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# Modeling human-AV interactions for safety and acceptance of automated vehicles

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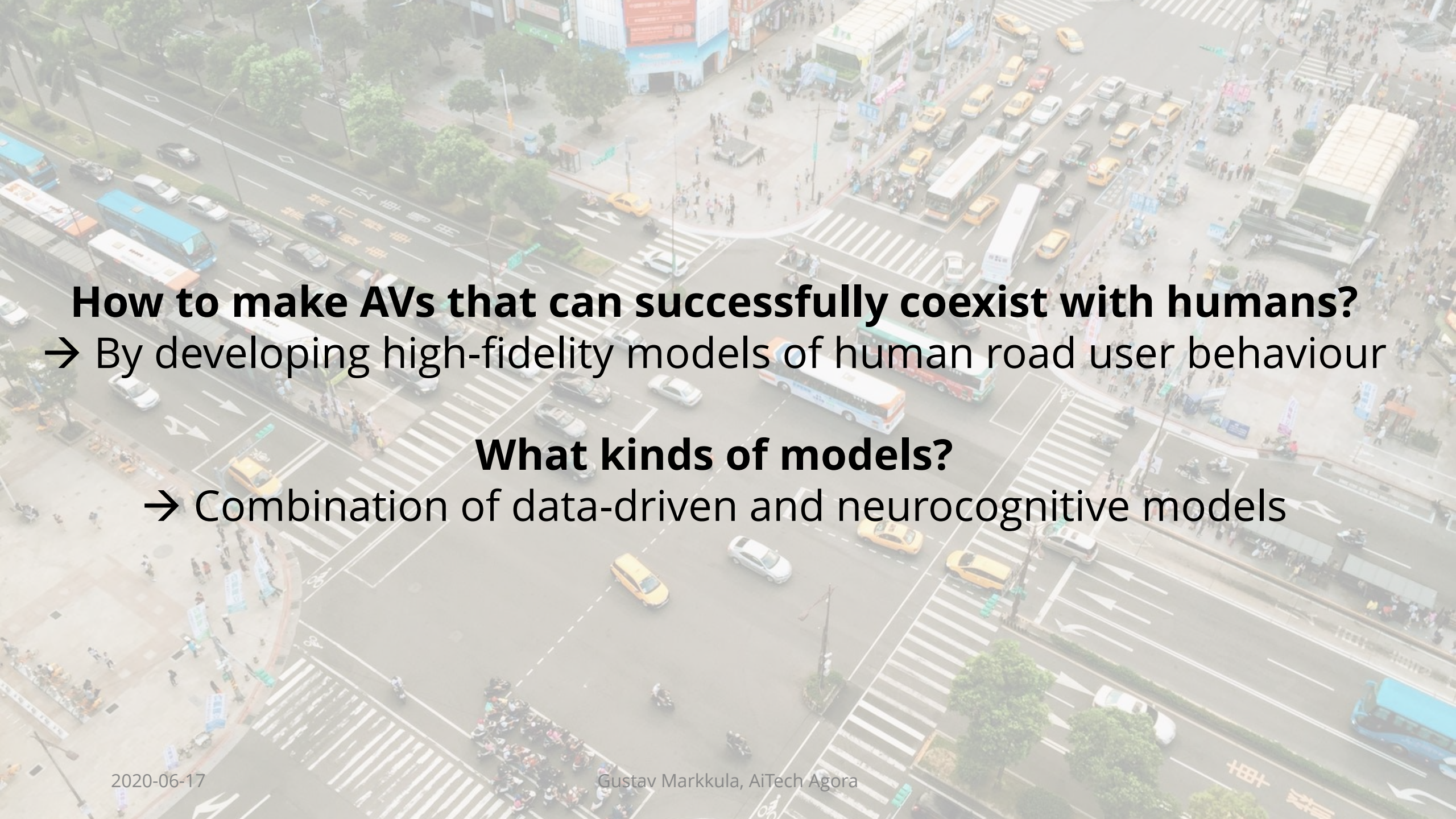

**How to make AVs that can successfully coexist with humans?**

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

**What kinds of models?**

→ Combination of data-driven and neurocognitive models


To what extent are these situations examples of **meaningful human control of automation**?

- A road user effectively interacting with an AV, transparently affecting the behaviour of the AV with their own behaviour
- An engineer studying and adjusting how an AV will interact with humans, using computer simulations across wide ranges of scenarios

# AV deployment: two main risks

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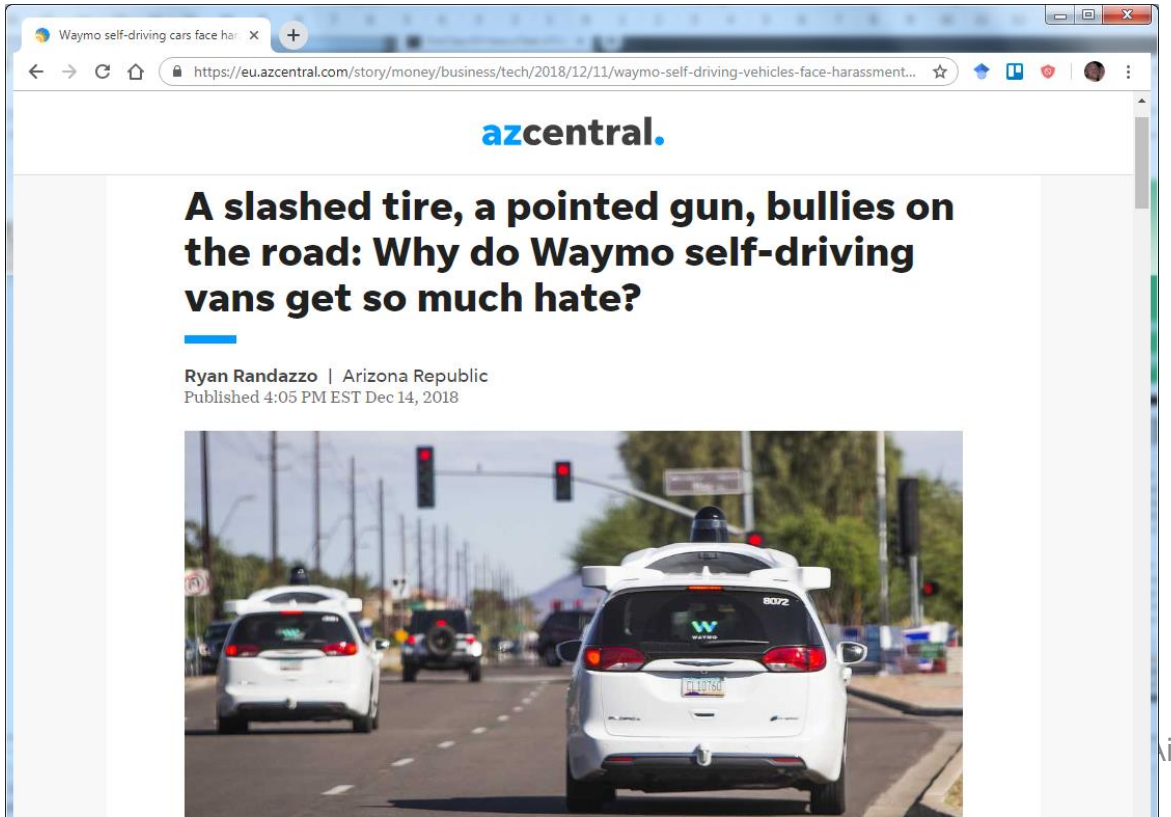
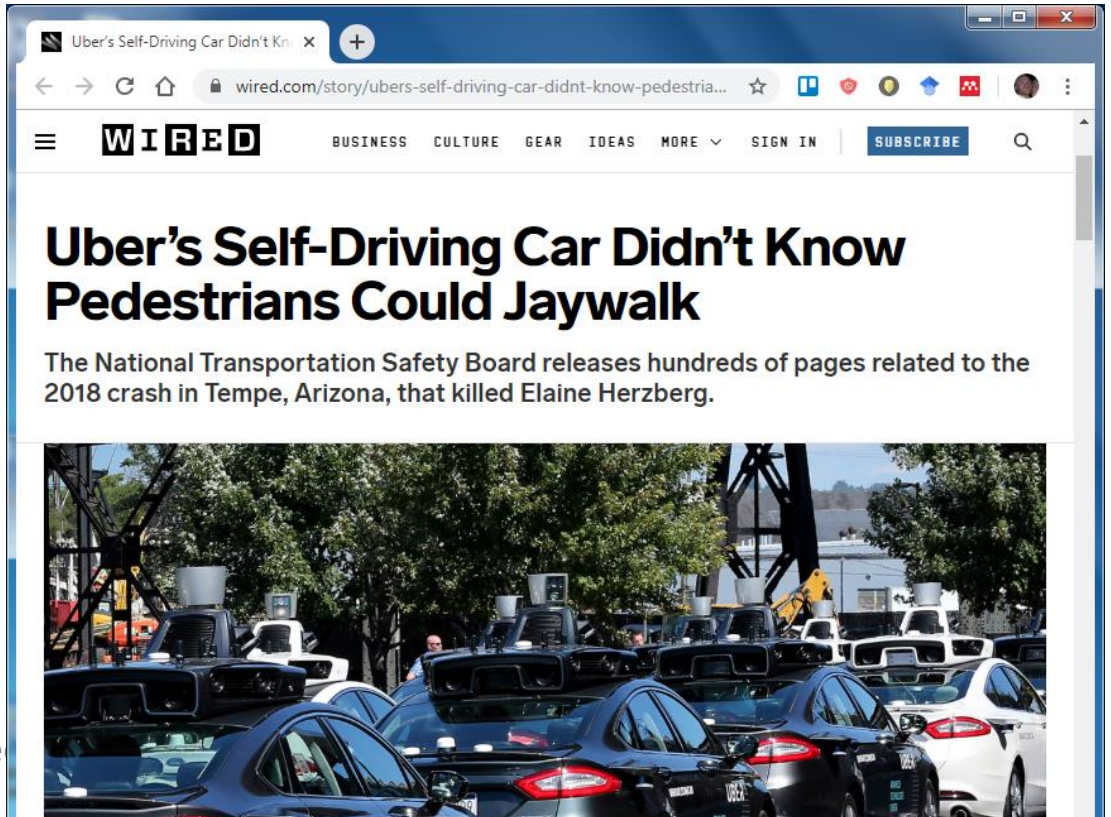
- Human frustration ← subtleties of local interactions, near-crashes
- Human injury ← crashes



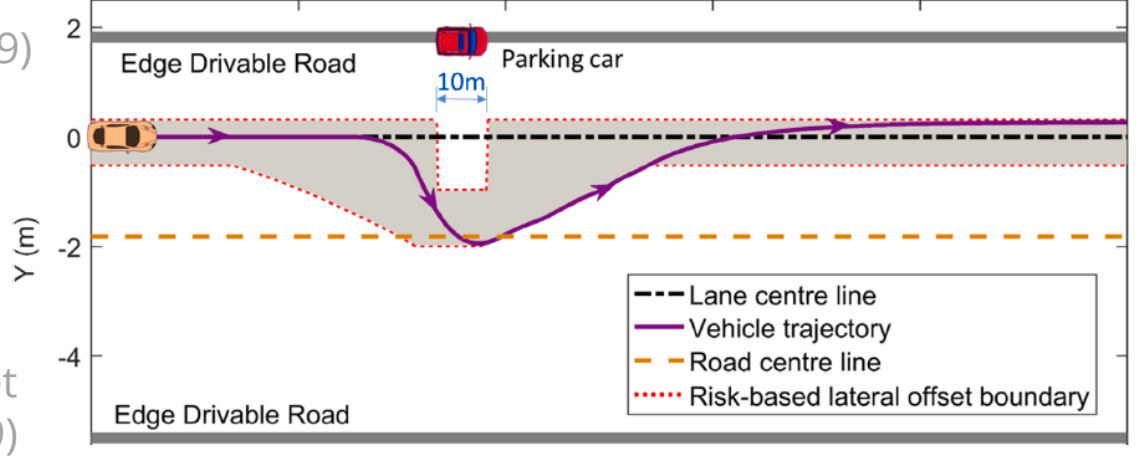
# Why high-fidelity models of human behaviour?

To make…

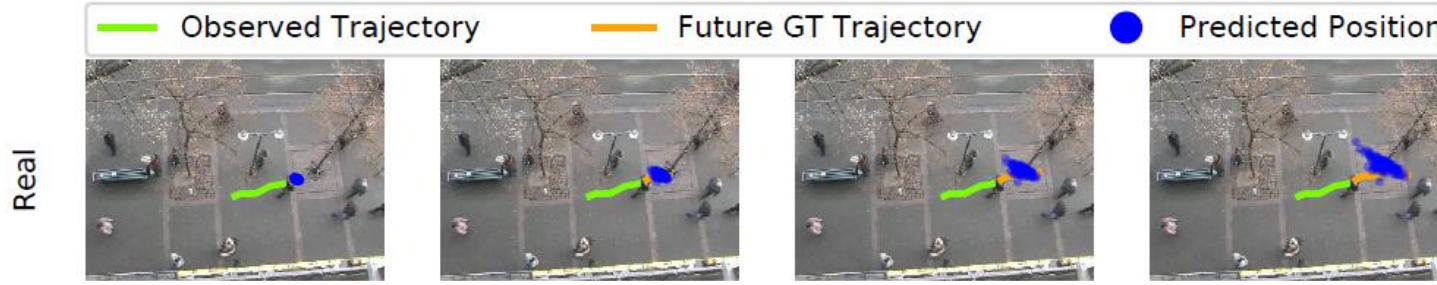
- … AVs drive like humans?
- … online AV predictions about human behaviour
- … agents for virtual environments, for simulated AV testing

(Waymo Safety Report, 2018)

(Wei et al., 2019)




(Anderson et al., 2019)

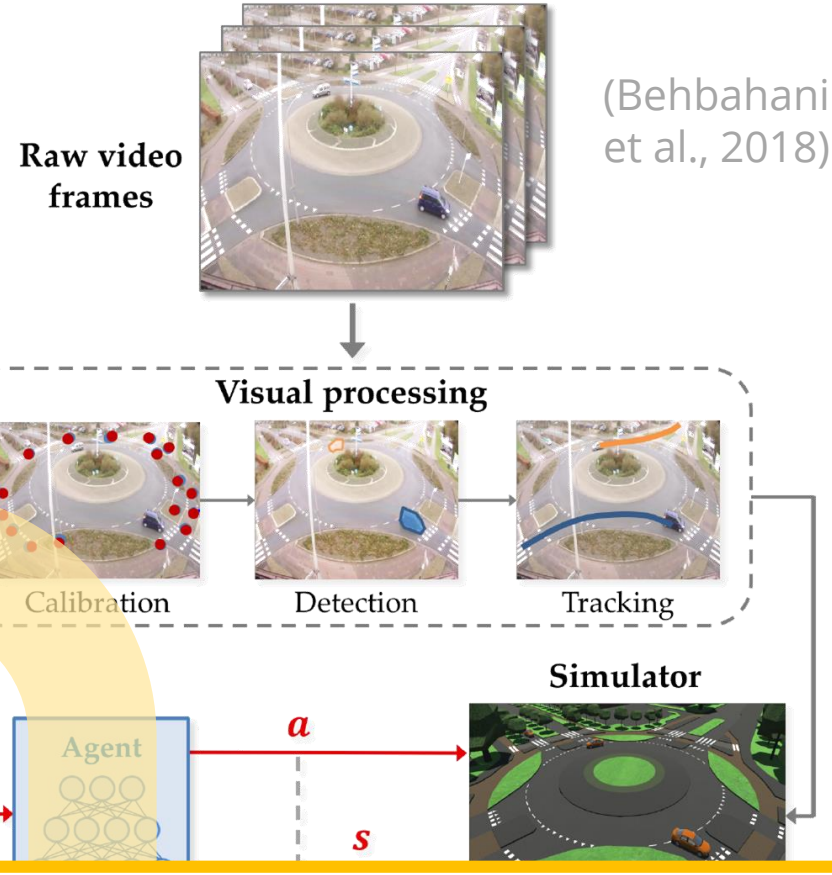



No humans here… ?

# Data-driven models

- 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 white-box neurocognitive models**




(Behbahani et al., 2018)

Insight into how mechanisms generalise

Model ⇄ Controlled experiment

# Framework for routine and (near-)crash driving

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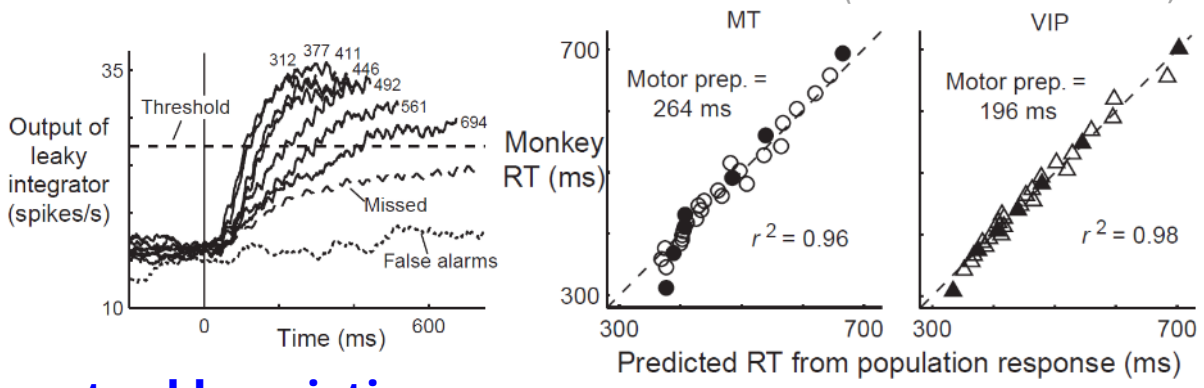
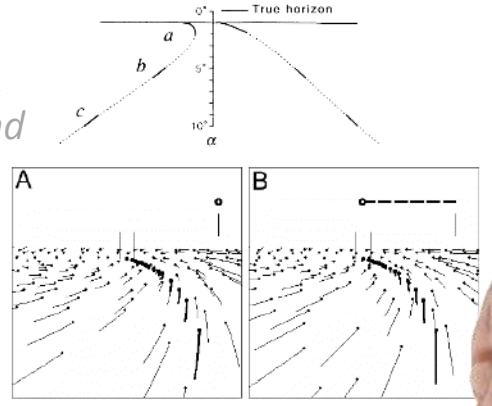
## Evidence accumulation

*(Cook and Maunsell, 2002)*



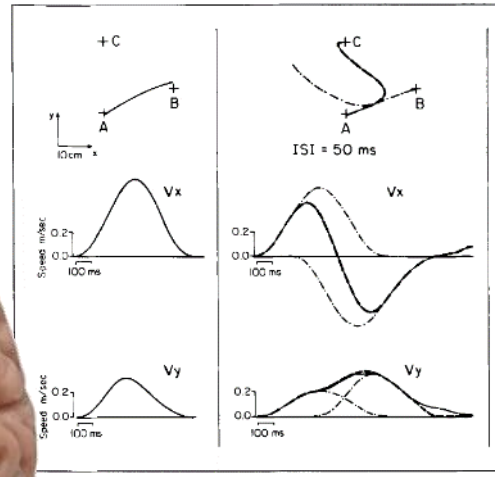

## Perceptual heuristics

*(Land and Horwood, 1995; Wann and Wilkie, 2004; Salvucci and Gray, 2004)*

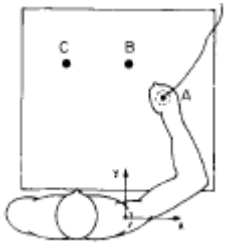



$$\dot{\varphi} = k_f\dot{\theta}_f + k_n\dot{\theta}_n + k_I\theta_n$$

## Motor primitives




*(Flash and Henis, 1991)*



# Framework for routine and (near-)crash driving

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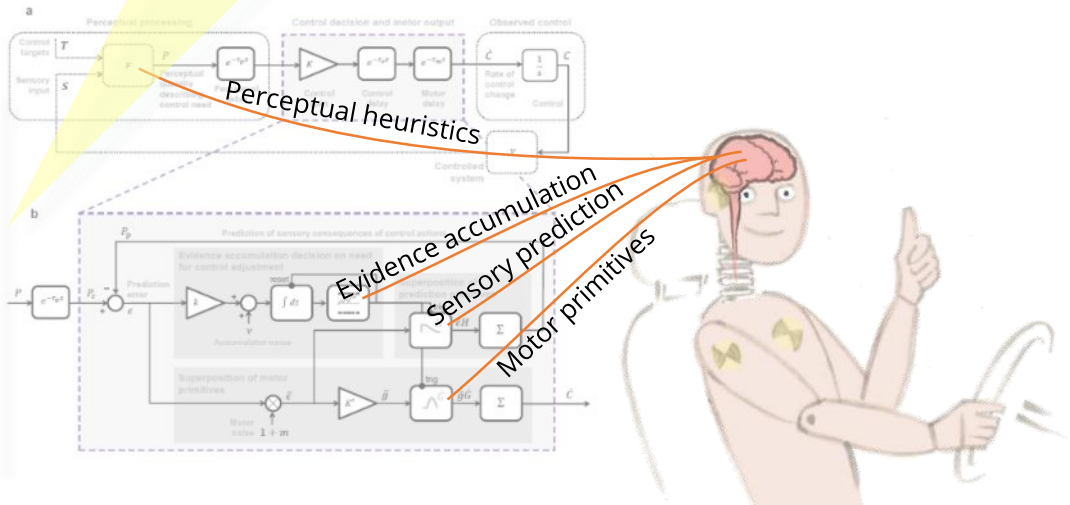
#1. Intermittent (motor primitive) adjustments

#2. Accumulation of evidence of various kinds

#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 routine and (near-)crash braking

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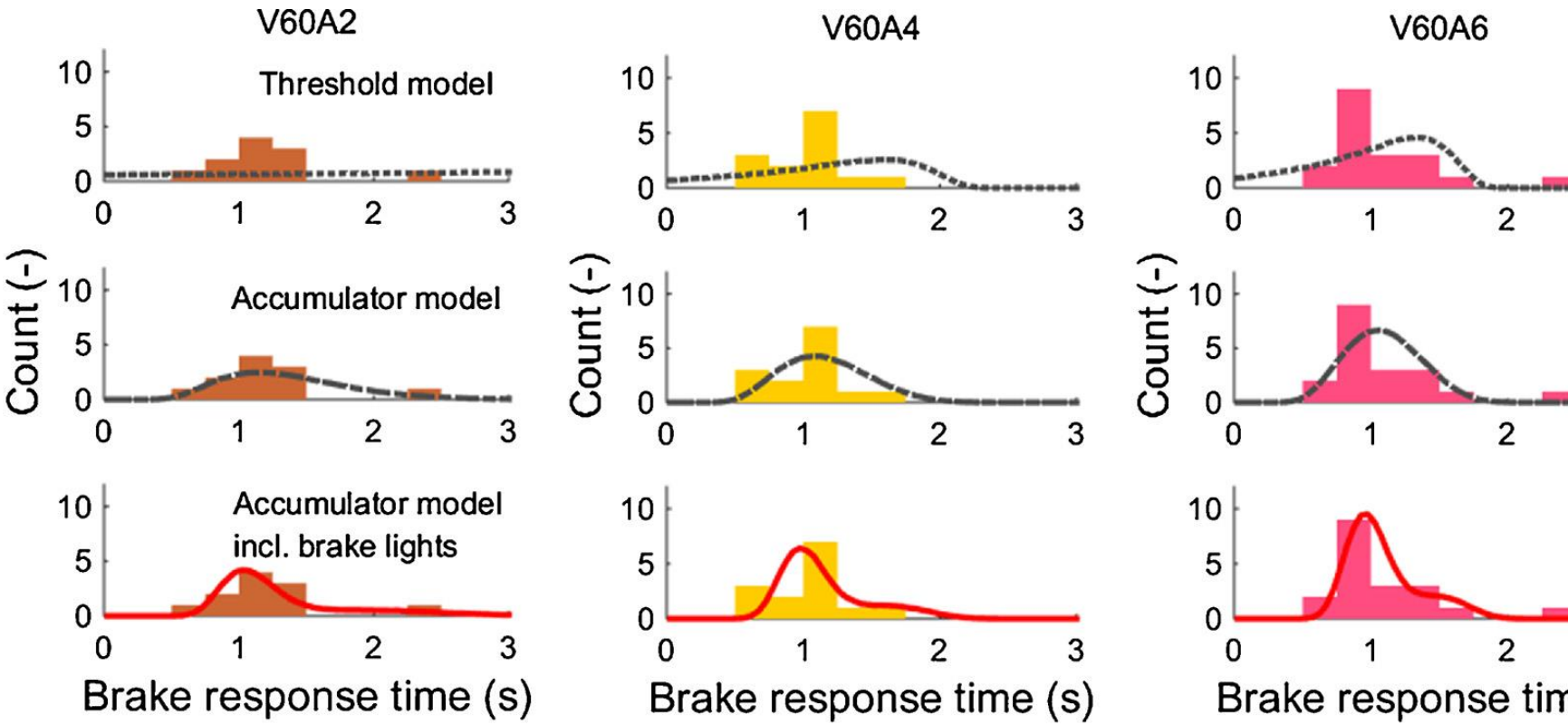
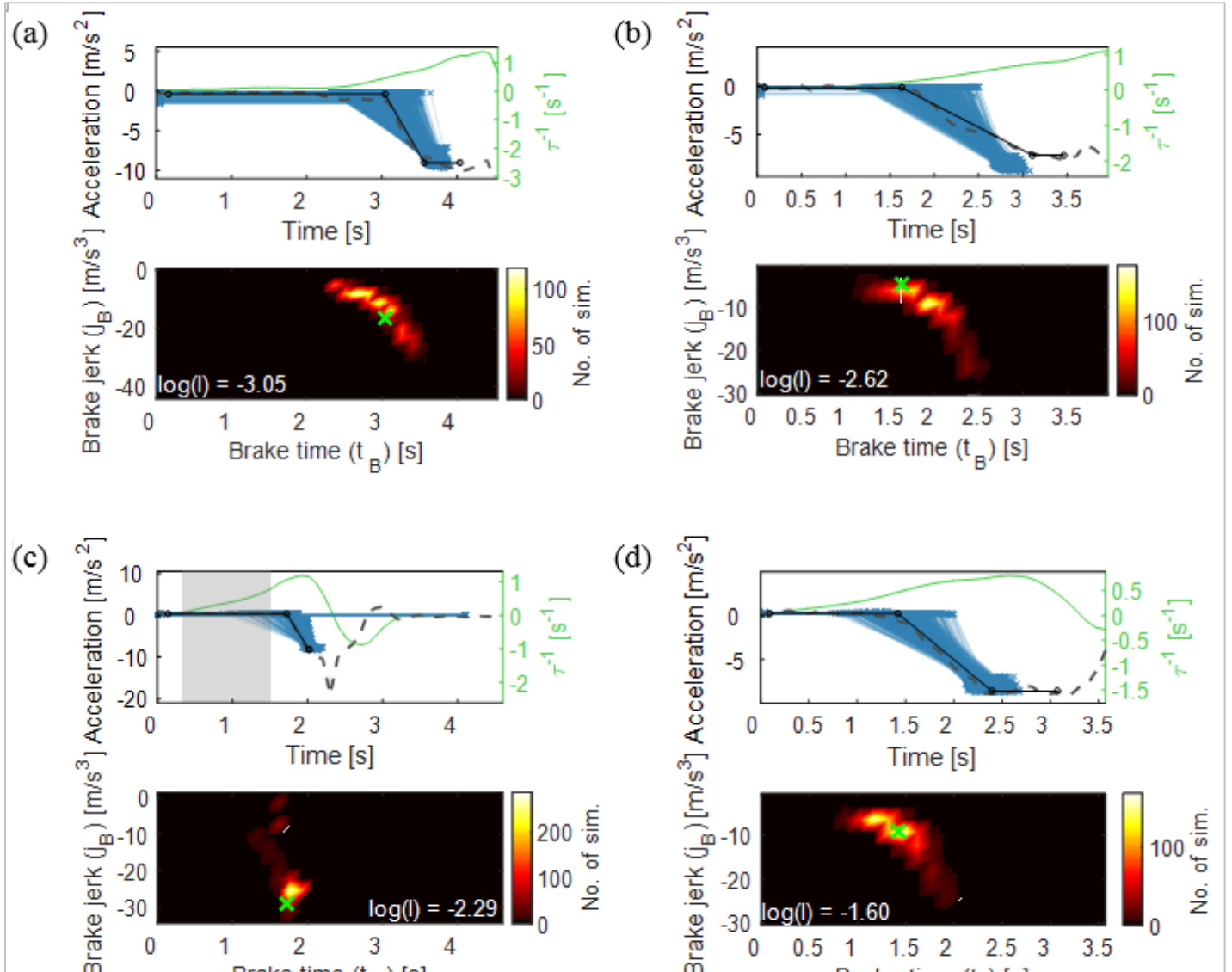
(Xue et al., 2018)



# … Explains routine and (near-)crash braking

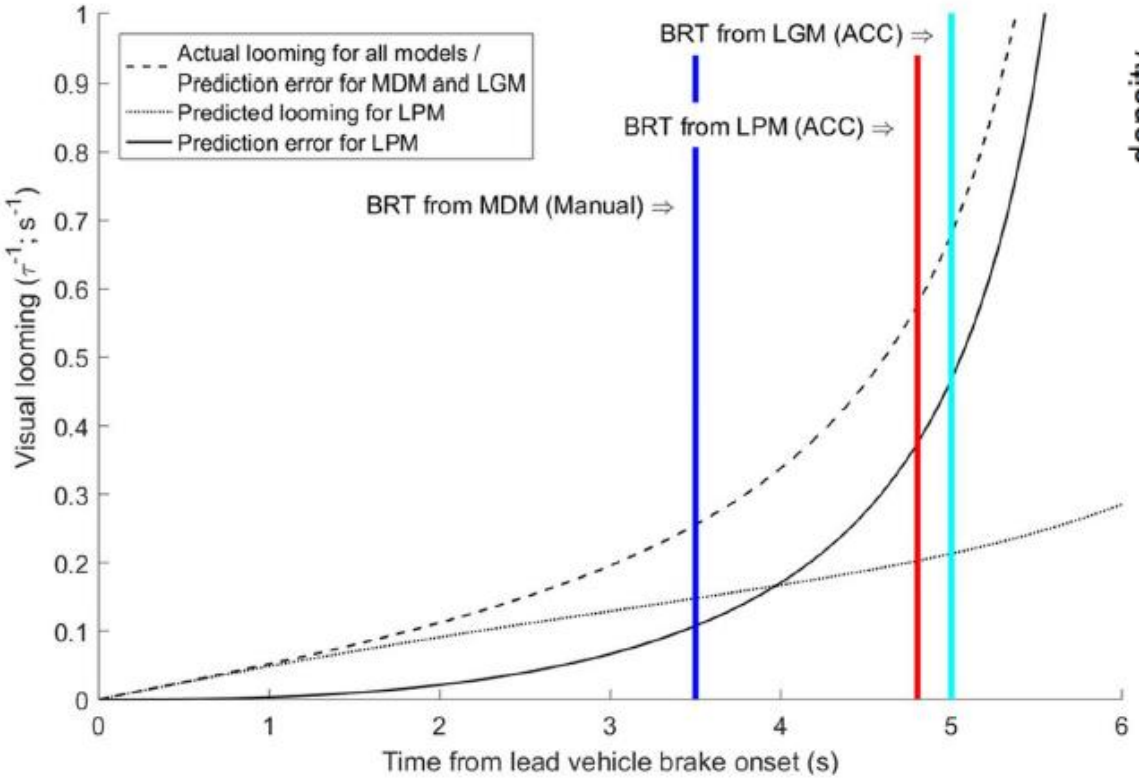
(Victor et al, 2015)

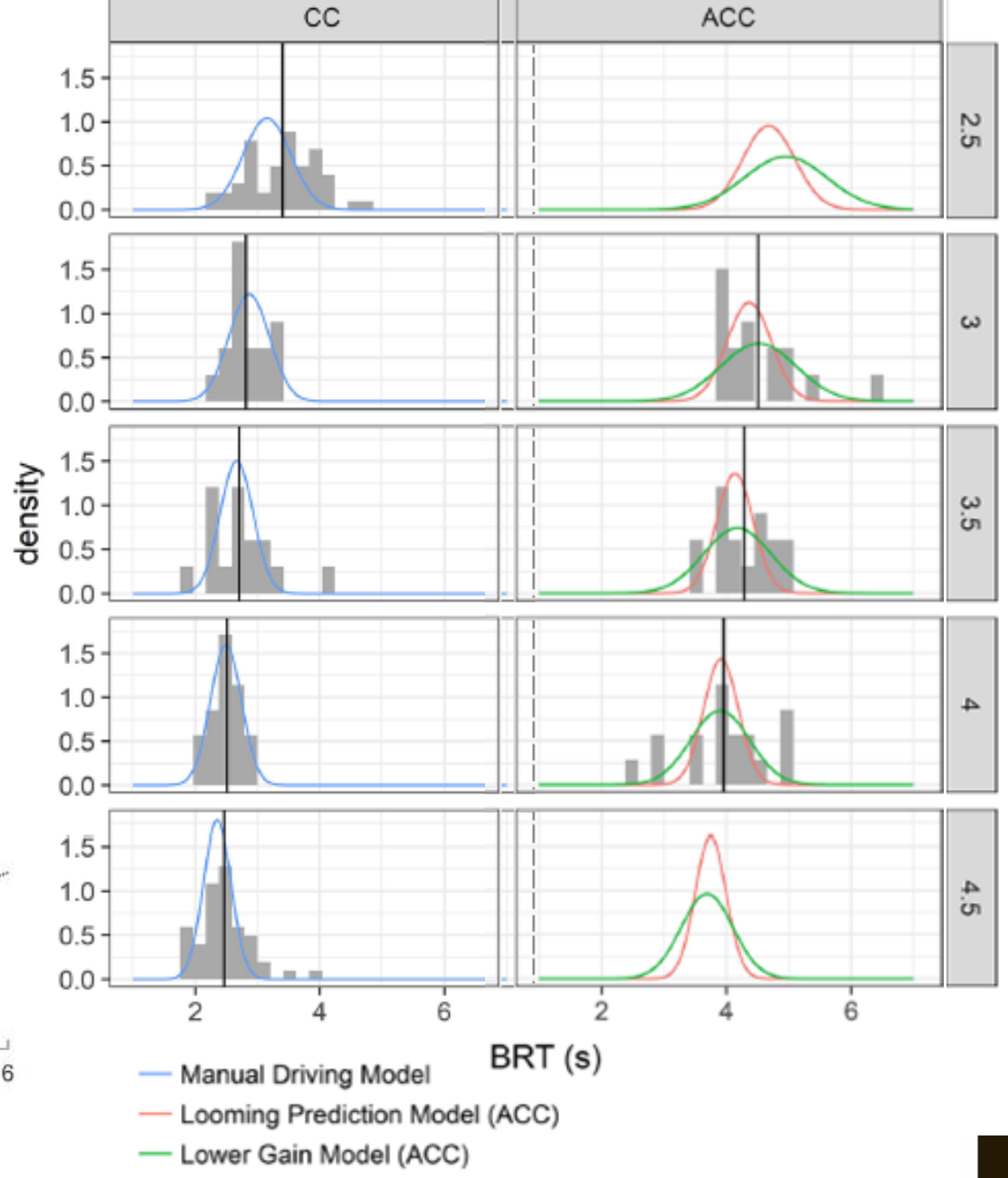



(Svärd et al., 2020, https://psyarxiv.com/6nkgv)

# ”Predictive processing” extension explains response to automation failures

(Piccinini et al, 2019)



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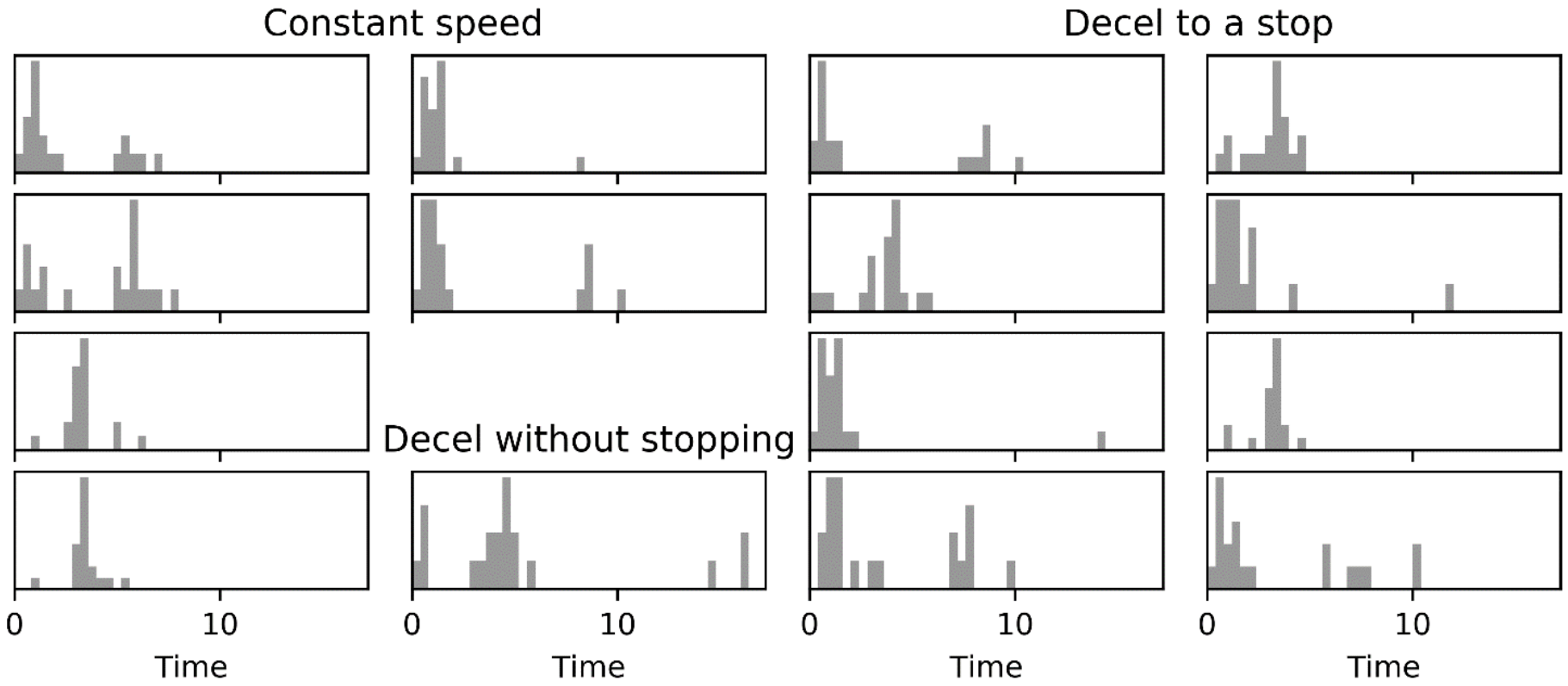
# Using EEG to peek into the decision process

(unpublished data removed)

# Generalising to road crossing interactions

(Giles et al., 2019)

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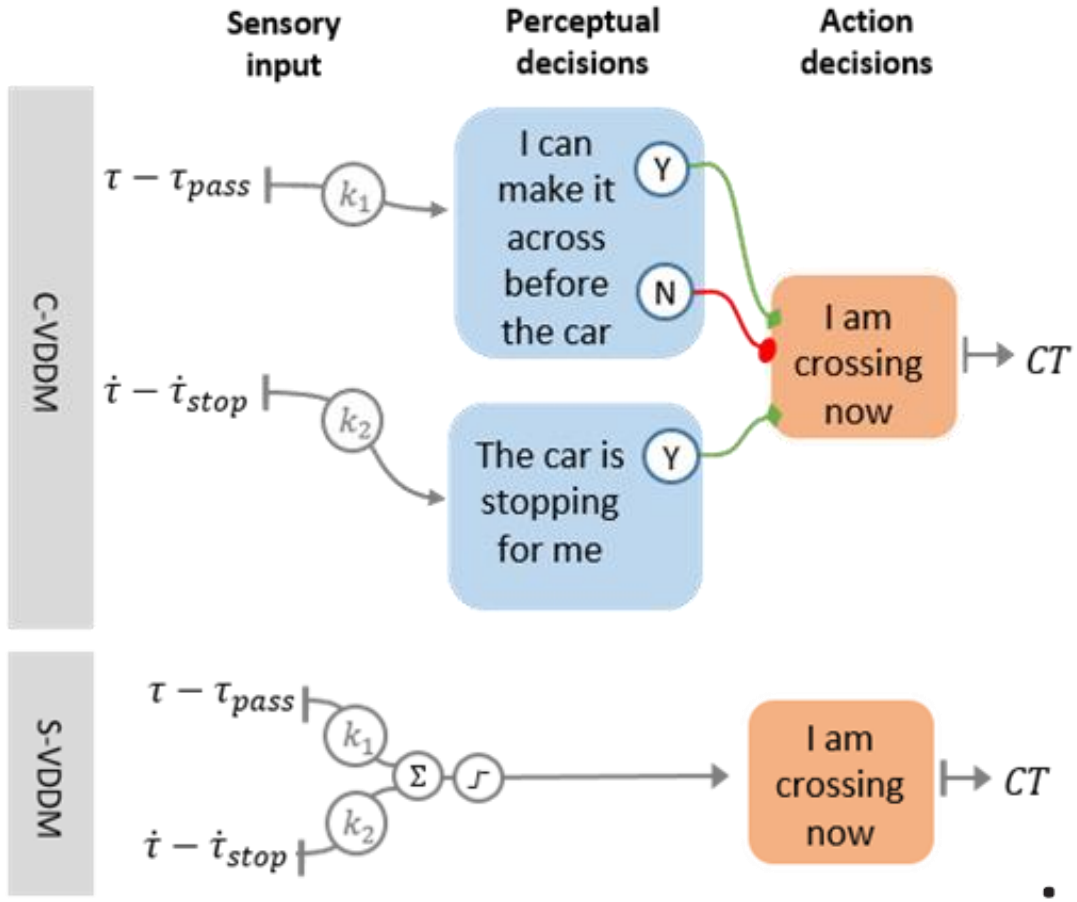
# Generalising to road crossing interactions

(Giles et al., 2019)

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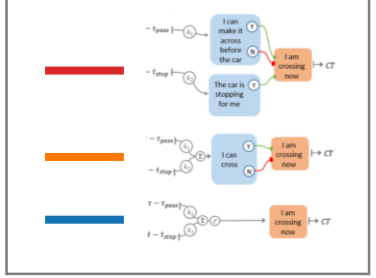
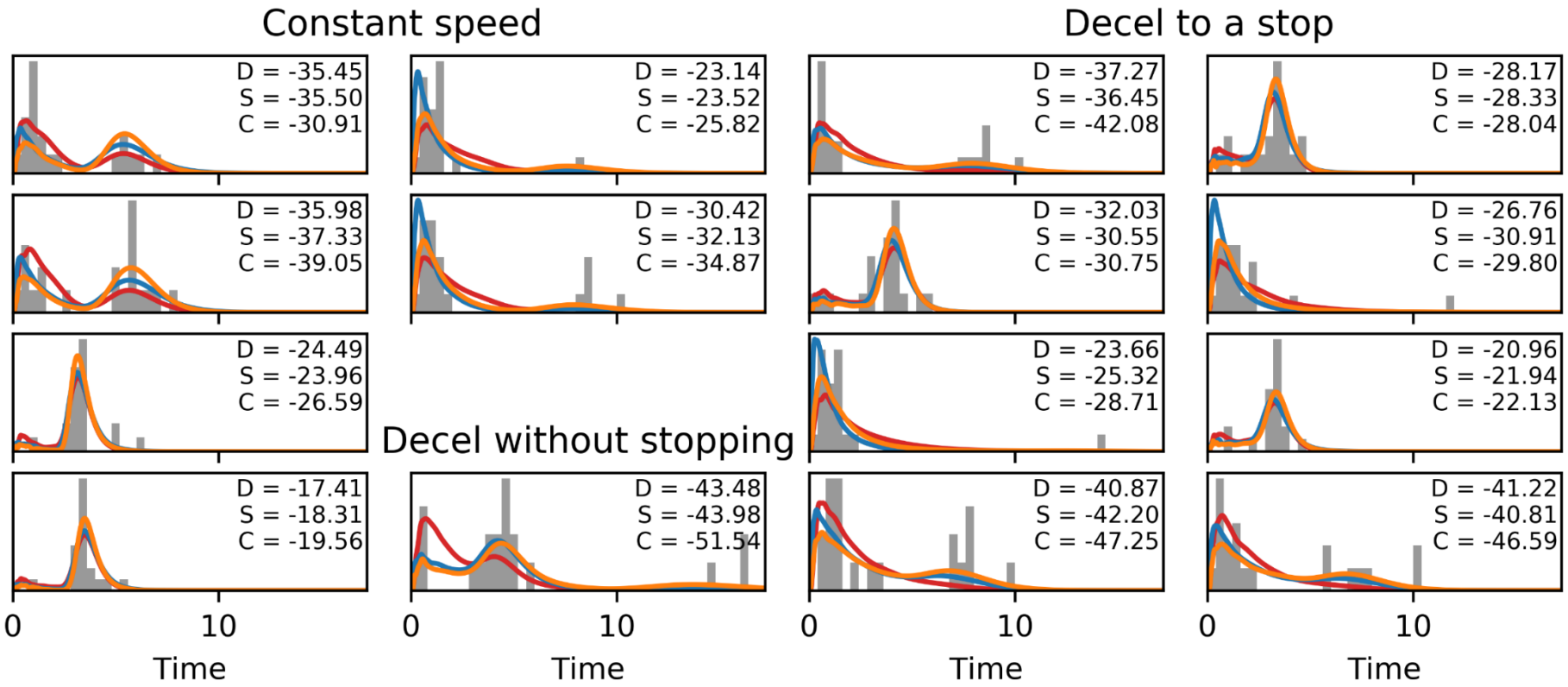
# Generalising to road crossing interactions



(Giles et al., 2019)

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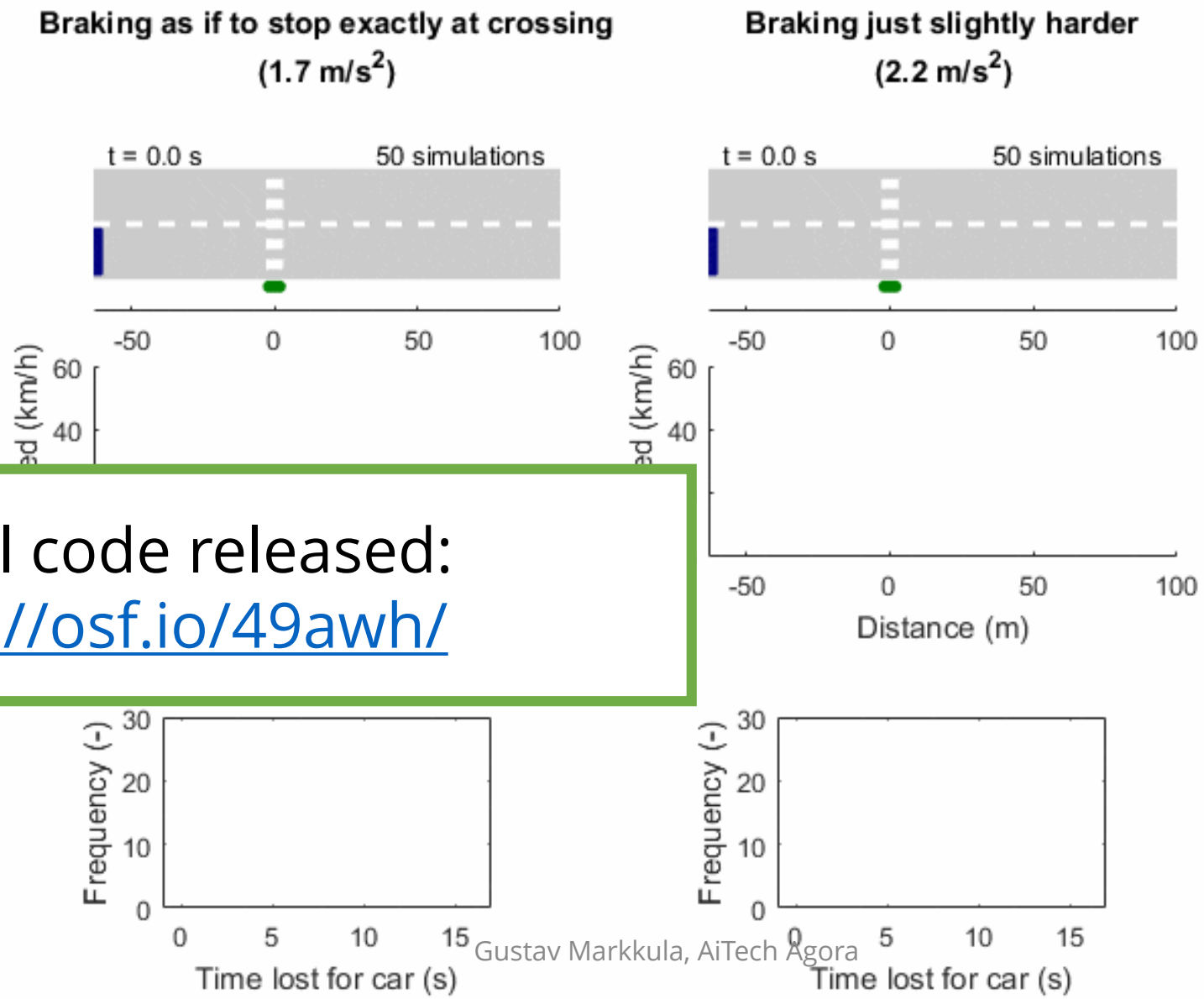
# Using models to optimise AV behaviour




Model code released:
https://osf.io/49awh/

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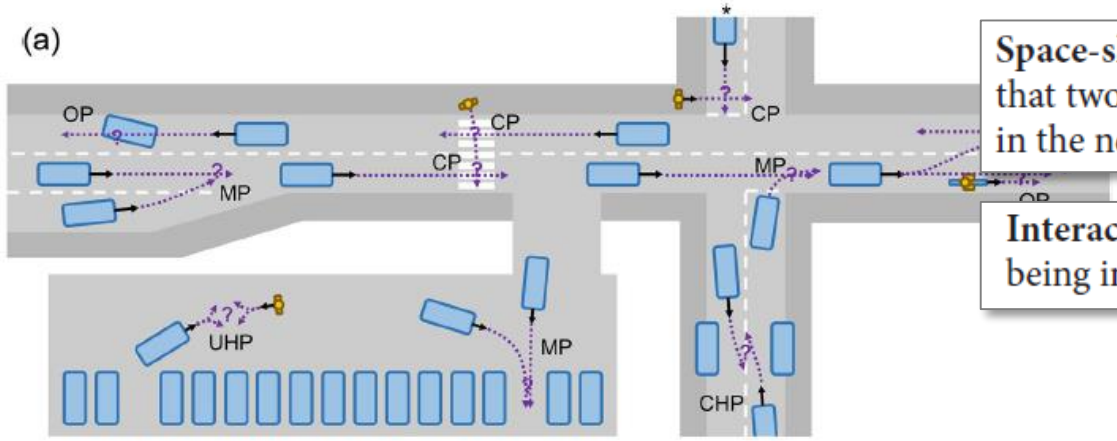
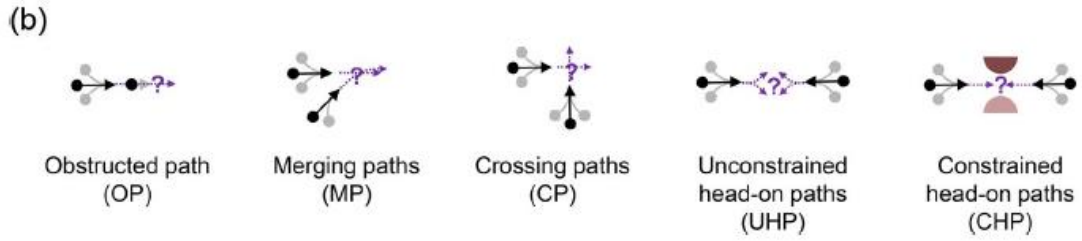
# But there is lots more to interactions in traffic…

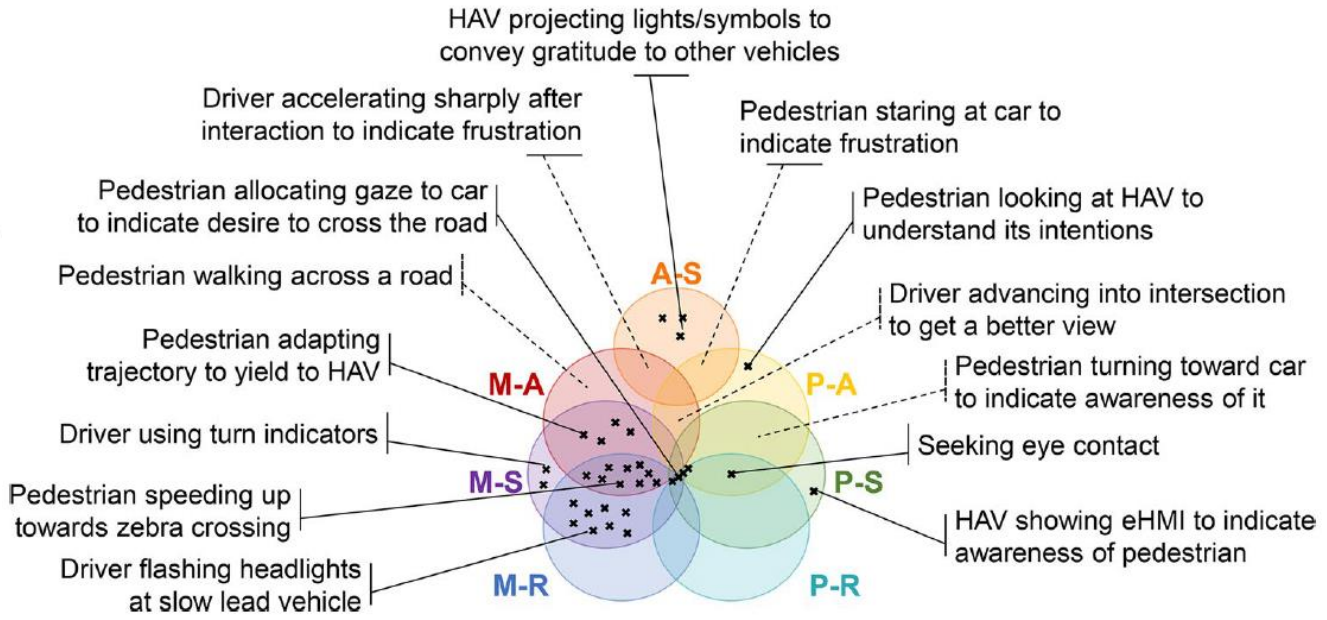



**Space-sharing conflict:** An observable situation from which it can be reasonably inferred that two or more road users are *intending to occupy the same region of space at the same time* in the near future.

**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)



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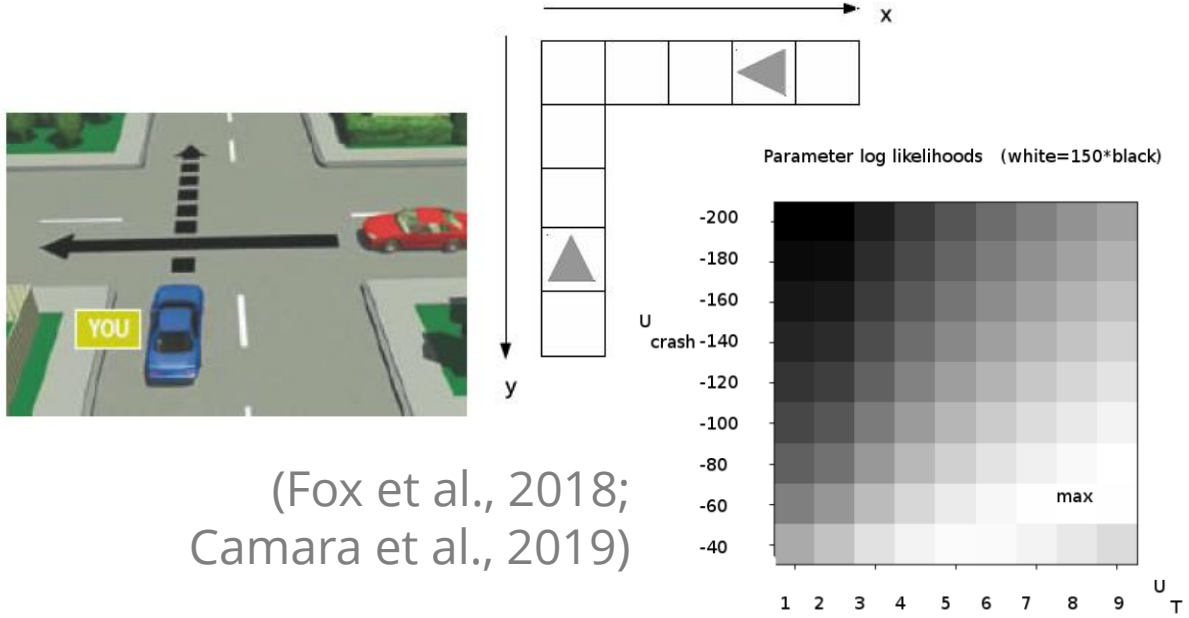
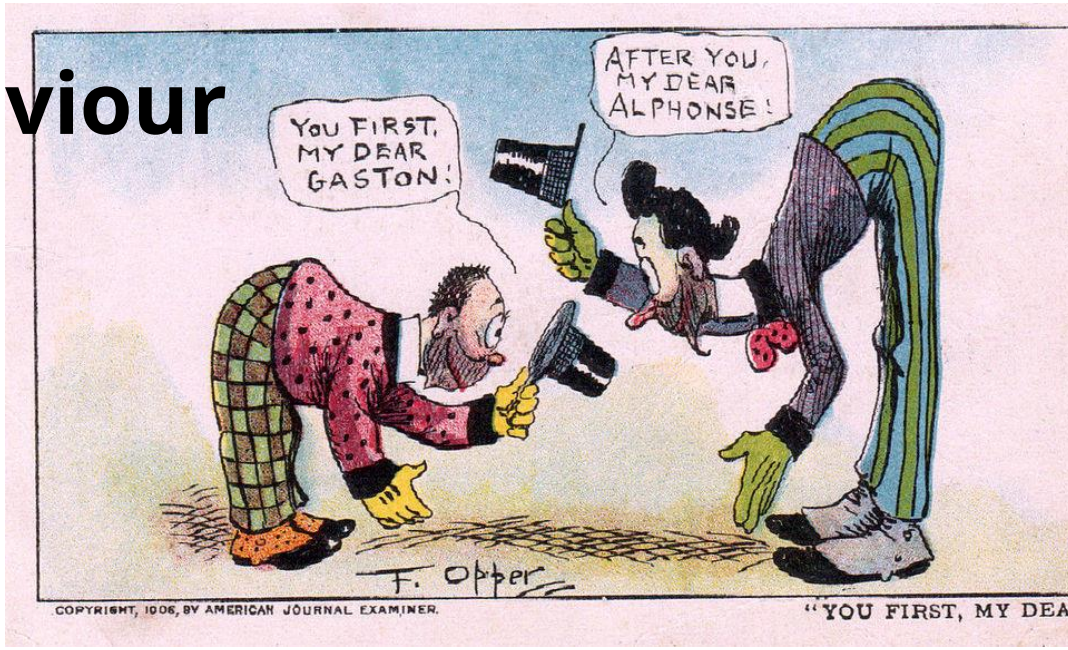
# Strategic (/game theoretic) behaviour

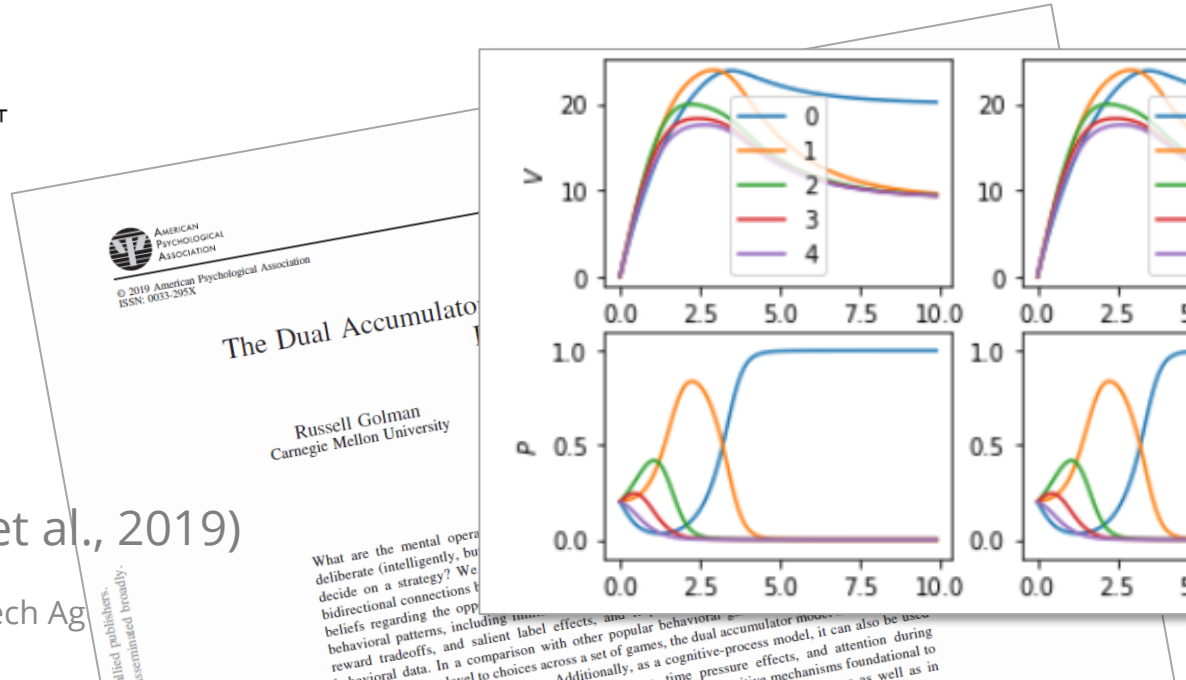



(Fox et al., 2018; Camara et al., 2019)

Fig. 7: Pedestrian behaviour preference




- Complication: human behaviour is often not game-theoretically optimal
- And humans value strange things



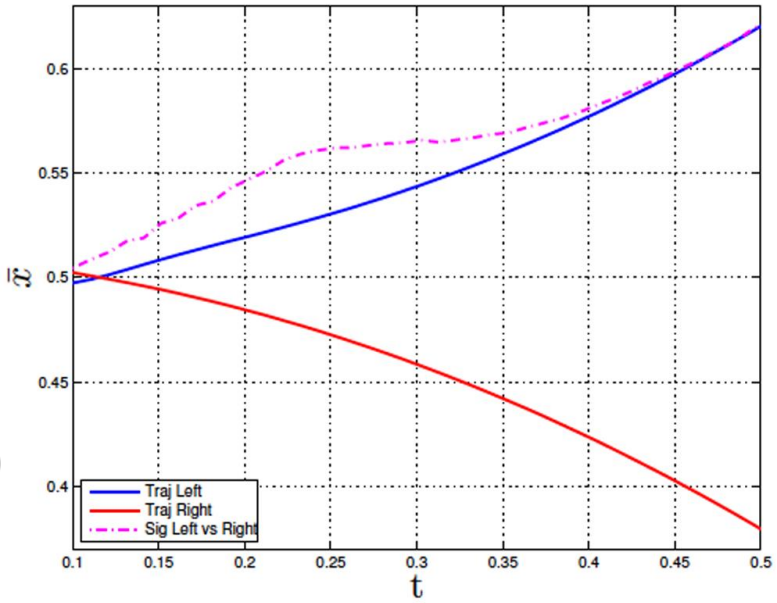

(Golman et al., 2019)

# Other important areas for further model development

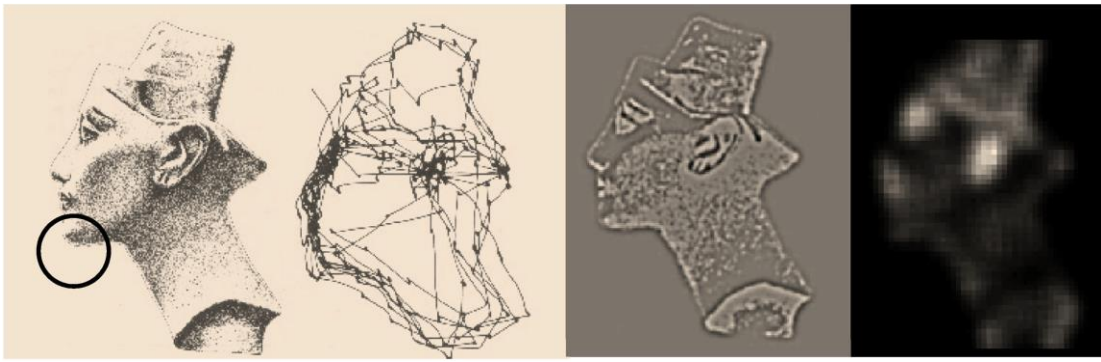
Human…

- … recognition of actions/ intentions
- … communication
- … attention/gaze allocation

Overall: contemporary computational cognitive (neuro)science sort of provides the needed components…

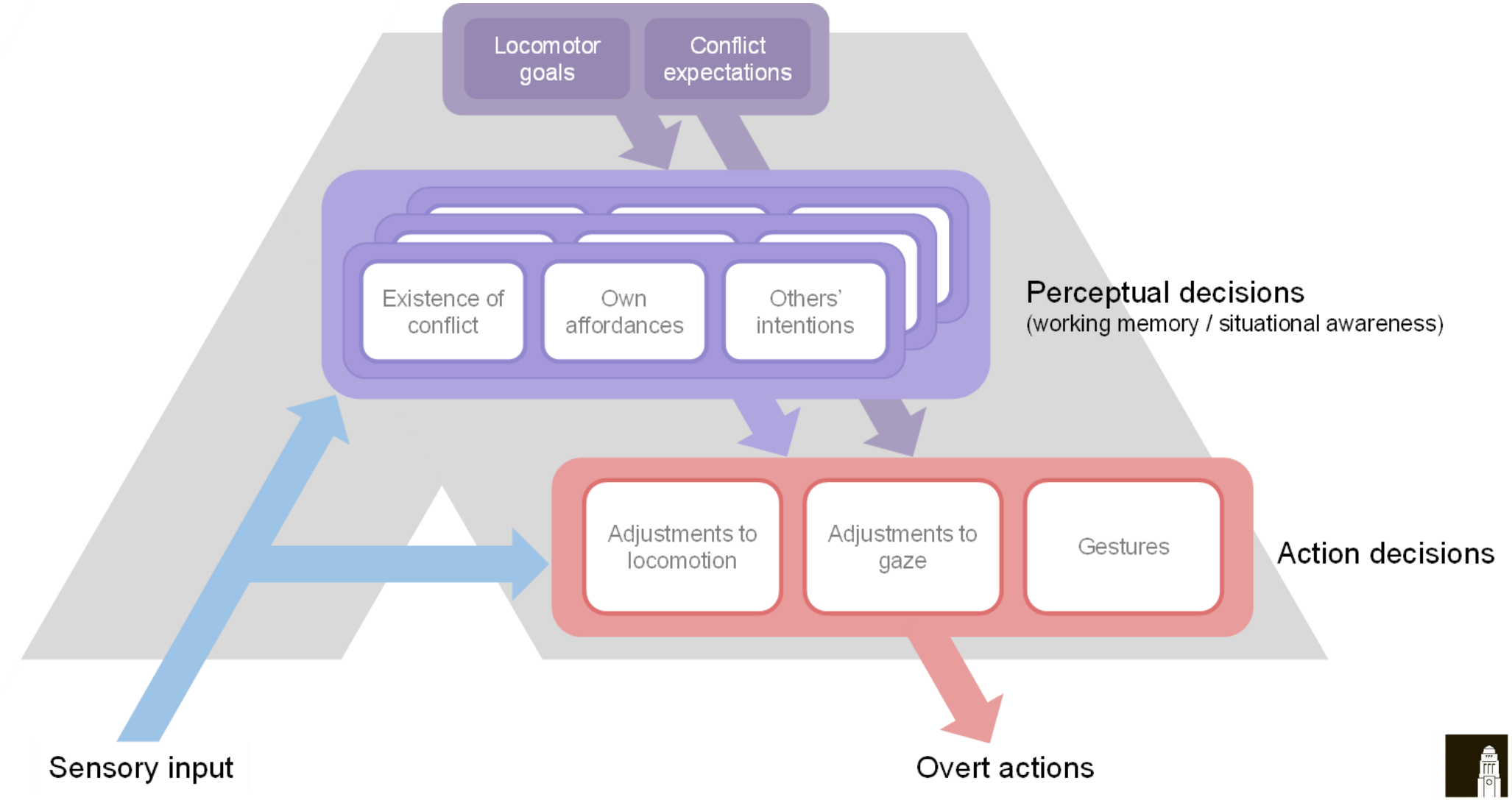



(Pezzulo et al., 2013)



(Friston et al., 2012)

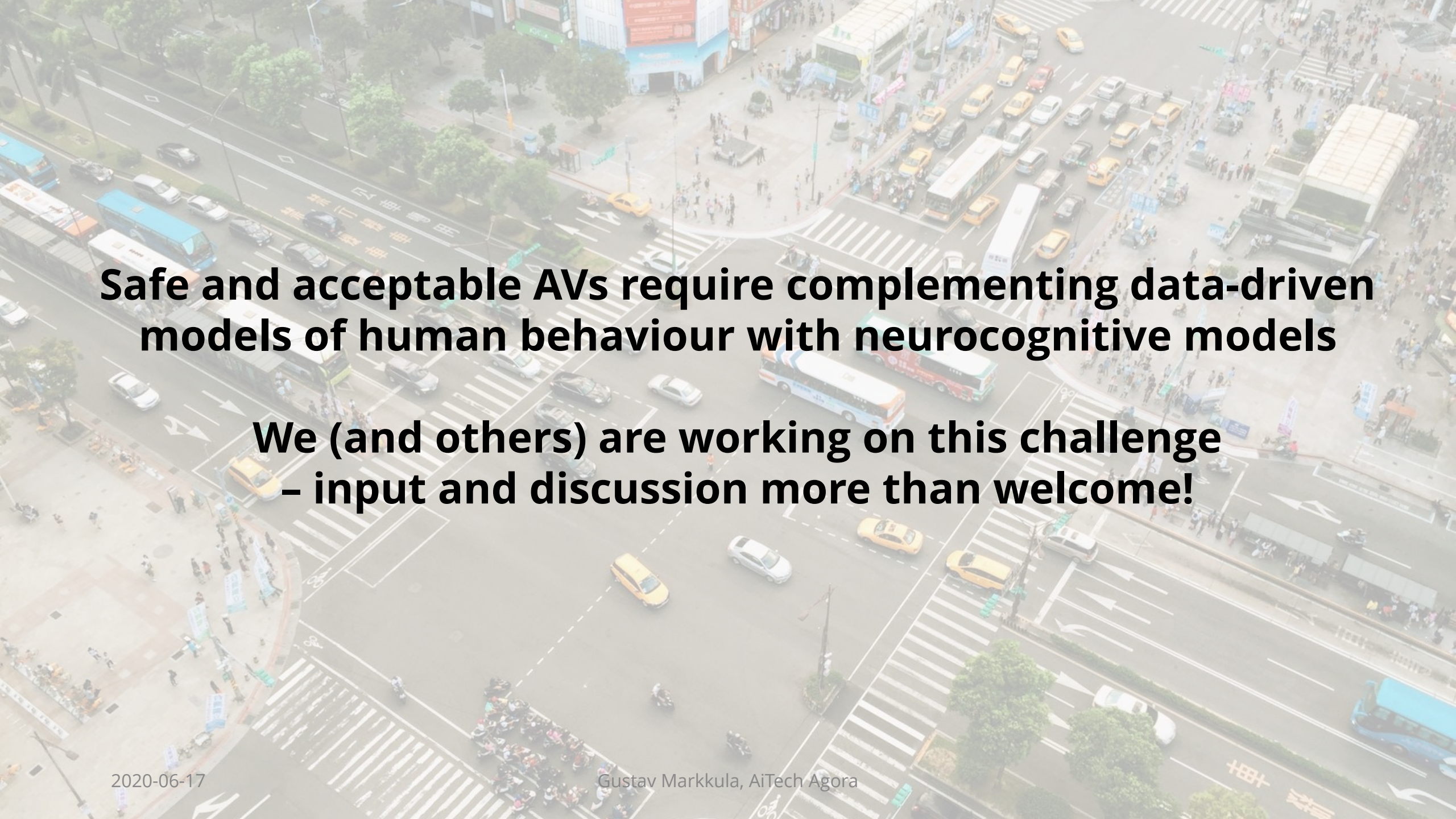
# Towards a neurocognitive modelling framework



# COMMOTIONS
# Computational Models of Traffic Interactions for Testing of Automated Vehicles

- 2019-2023, £1.4M UK project
- More complete neurocognitive models of interactions
- Investigate complementarity with data-driven models

”Green paper” inviting input:
https://osf.io/vbcaz



**Safe and acceptable AVs require complementing data-driven models of human behaviour with neurocognitive models**

**We (and others) are working on this challenge – input and discussion more than welcome!**

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# Thanks!

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”Green paper” inviting input:
https://osf.io/vbcaz

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