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Why a neurocognitive understanding of human road users is needed to ensure safety and acceptance of automated vehicles

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How to make AVs that can successfully coexist with humans?

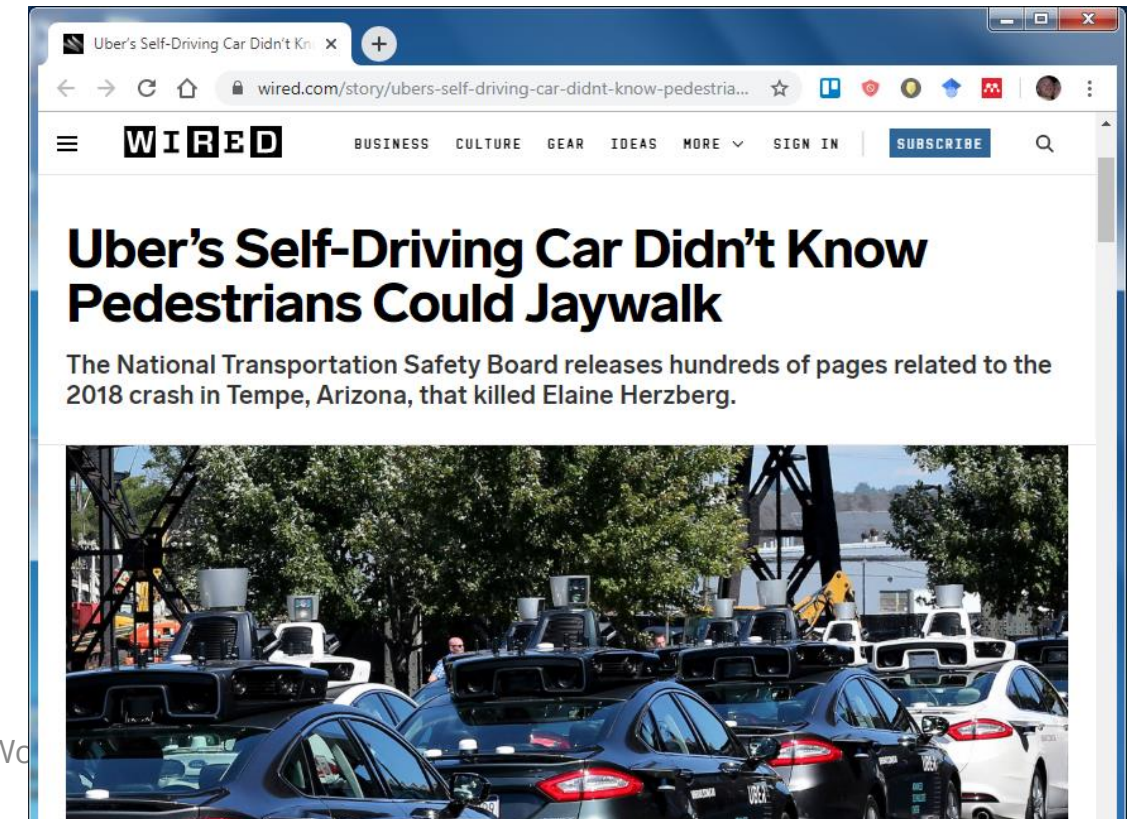
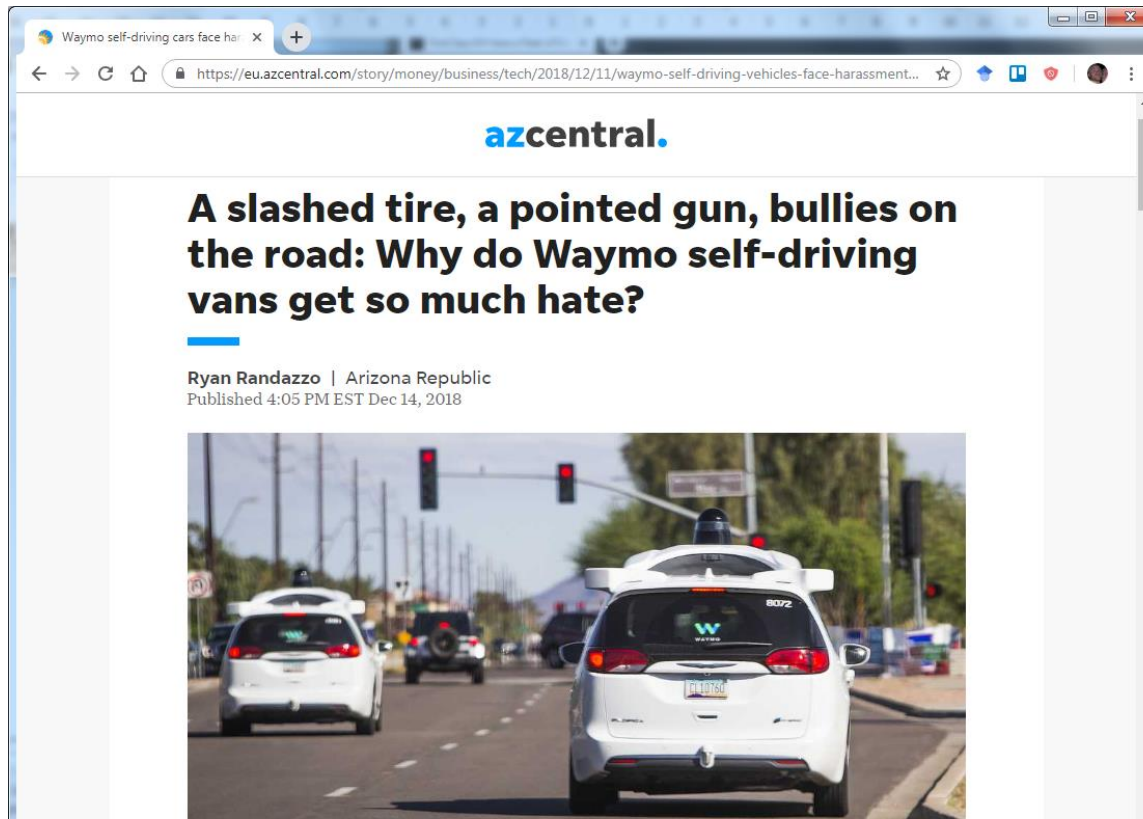
→ By developing high-fidelity models of human road user behaviour

What kinds of models?

→ Combination of data-driven and neurocognitive models

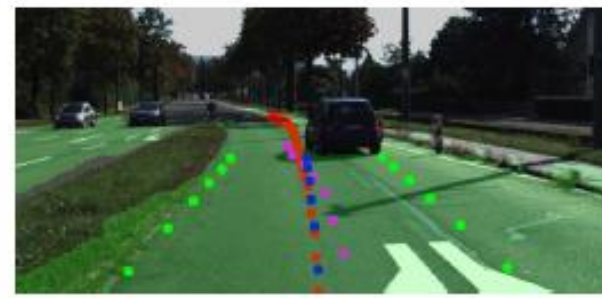
AV deployment: two main risks

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

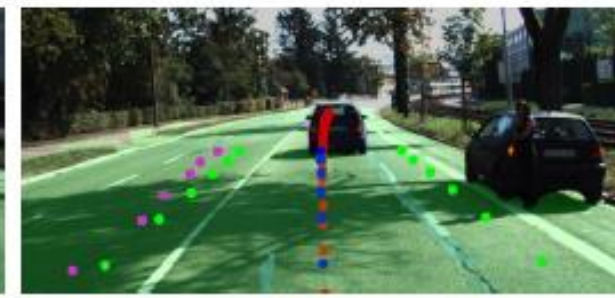


Why high-fidelity models of human behaviour?

(Li et al., 2019, IROS)



(a) No LMs.



(b) Passing static obstacle.

To make...

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

(Anderson et al., 2019, IROS)

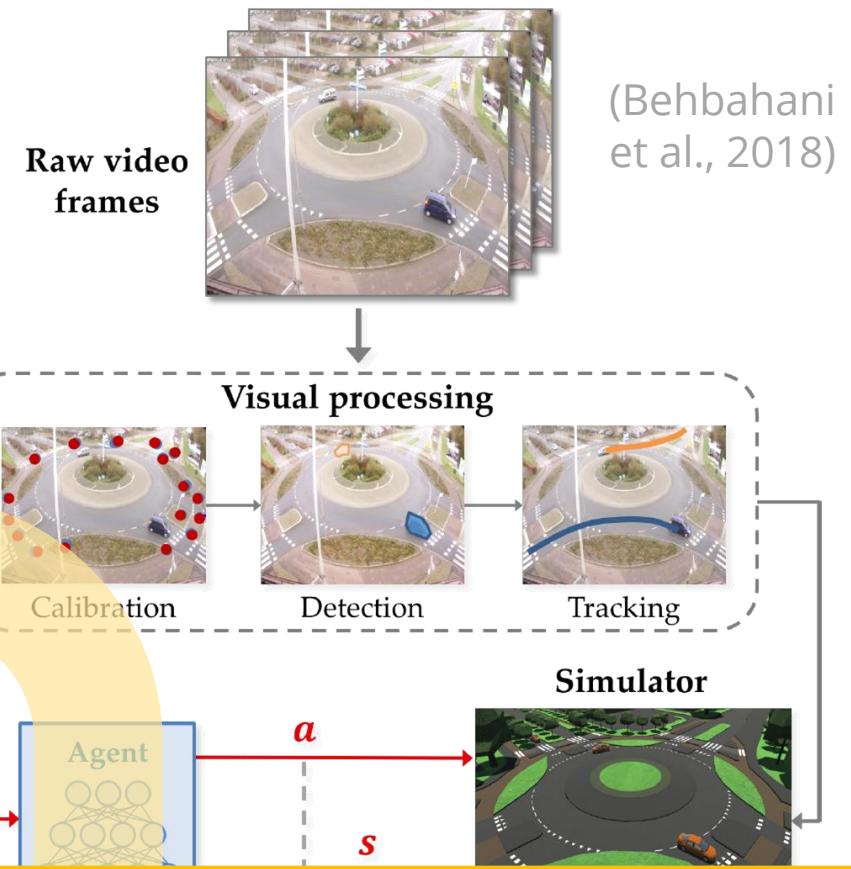


(Waymo Safety Report 2018)

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**

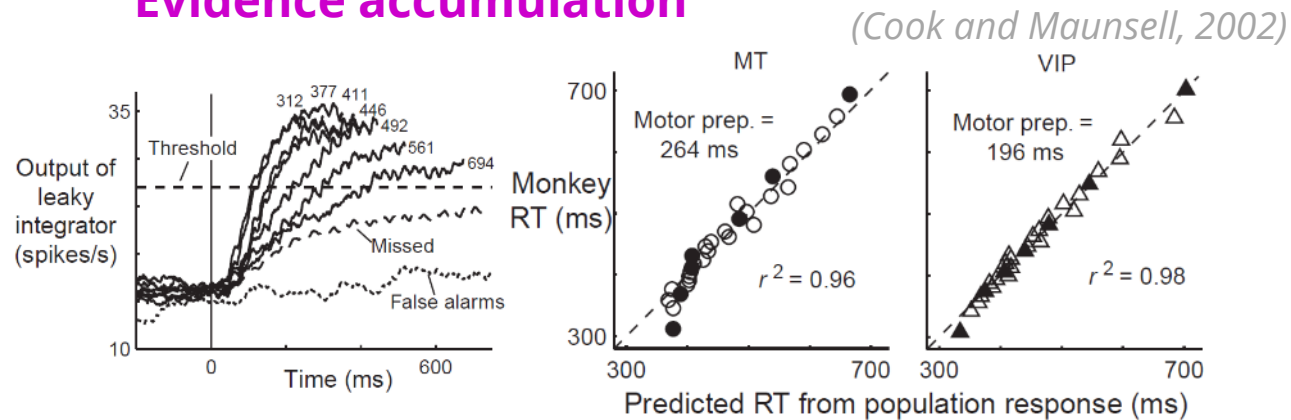


Insight into how mechanisms generalise



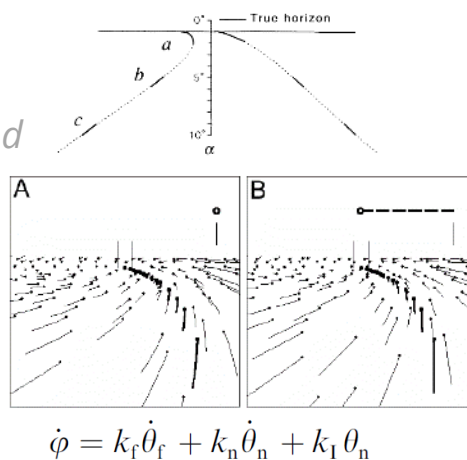
Framework for routine and (near-)crash driving

Evidence accumulation

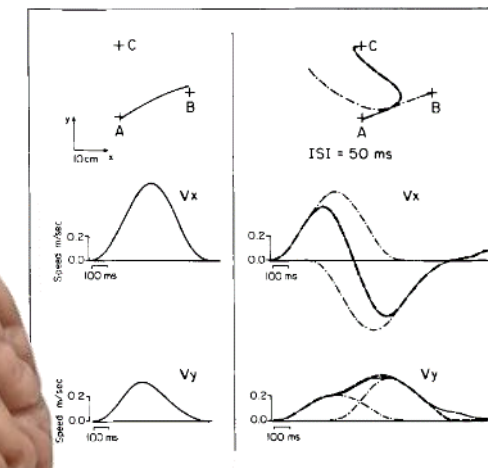


Perceptual heuristics

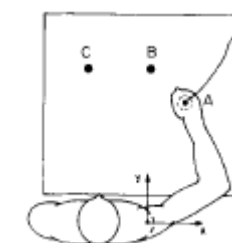
(Land and Horwood, 1995; Wann and Wilkie, 2004; Salvucci and Gray, 2004)



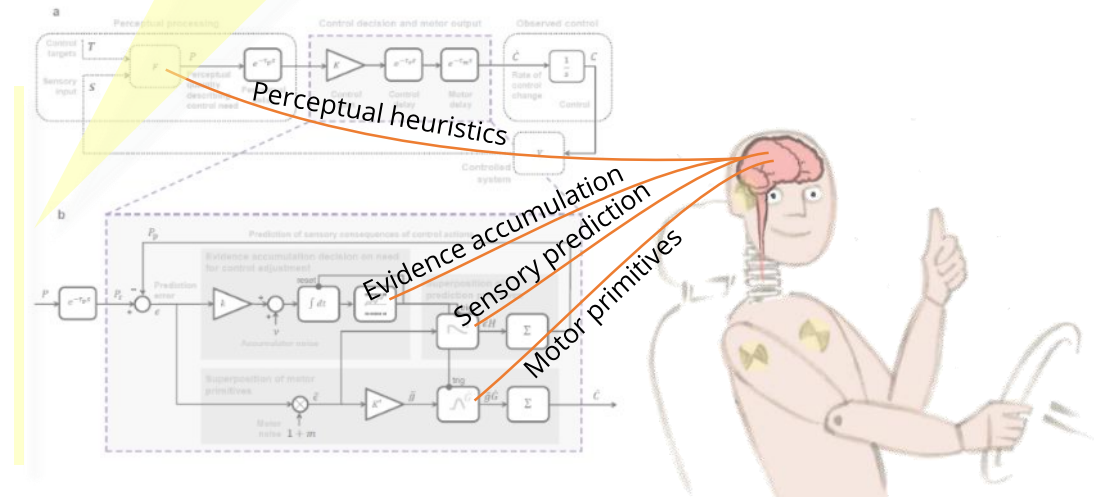
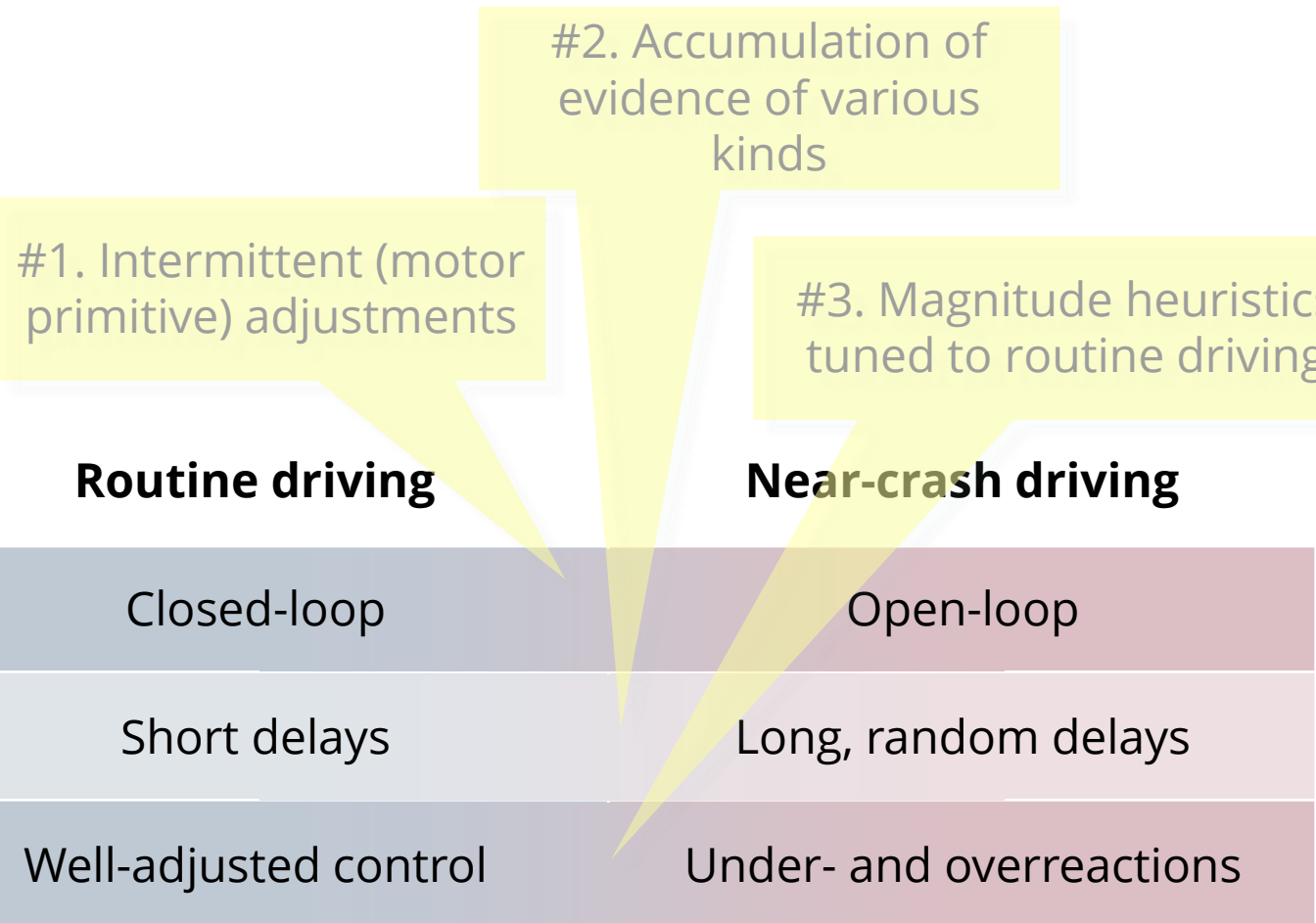
Motor primitives



(Flash and Henis, 1991)



Framework for routine and (near-)crash driving

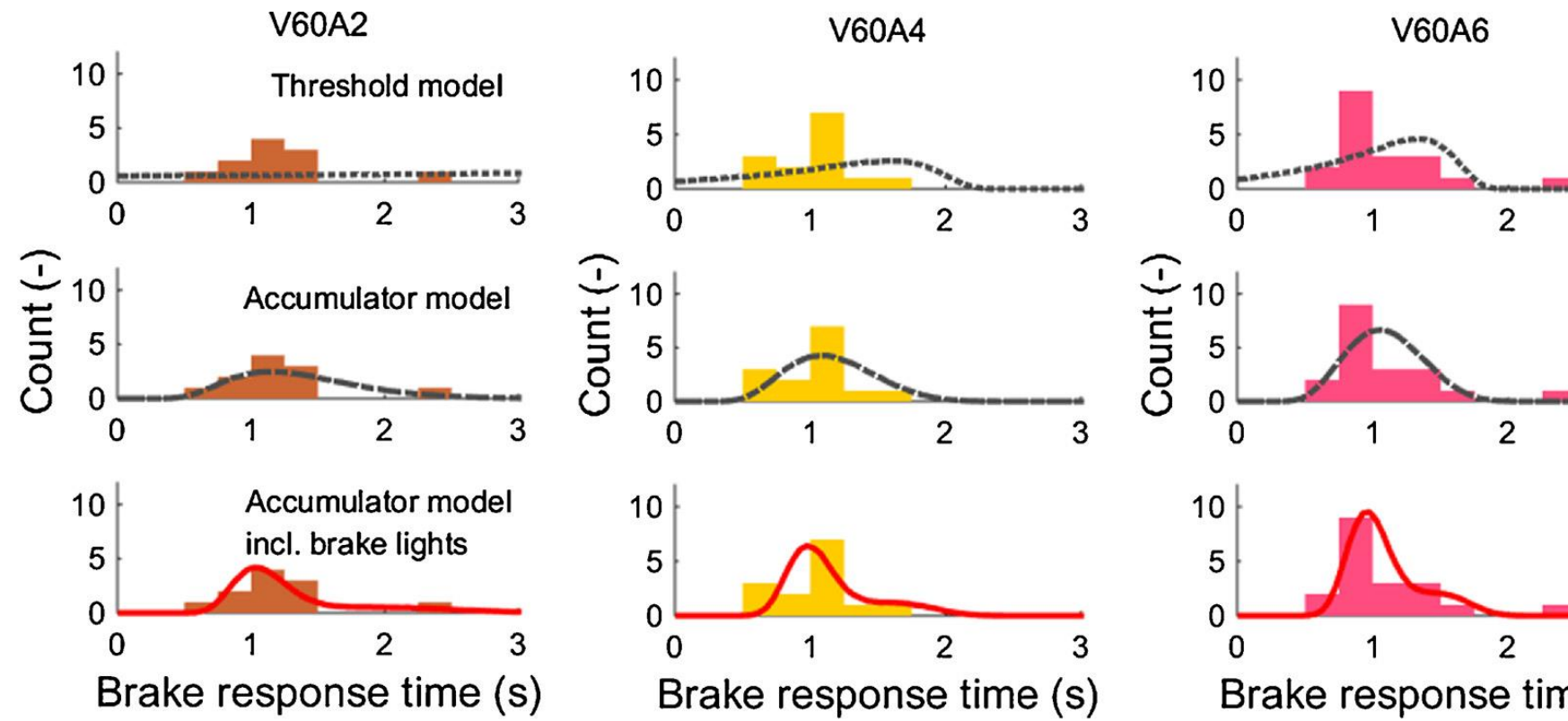


(Markkula, 2014, 2015;
Markkula et al, 2018 Biol Cyb)

... Explains routine and (near-)crash braking



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



... Explains routine and (near-)crash braking

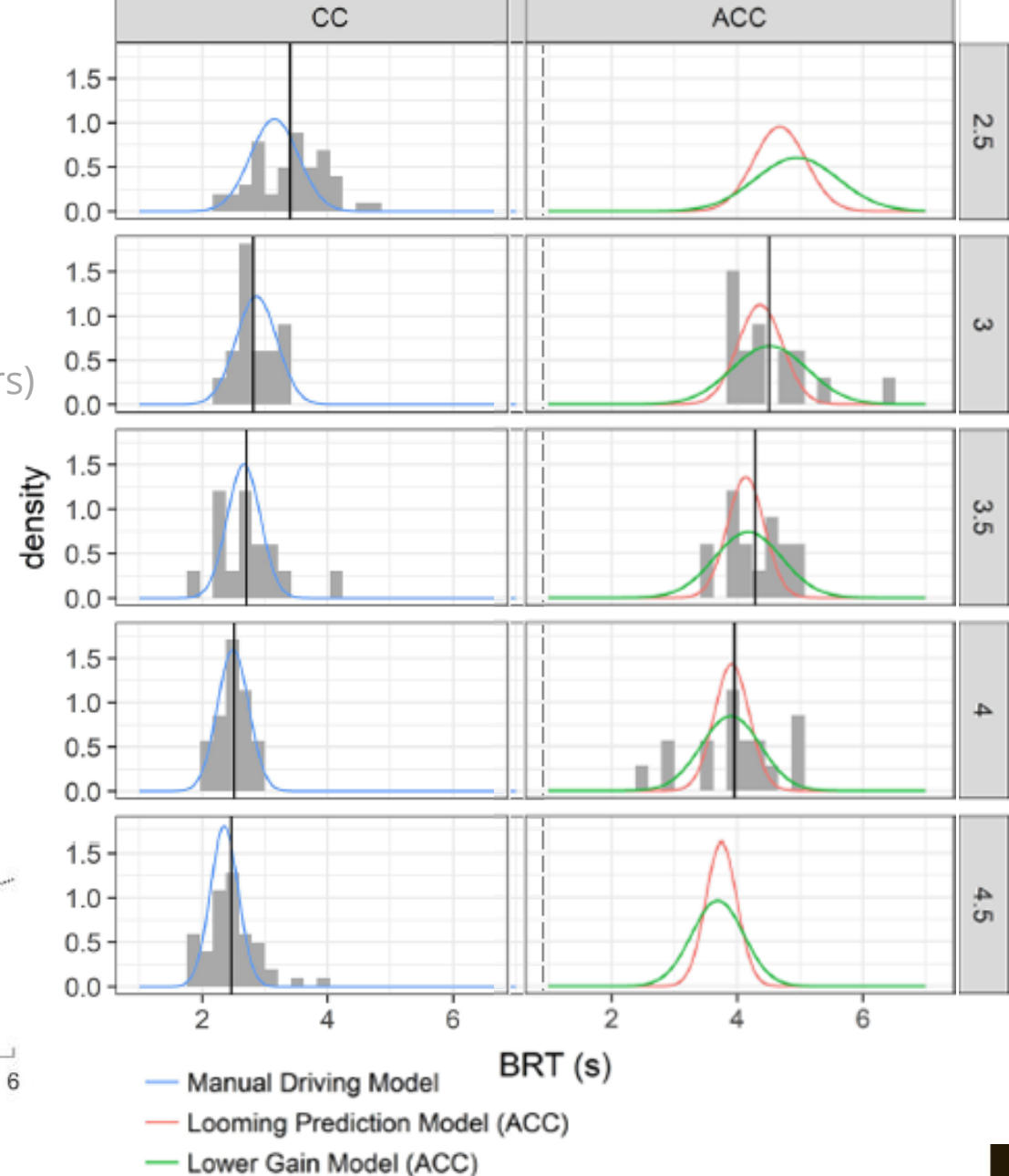
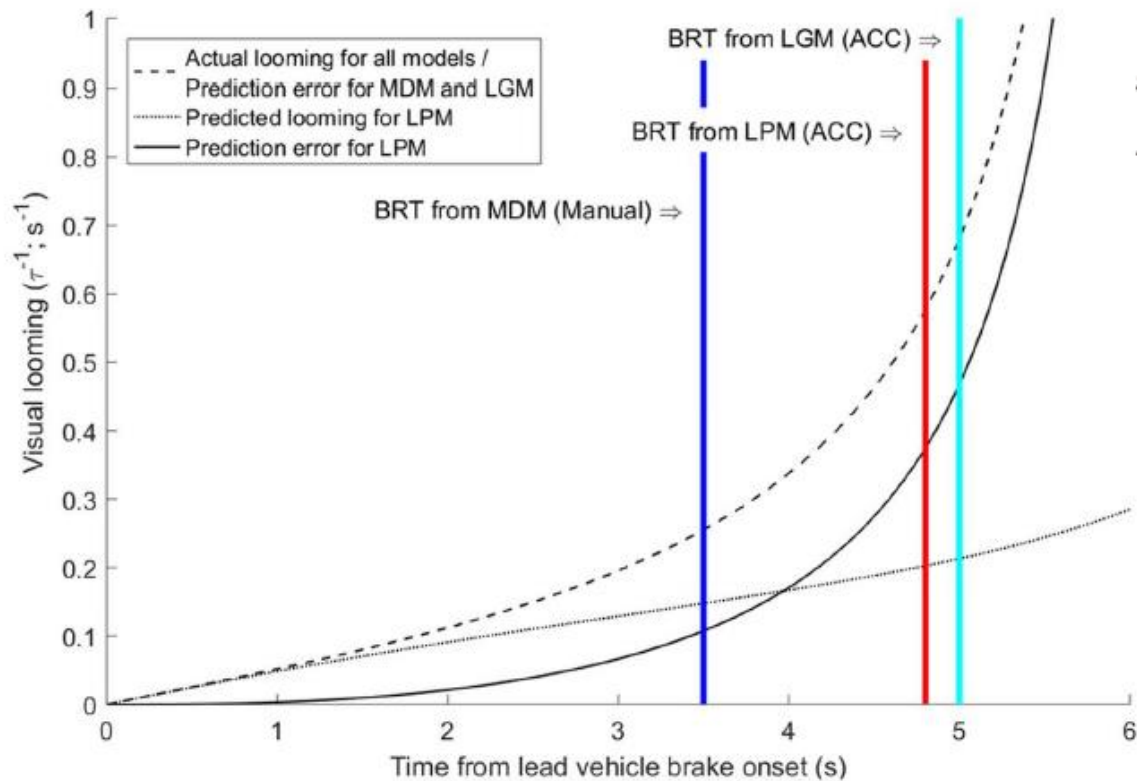


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(Victor et al, 2015, TRB report)

"Predictive processing" extension explains response to automation failures

(Piccinini et al, 2019, Hum Factors)

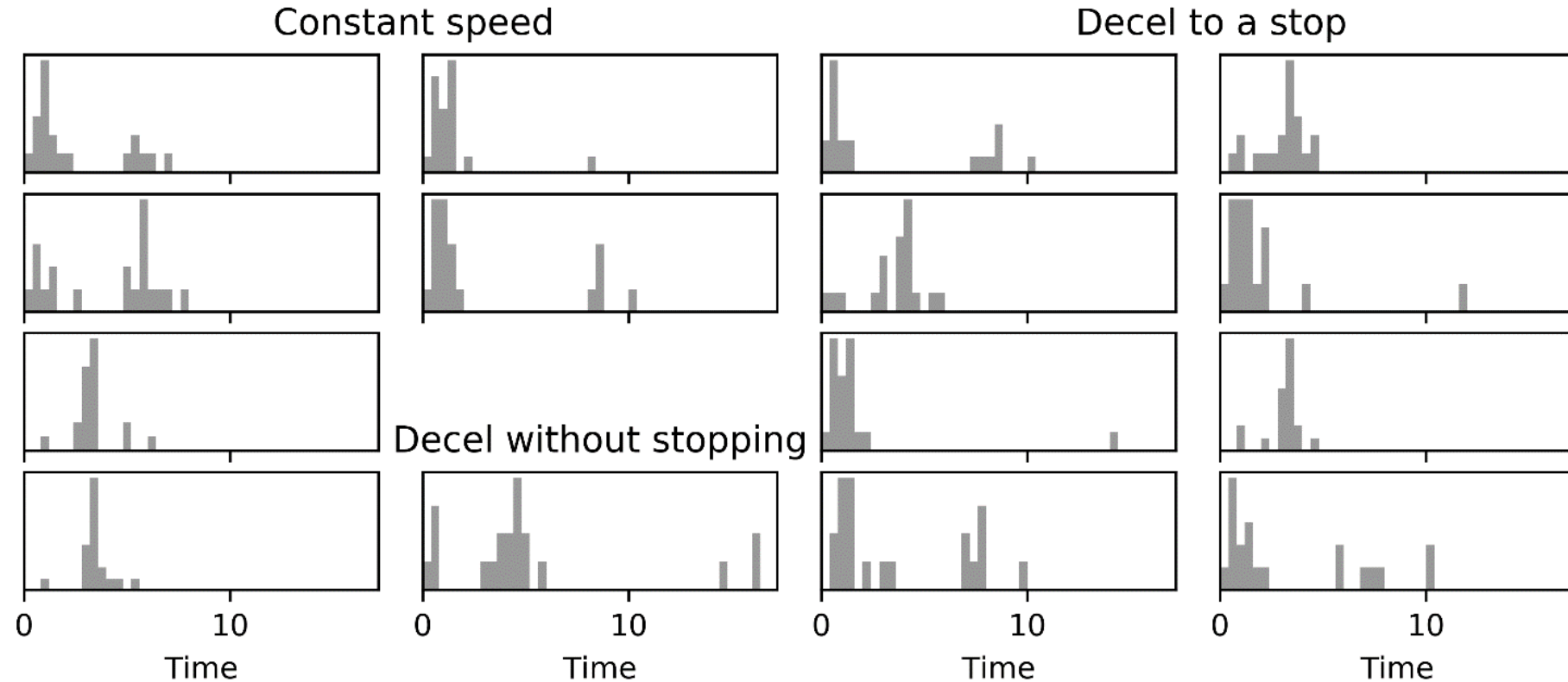


Using EEG to peek into the decision process?

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Generalising to road crossing interactions

(Giles et al., 2019)



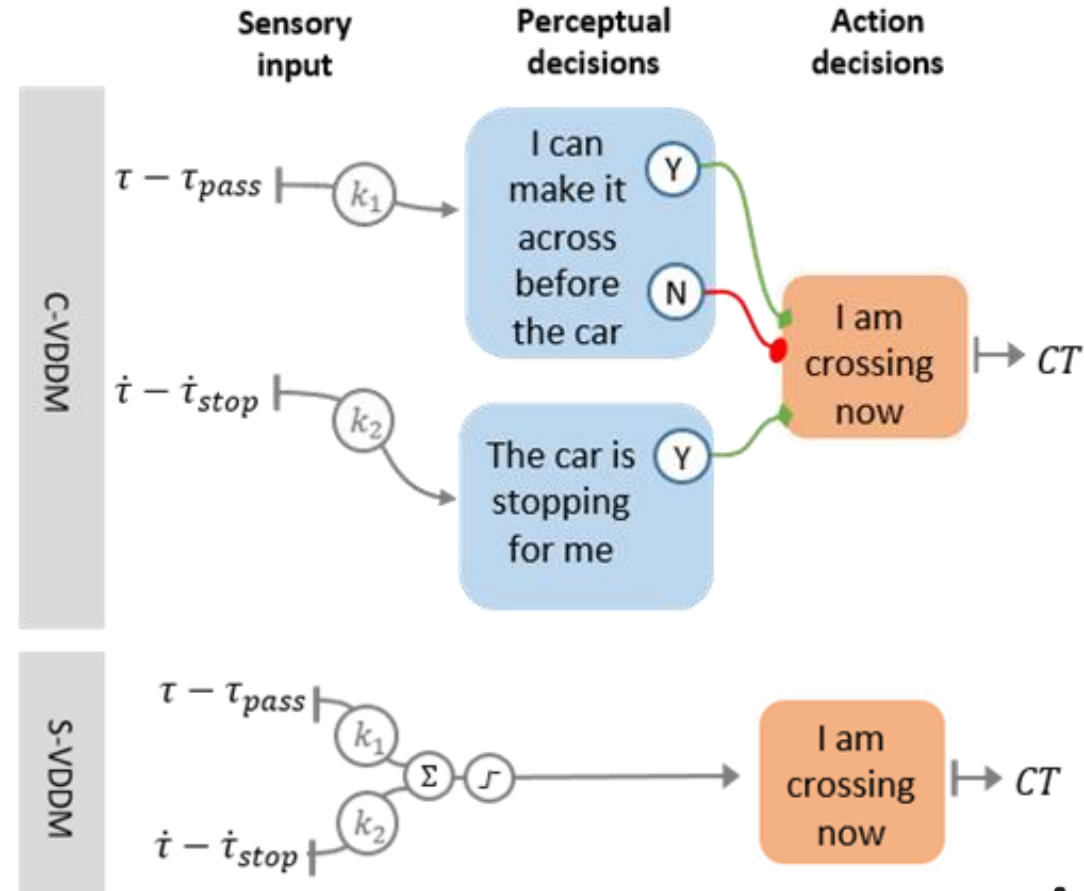
interACT



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Generalising to road crossing interactions

(Giles et al., 2019)

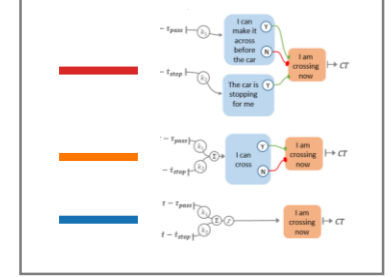


interACT

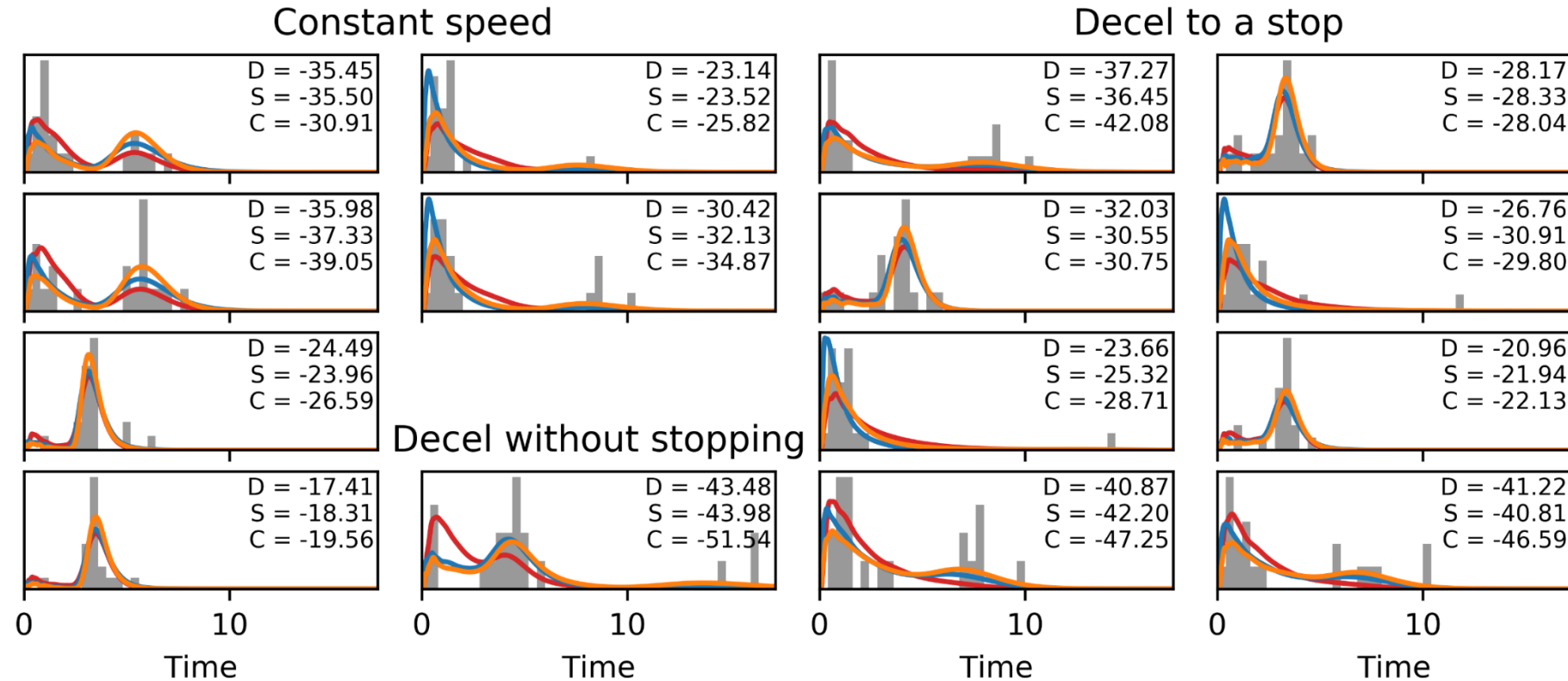


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Generalising to road crossing interactions



(Giles et al., 2019)



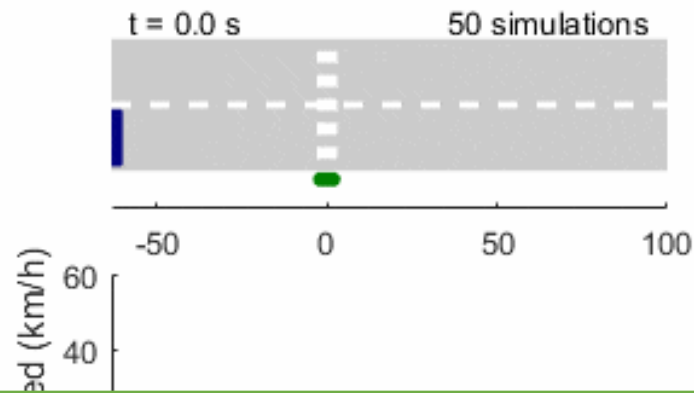
interACT



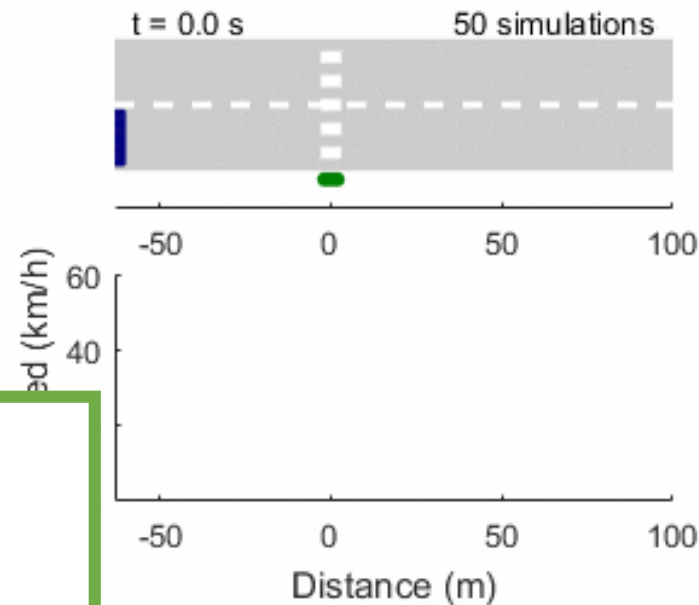
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Using models to optimise AV behaviour

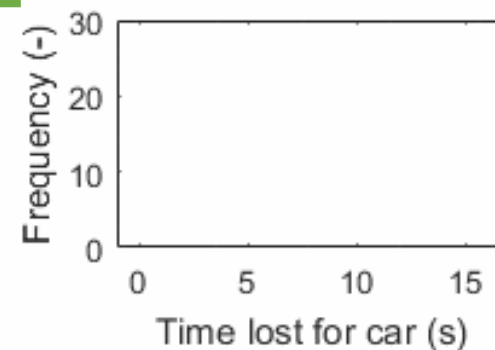
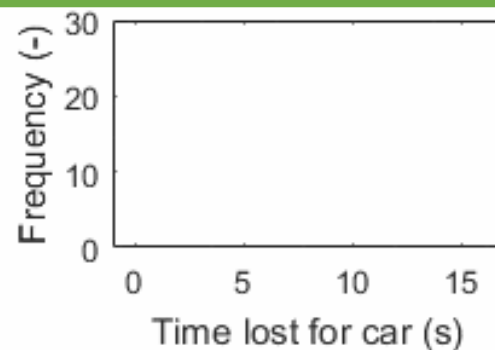
Braking as if to stop exactly at crossing
(1.7 m/s^2)



Braking just slightly harder
(2.2 m/s^2)



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



interACT



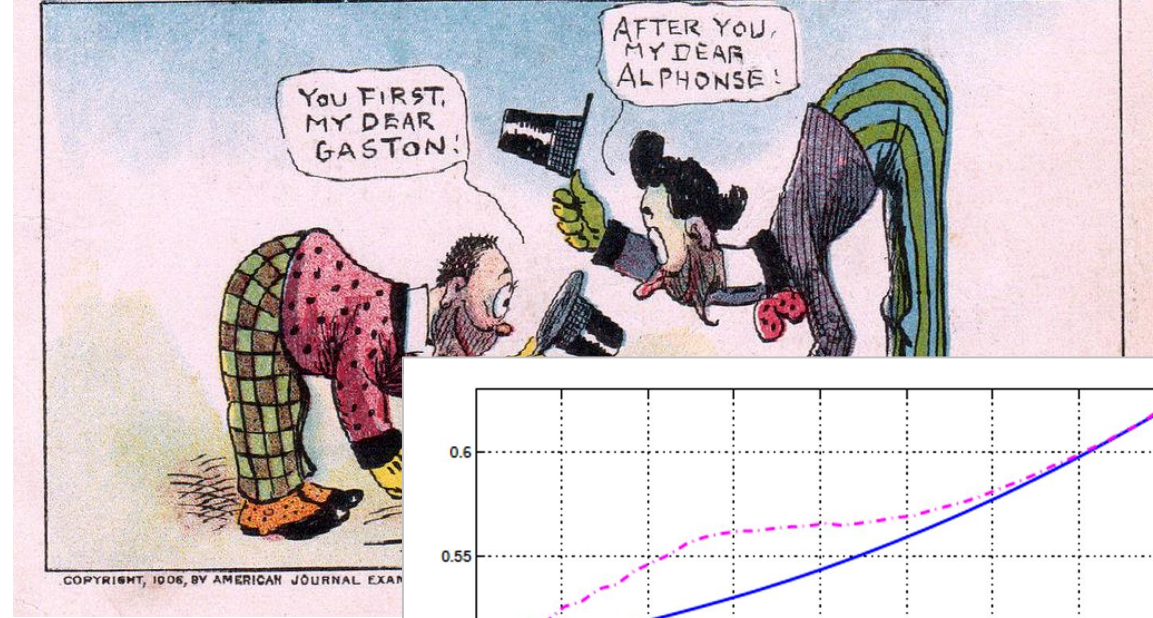
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Some key areas for further model development

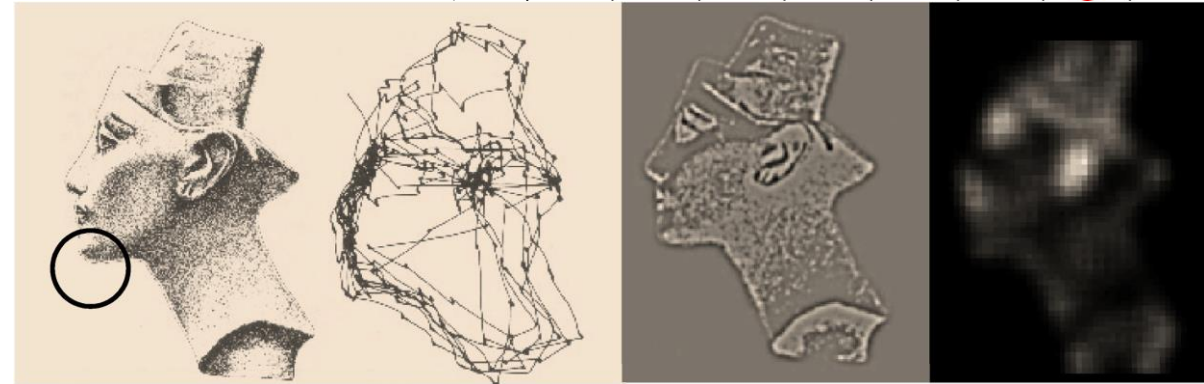
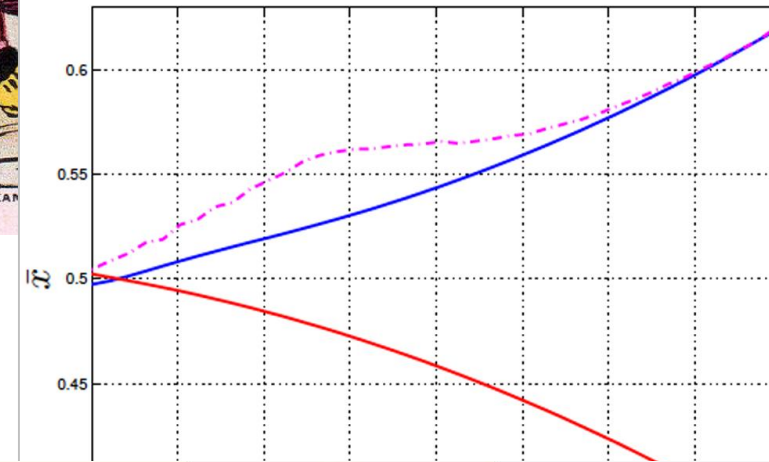
Human...

- ... recognition of actions/intentions
- ... communication
- ... strategic/game-theoretic behaviour
- ... attention/gaze allocation

(Friston et al., 2012, Front Psychol)



(Pezzulo et al., 2013, PLOS One)



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>

Two 3.5-year postdoc positions:
<https://jobs.leeds.ac.uk/ENVTR1108>
<https://jobs.leeds.ac.uk/ENVTR1109>

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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