Multitasking while Driving: Central Bottleneck or Problem State Interference?

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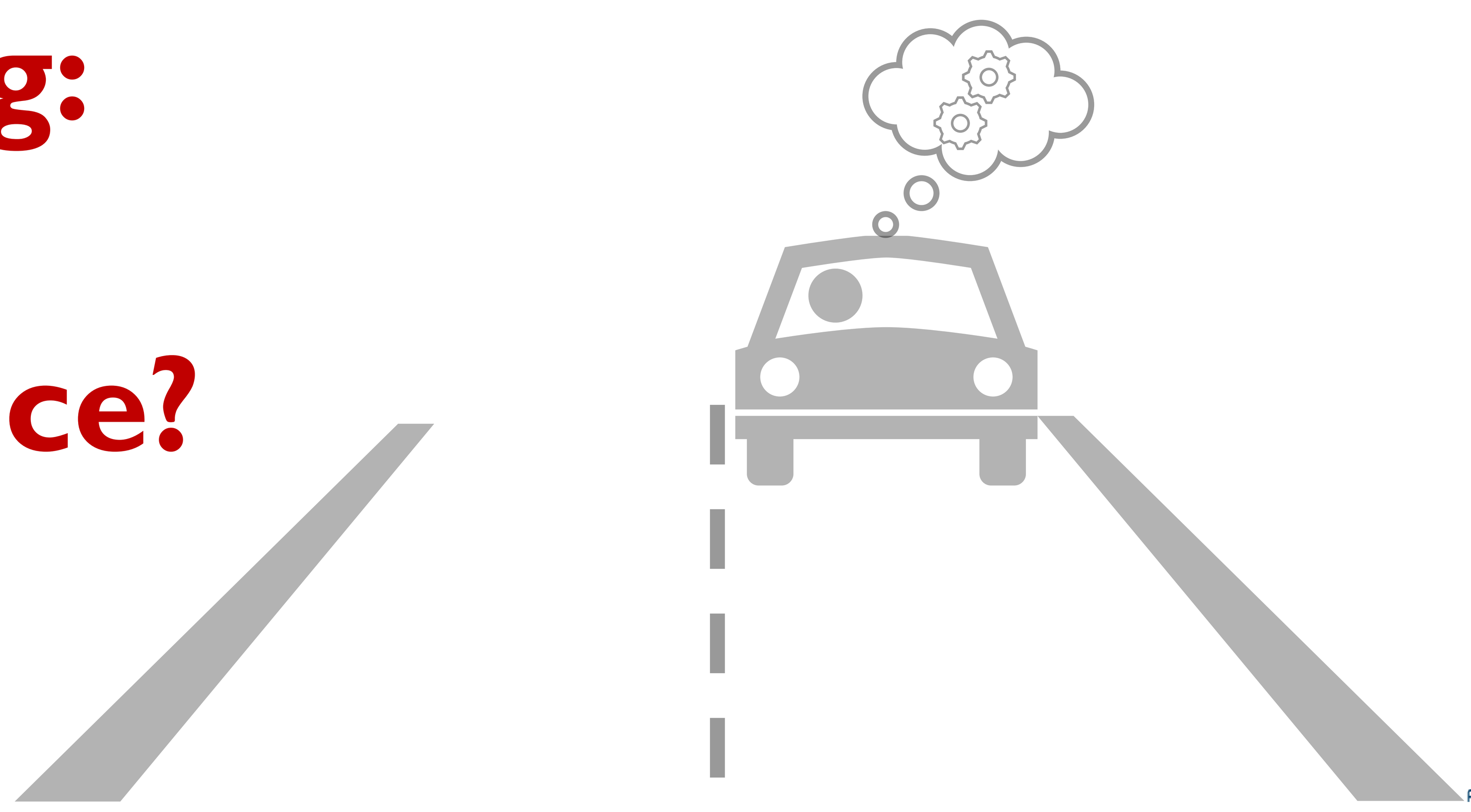
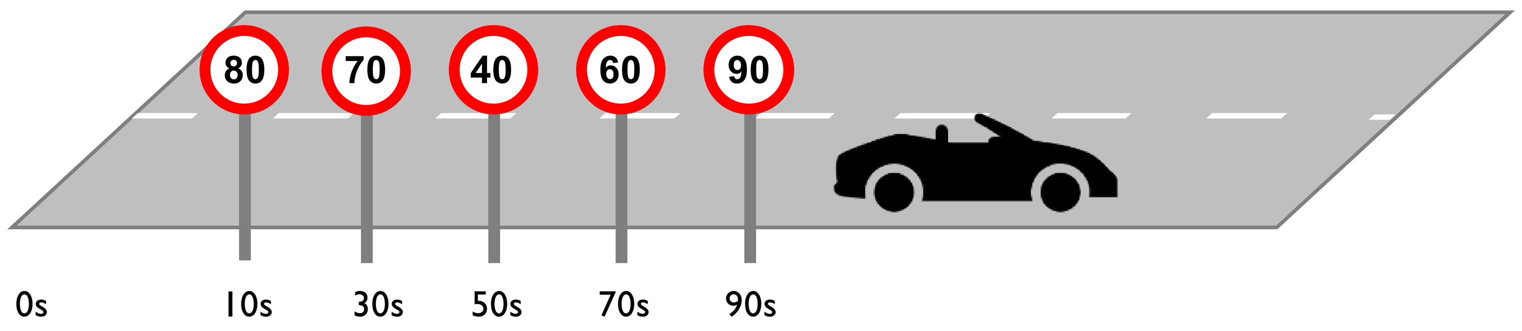


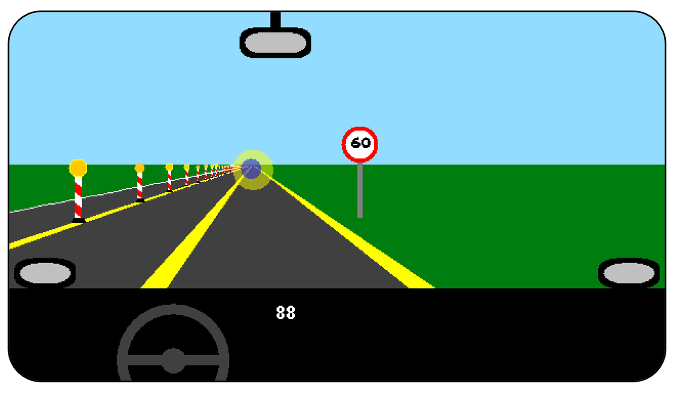
Introduction

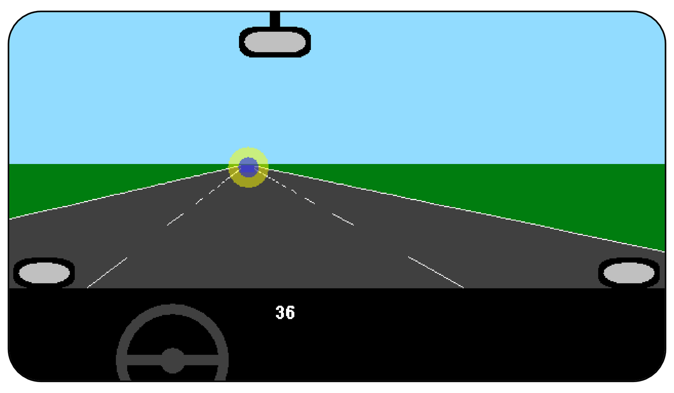
In recent studies, fNIRS has been used to classify periods of high mental workload while driving (Unni et al., 2017). However, interactions between different cognitive concepts have been found by Scheunemann et al. (2019), impairing the ability to identify periods of high mental workload accurately. These interactions have been attributed to either a central bottleneck or to the so-called problem-state bottleneck, related to working memory usage. In this work, we contrast the two opposing hypotheses by adapting the seminal driving model by Salvucci (2006) and evaluating the model's behavior by comparing it to human behavioral data.

Experimental Design



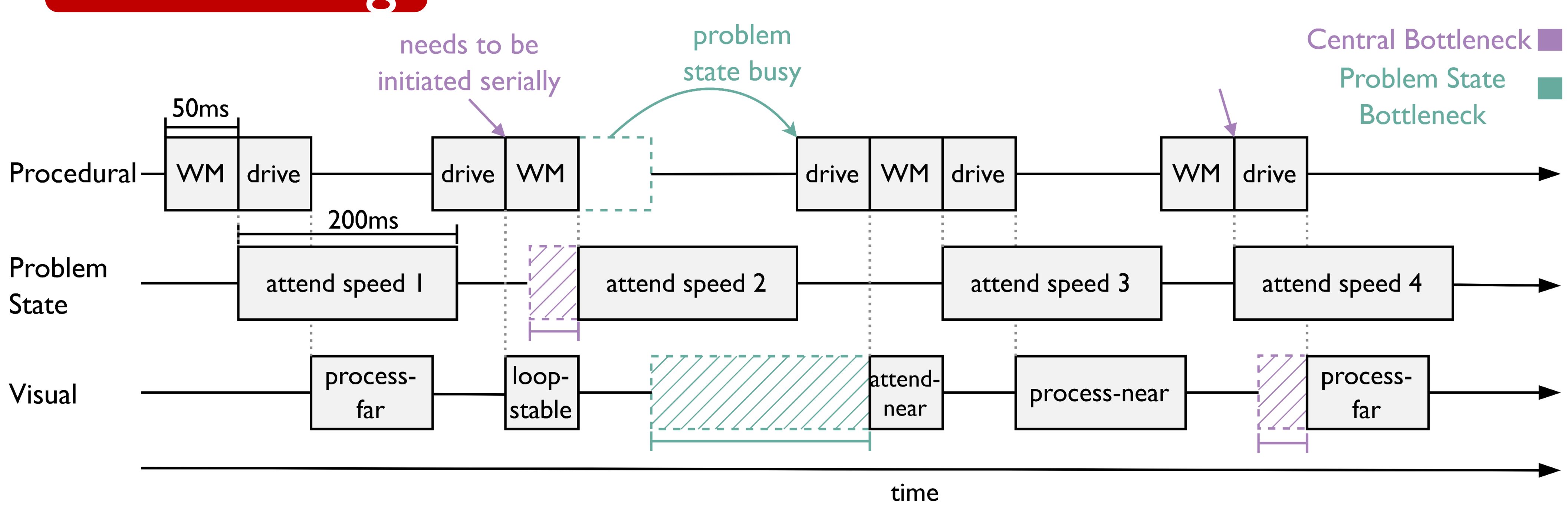
n-back level	0-back	1-back	2-back	3-back	4-back
correct speed	90	60	40	70	80





- Highway: 3.5m lane-width, 3 open lanes
- Construction: 2.5m lane-width, left lane blocked off
- Speed dictated by the modified n-back task
- Validated by human behavioral data

Multitasking



- Threaded cognition (Salvucci & Taatgen, 2008) predicts a bottleneck at the central processing unit
- Problem-state-bottleneck model waits until problem state is available for steering control

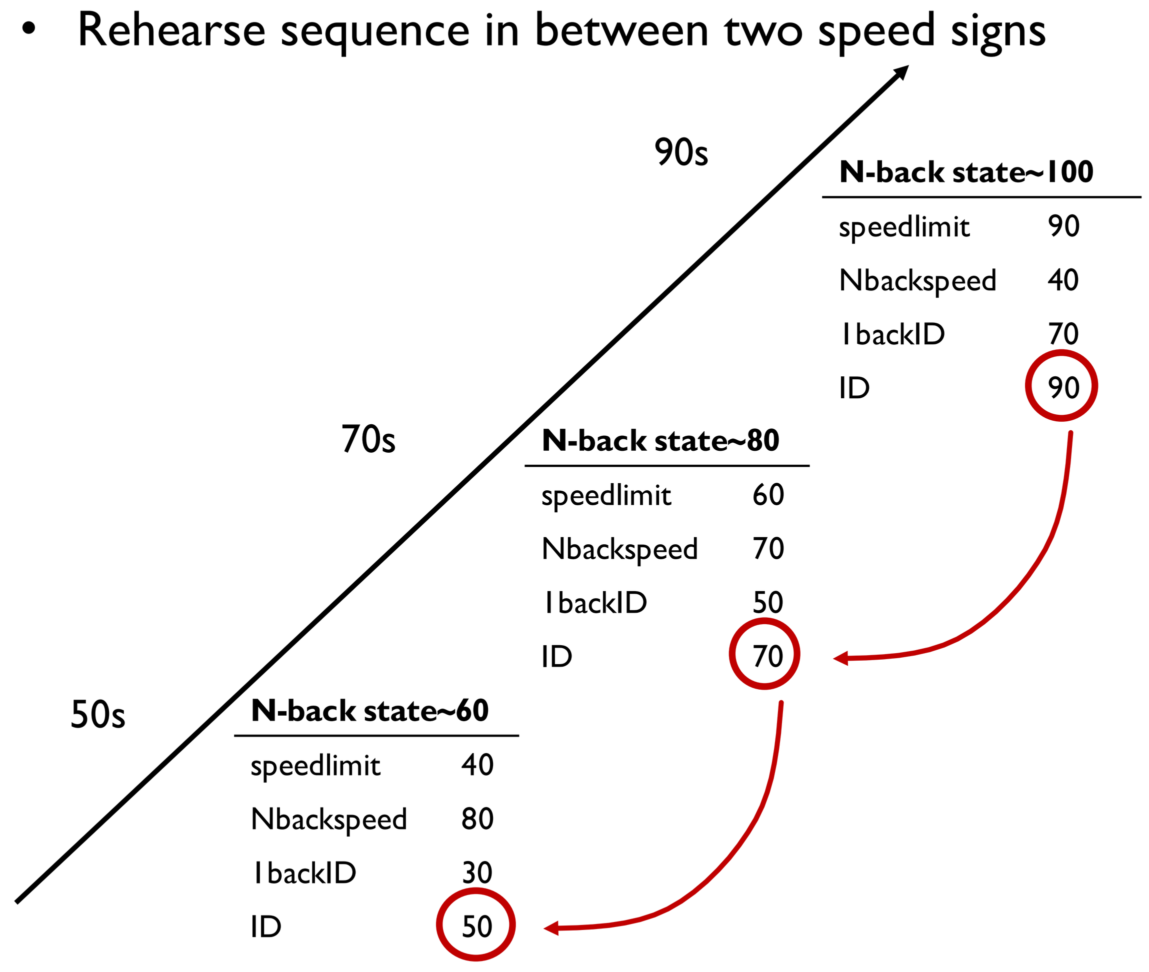
Models

Driving

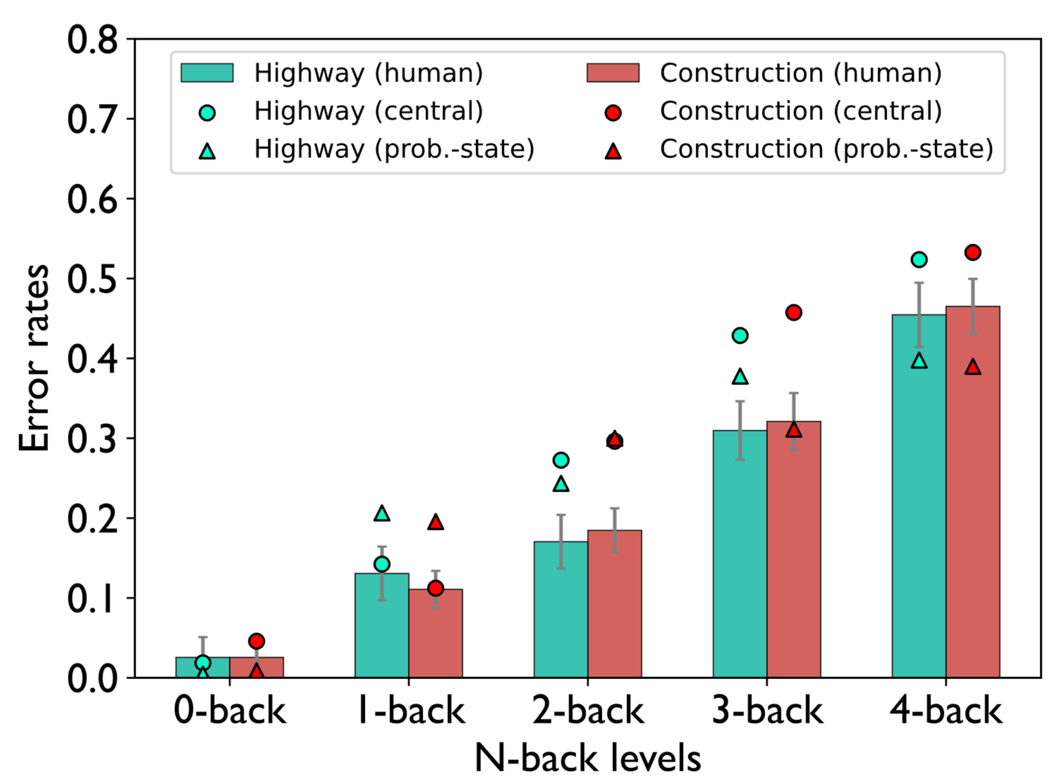
- Driving model in ACT-R with two control modes:
- Low-control loop does not adapt steering angle
- High-control loop adapts steering angle

N-back

- Speed signs encoded with episodic tag (ID) and tag of previous speed sign
- Sequential memorizing and recall starting from most recently encountered
- Errors modeled by retrieving incorrect but similar information
- Rehearse sequence in between two speed signs



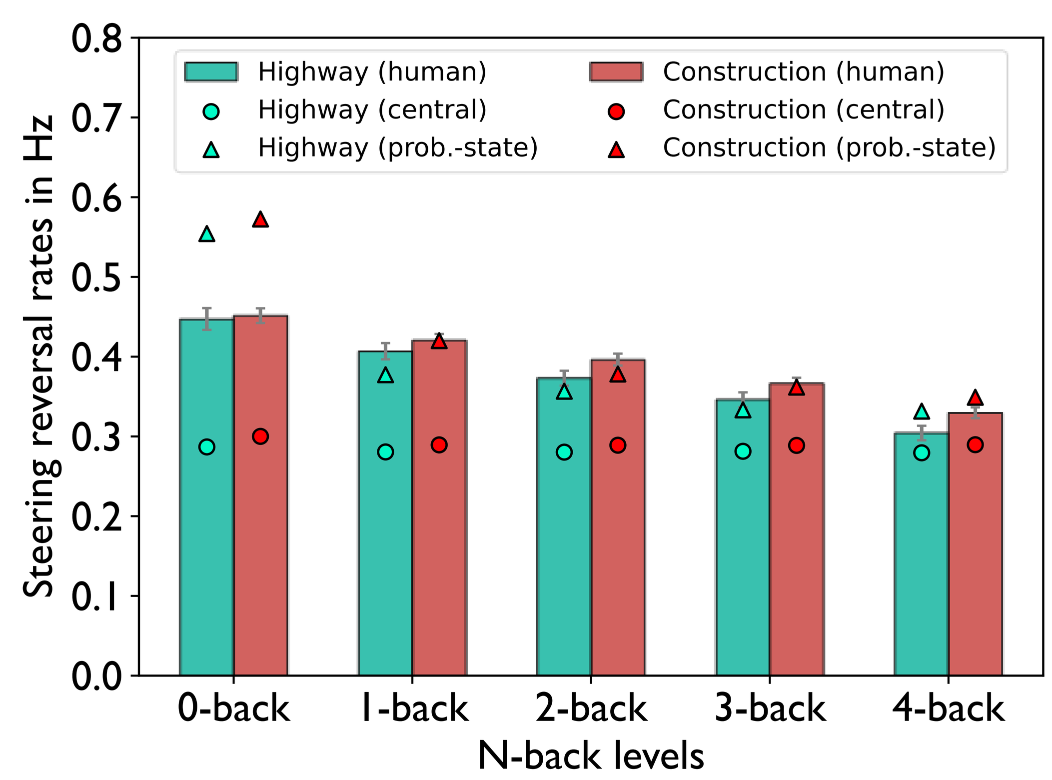
Results



- Errors in the speed regulation task increase with increasing difficulty
- No effect of lane condition on n-back performance

- Steering reversal rates decrease with increasing n-back level
  - Competition for resources leads to fewer steering updates
- Steering reversal rates increase in the construction condition due to an increased time in the high-control loop

→ problem-state-bottleneck model matches human data better



Conclusion

- Models show how both tasks compete for available resources
- Problem-state bottleneck model can account for a wider range of human behavior
- Results indicate a bottleneck at a task-specific resource → problem-state
- Disambiguating the human state with regard to different kinds of workload can be useful in the design of adaptive automated driving systems

Your comments and questions

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