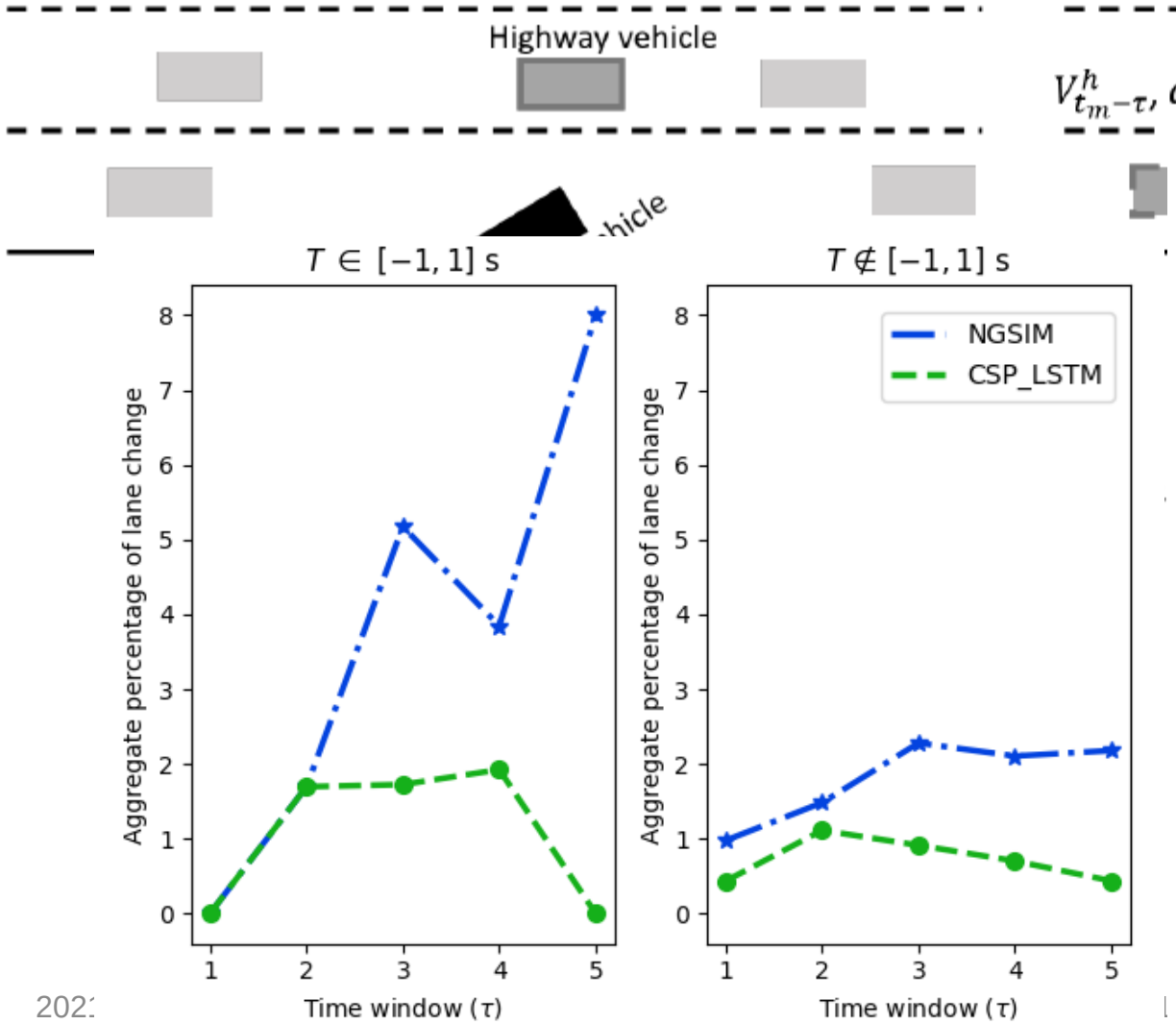
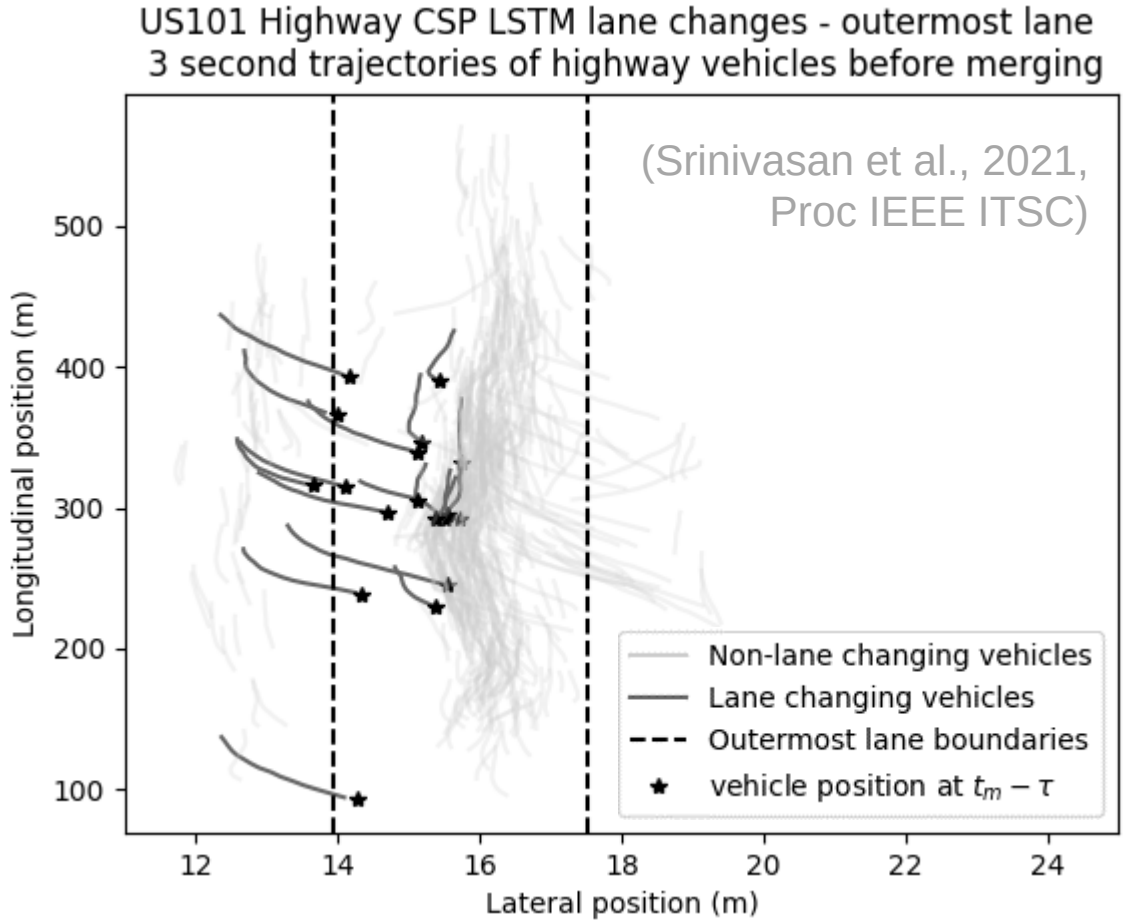
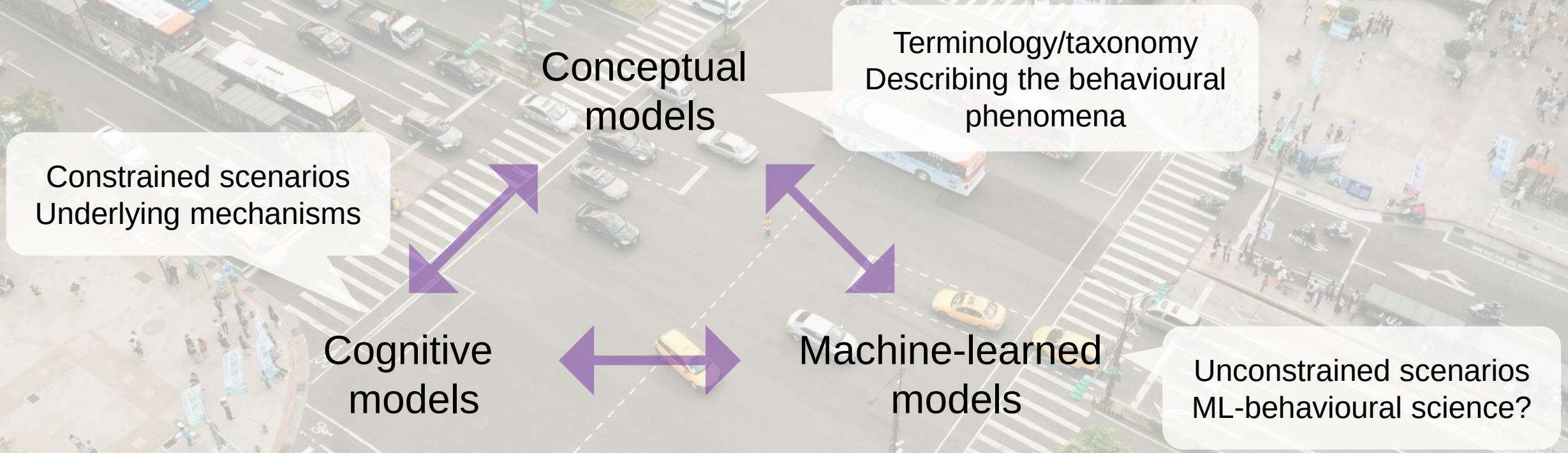




Safe and acceptable AVs – and improved human traffic safety – requires complementary models of different types



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Thanks for listening!

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