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# Dealing with highly dynamic models

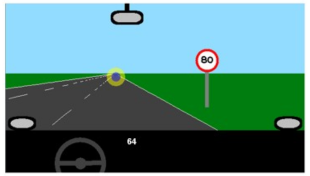
## How behavioral and neuroimaging data can guide the modeling process in applied driving models

Moritz Held (M.Sc.), 23.03.2022

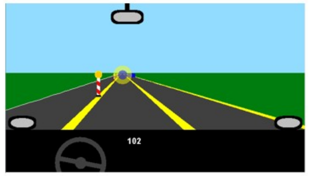
Prof. Jochem Rieger
Dr. Jelmer Borst

# Cognitive Load while Driving

| 2 conditions for **visuospatial demands** | Five different **working memory load levels** (primary task)<br>Modeled by n-back (0-back vs. 4-back) |
|---|---|

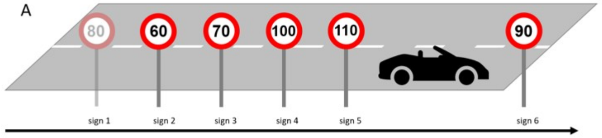



Normal lane width (3.5m)




Reduced lane width (2.5m)

A




B

| | sign 1 | sign 2 | sign 3 | sign 4 | sign 5 | sign 6 |
|---|---|---|---|---|---|---|
| 0-back: | 80 | 60 | 70 | 100 | 110 | 90 |
| 1-back: | 80 | 80 | 60 | 70 | 100 | 110 |
| 2-back: | 80 | 60 | 80 | 60 | 70 | 100 |
| 3-back: | 80 | 60 | 70 | 80 | 60 | 70 |
| 4-back: | 80 | 60 | 70 | 100 | 80 | 60 |

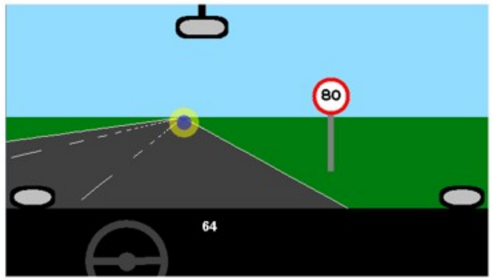
## Assessing the Driver's Current Level of Working Memory Load with High Density Functional Near-infrared Spectroscopy: A Realistic Driving Simulator Study

*Anirudh Unni[1], Klas Ihme[2], Meike Jipp[2] and Jochem W. Rieger[1]**

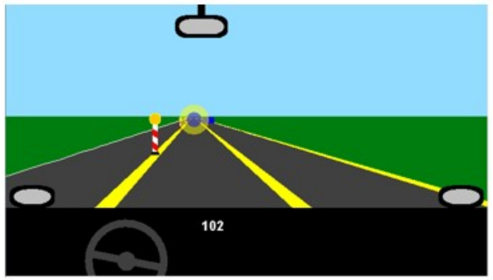
*[1] Department of Psychology, University of Oldenburg, Oldenburg, Germany, [2] Institute of Transportation Systems, German Aerospace Research Center, Braunschweig, Germany*

# Experimental Design

2 conditions for **visuospatial demands**



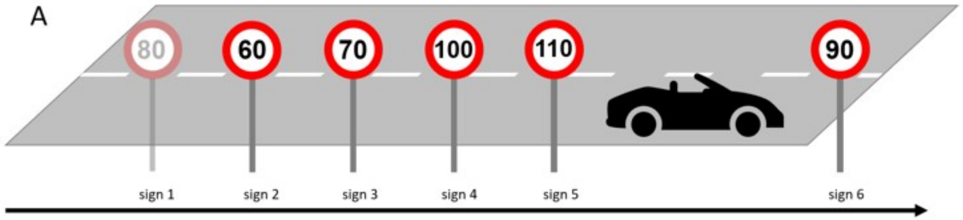

Normal lane width (3.5m)




Reduced lane width (2.5m)

Five different **working memory load levels** (primary task)
Modeled by n-back (0-back vs. 4-back)

A

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| 3-back: | 80 | 60 | 70 | 80 | 60 | 70 |
| 4-back: | 80 | 60 | 70 | 100 | 80 | 60 |

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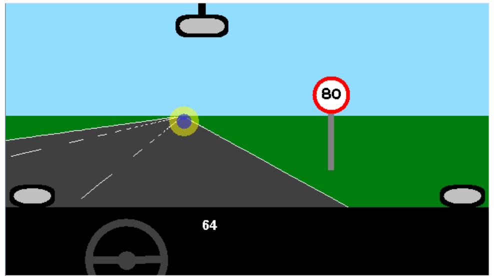
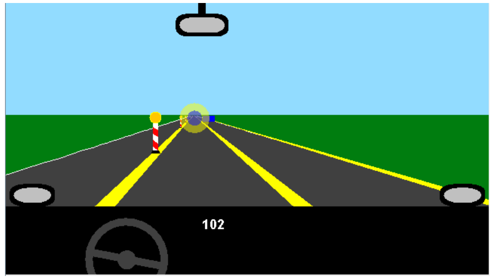
# Experimental Design

2 conditions for **visuospatial demands**




Normal lane width (3.5m)




Reduced lane width (2.5m)

Five different **working memory load levels** (primary task)
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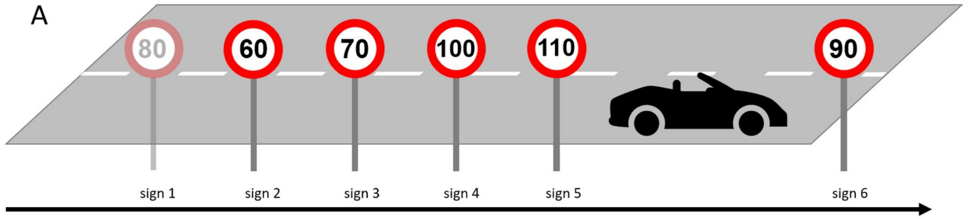


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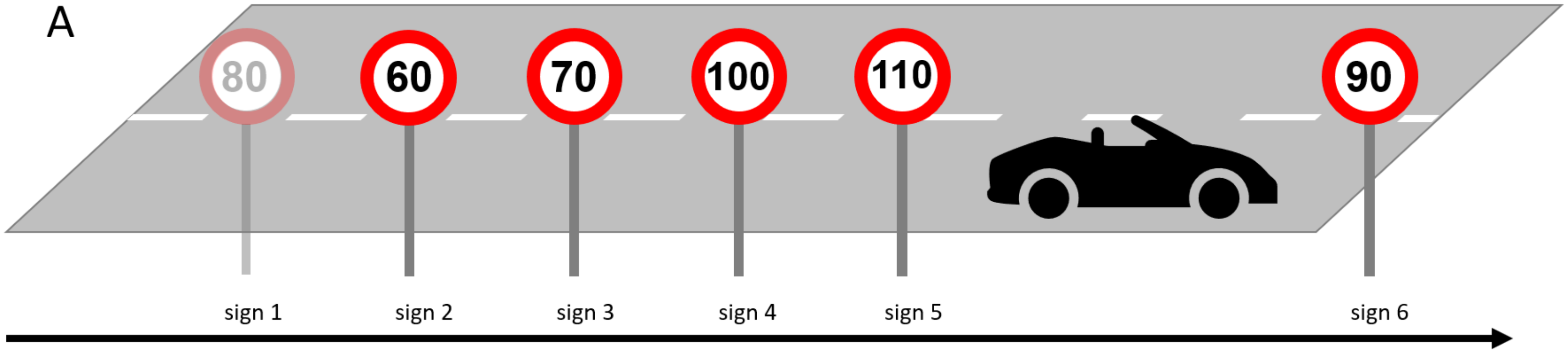
# Experimental Design

A

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# Cognitive Load while Driving

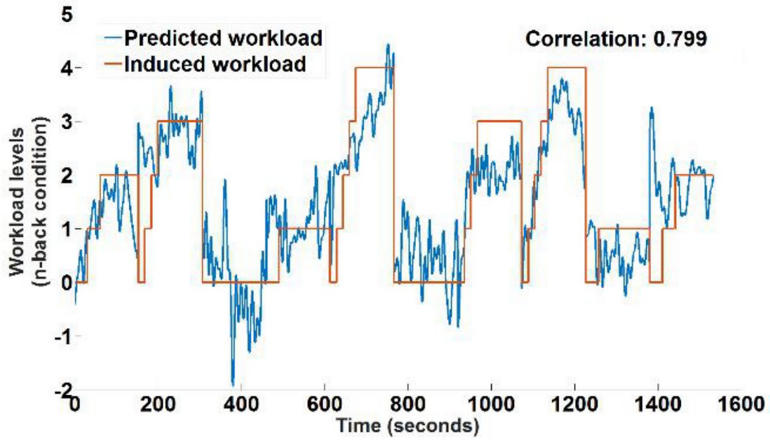
- Continuously measure workload and accurately predict momentary workload
- Brain activity measured with functional near infrared spectroscopy (fNIRS)
- Found interactions between the cognitive concepts that were manipulated (visuospatial attention & working memory load) making prediction difficult

**Assessing the Driver's Current Level of Working Memory Load with High Density Functional Near-infrared Spectroscopy: A Realistic Driving Simulator Study**

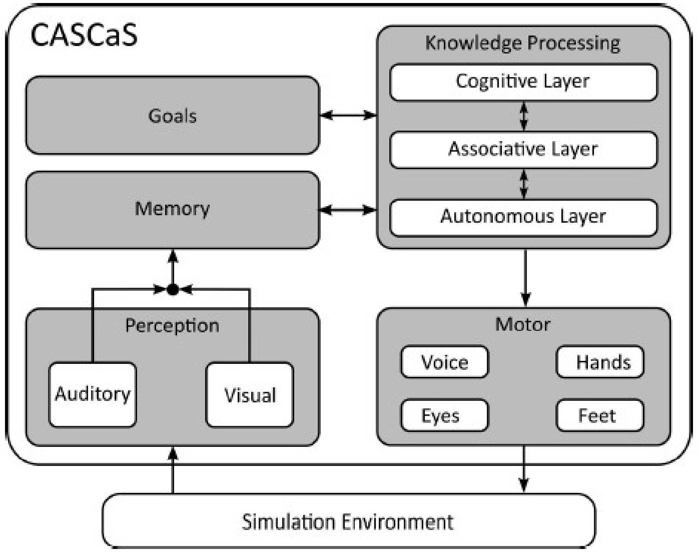
*Anirudh Unni[1], Klas Ihme[2], Meike Jipp[2] and Jochem W. Rieger[1]**

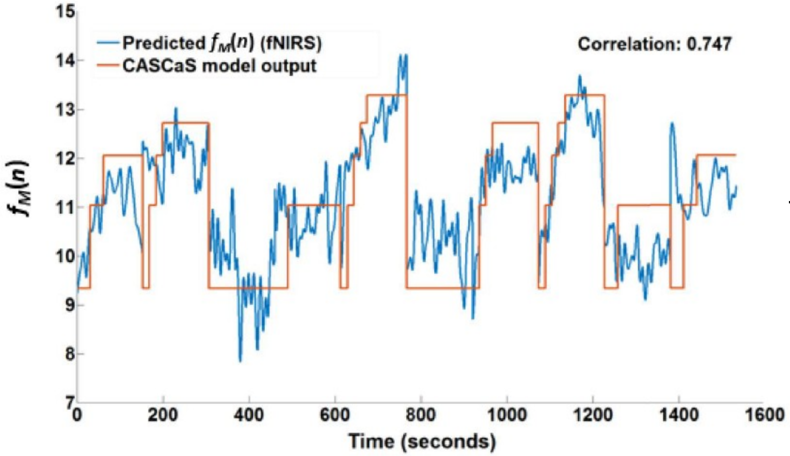
*[1] Department of Psychology, University of Oldenburg, Oldenburg, Germany, [2] Institute of Transportation Systems, German Aerospace Research Center, Braunschweig, Germany*

# The cognitive architecture for safety critical task simulation (CASCaS)




Ten-fold cross-validated prediction of working memory load from HbR fNIRS using multivariate regression analysis for an example participant (Wortelen et al., 2016)




Ten-fold cross-validated prediction of CASCaS workload indicator fM(n) from HbR fNIRS measurements using multivariate regression analysis for an example participant. (Wortelen et al., 2016)

Wortelen, B., Unni, A., Rieger, J. W., and Lüdtke, A. (2016). “Towards the integration and evaluation of online workload measures in a cognitive architecture,” in Proceedings of the 7th IEEE Conference on Cognitive Infocommunications, Wroclaw.

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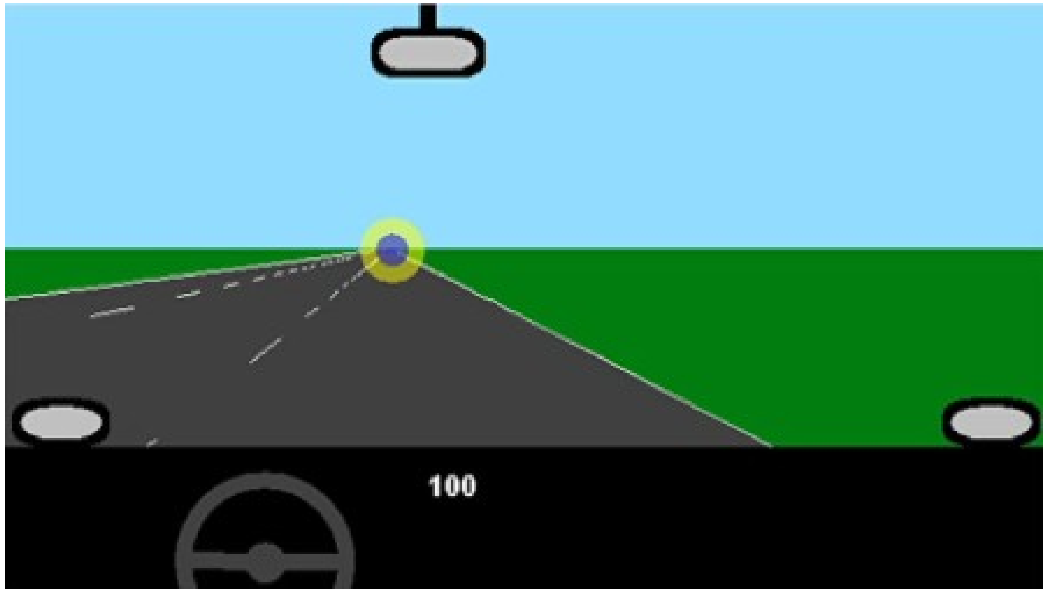
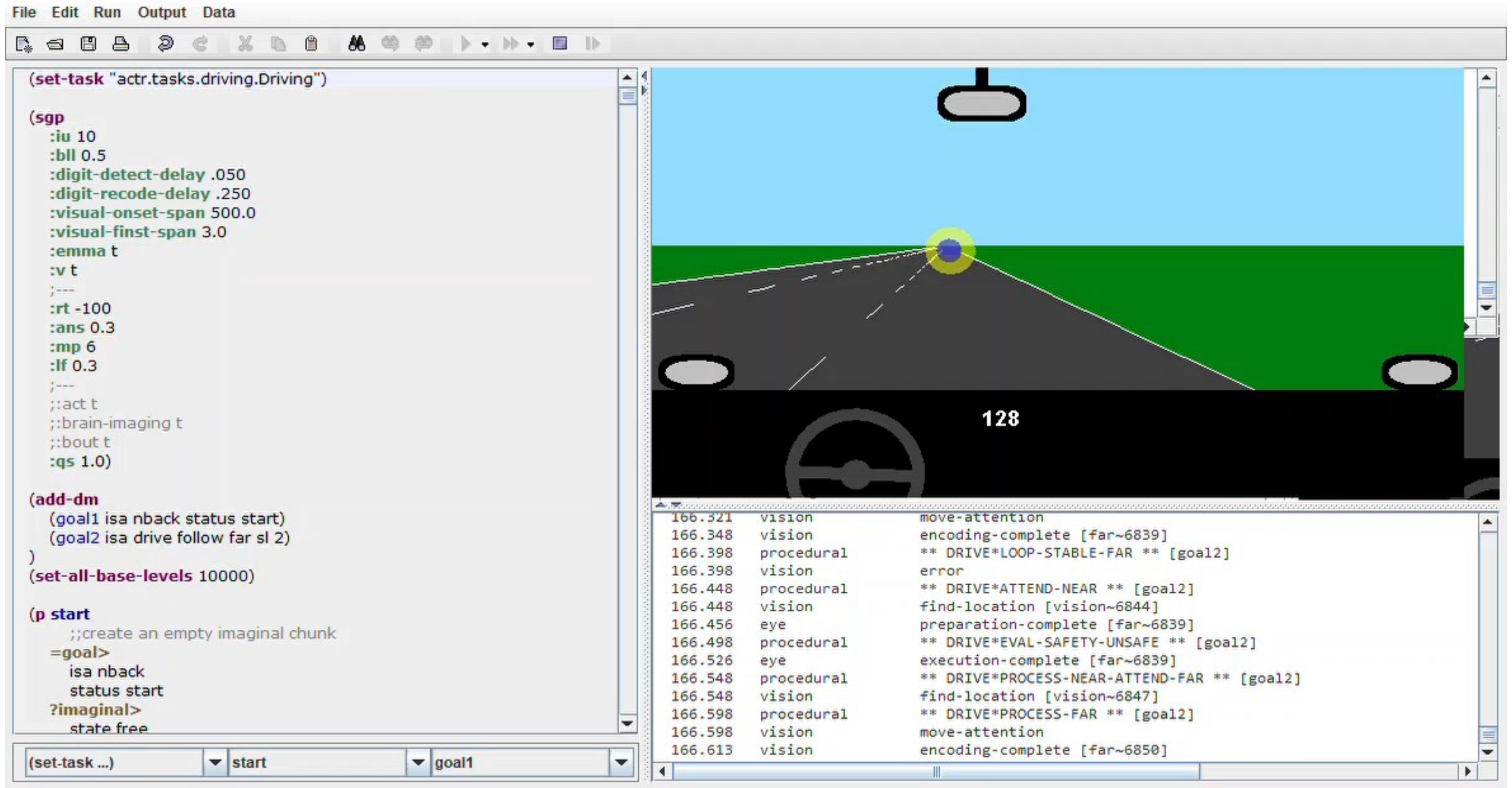
# Driving model (based on Salvucci, 2006)

- Models of multitasking by Salvucci and Beltwoska (2008) show effect of a cognitive task on driving performance
- Drive safely on the lane
- Adhere to traffic laws (keep to right lane as much as possible)
- Handle traffic around the car
  - Overtake traffic to stick to the n-back speed
- Be able to drive on narrower lanes




Salvucci, D. D. & Beltowska, J. (2008). Effects of memory rehearsal on driver performance: Experiment and theoretical account. *Human Factors*, *50*(5), 834–844. https://doi.org/10.1518/001872008X354200

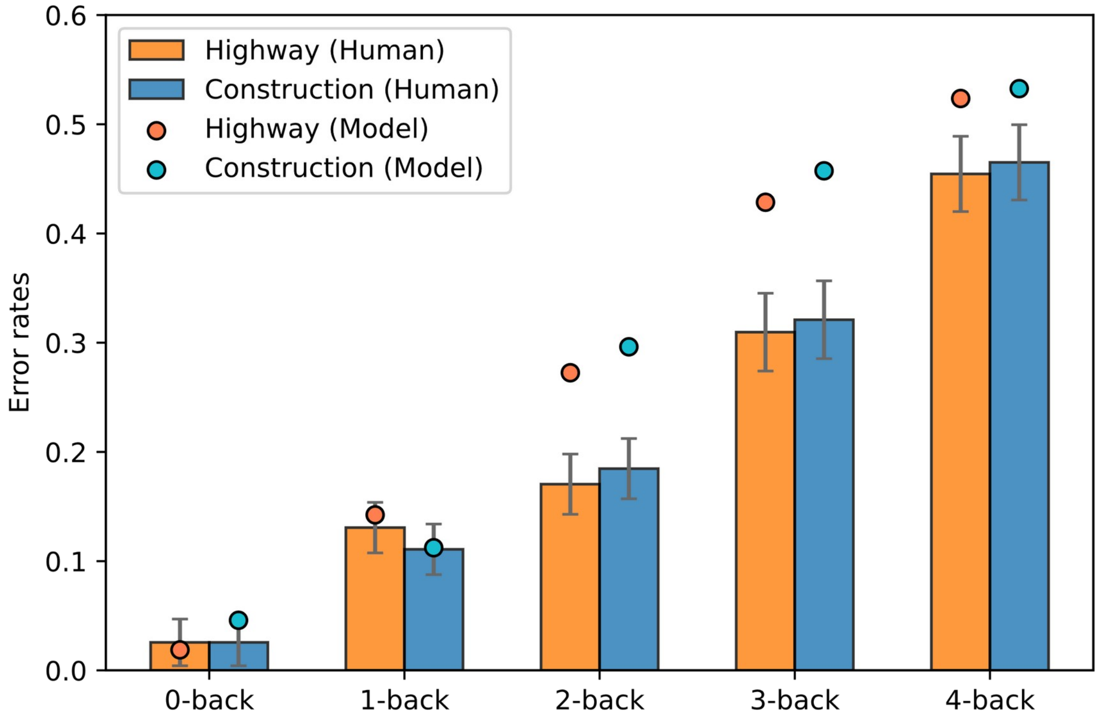
# Model demo


File Edit Run Output Data
(set-task "actr.tasks.driving.Driving")
(sgp
:iu 10
:bll 0.5
:digit-detect-delay .050
:digit-recode-delay .250
:visual-onset-span 500.0
:visual-finst-span 3.0
:emma t
:v t
;---
:rt -100
:ans 0.3
:mp 6
:lf 0.3
;---
;;:act t
;;:brain-imaging t
;;:bout t
:qs 1.0)
(add-dm
(goal1 isa nback status start)
(goal2 isa drive follow far sl 2)
)
(set-all-base-levels 10000)
(p start
;;create an empty imaginal chunk
=goal>
isa nback
status start
?imaginal>
state free
(set-task ...)
start
goal1
128
166.348 vision encoding-complete [far~6839]
166.398 procedural ** DRIVE*LOOP-STABLE-FAR ** [goal2]
166.398 vision error
166.448 procedural ** DRIVE*ATTEND-NEAR ** [goal2]
166.448 vision find-location [vision~6844]
166.456 eye preparation-complete [far~6839]
166.498 procedural ** DRIVE*EVAL-SAFETY-UNSAFE ** [goal2]
166.526 eye execution-complete [far~6839]
166.548 procedural ** DRIVE*PROCESS-NEAR-ATTEND-FAR ** [goal2]
166.548 vision find-location [vision~6847]
166.598 procedural ** DRIVE*PROCESS-FAR ** [goal2]
166.598 vision move-attention
166.613 vision encoding-complete [far~6850]

# Speed regulation errors

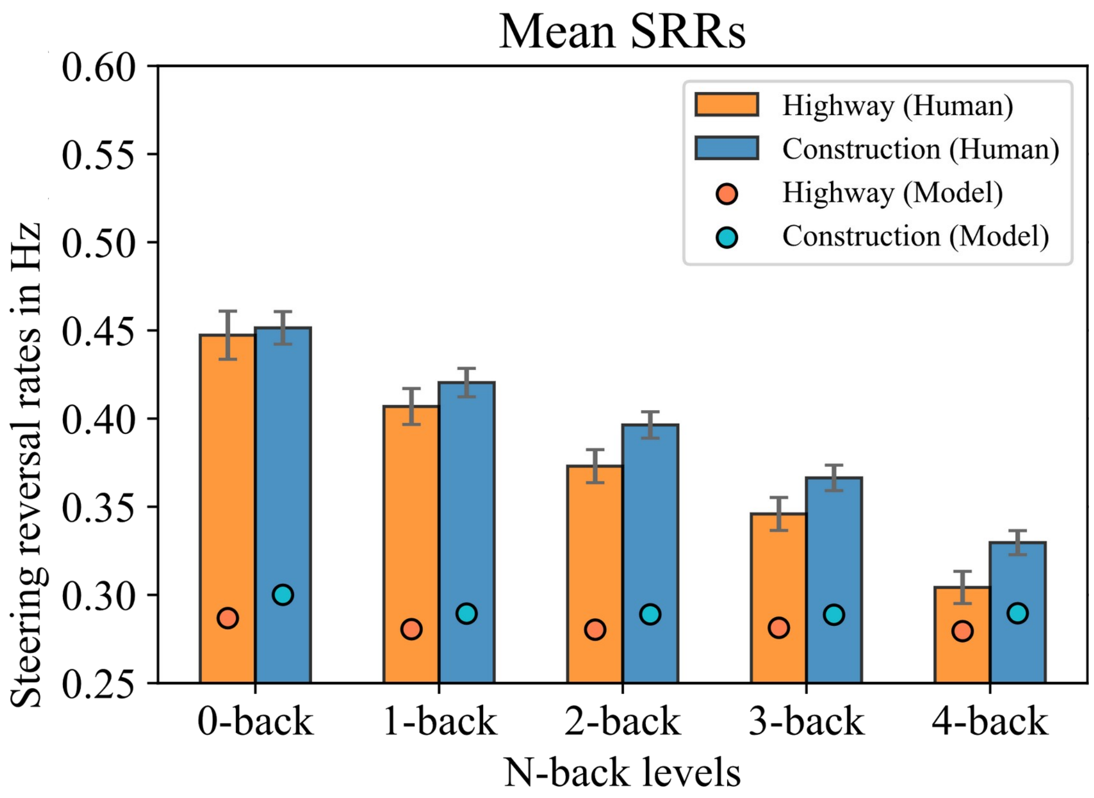
– Increase of error rate with increasing n-back level

– No difference between visuospatial conditions

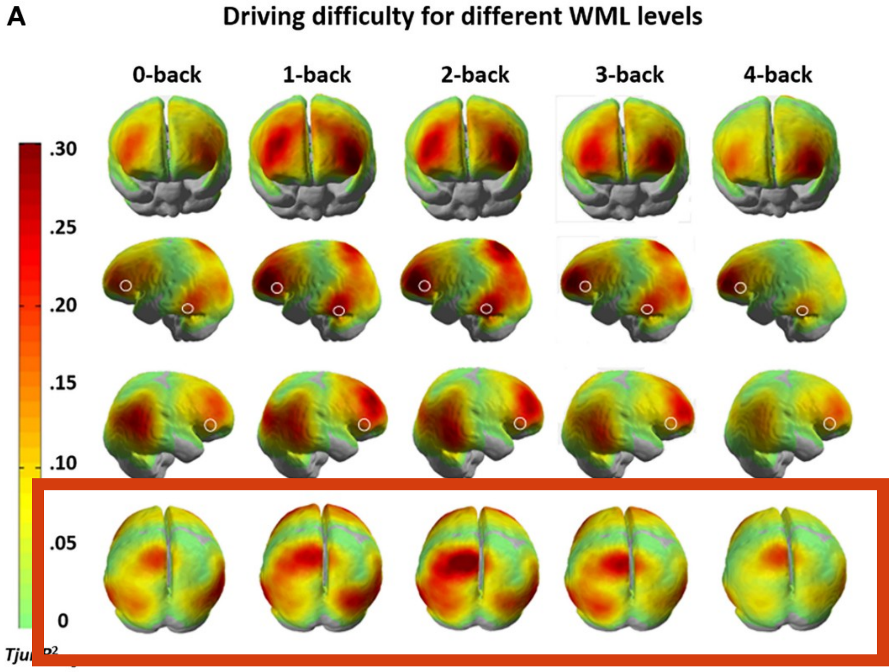


# Steering reversal rates

– Initial model could not capture the effect of decreasing steering reversals over n-back level

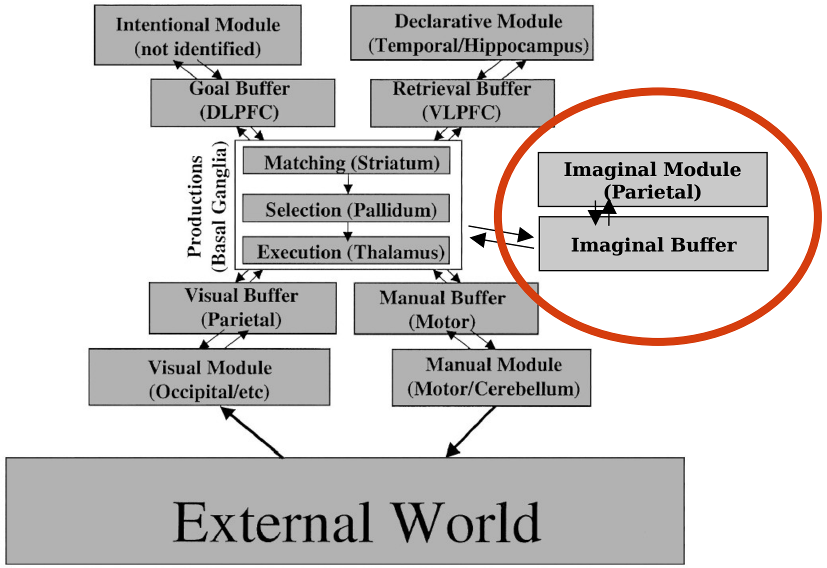


# Revising the model




Weighted mean of channel-wise predictivity (Tjur R2 avg) for driving difficulty at the different WML levels (Scheunemann et al., 2019)

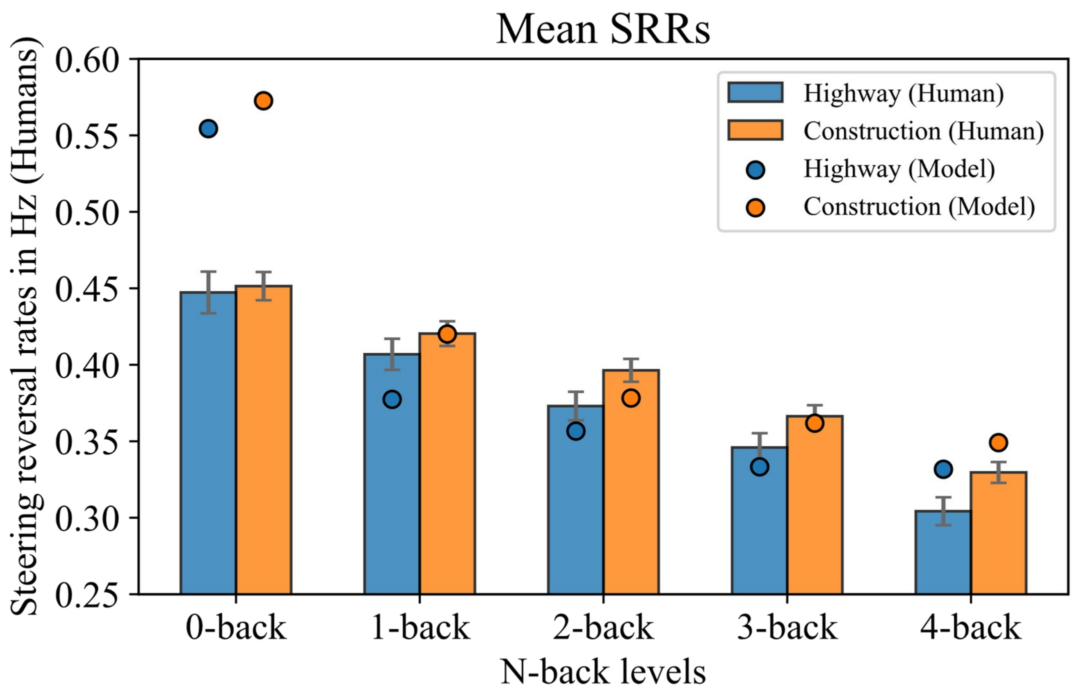
– Scheunemann et al. (2019) showed parietal lobe to be very predictive for driving difficulty at the different WML levels




Scheunemann, J., Unni, A., Ihme, K., Jipp, M. & Rieger, J. W. (2019). Demonstrating Brain-Level Interactions Between Visuospatial Attentional Demands and Working Memory Load While Driving Using Functional Near-Infrared Spectroscopy. *Frontiers in Human Neuroscience*, *12*, 542. https://doi.org/10.3389/fnhum.2018.00542

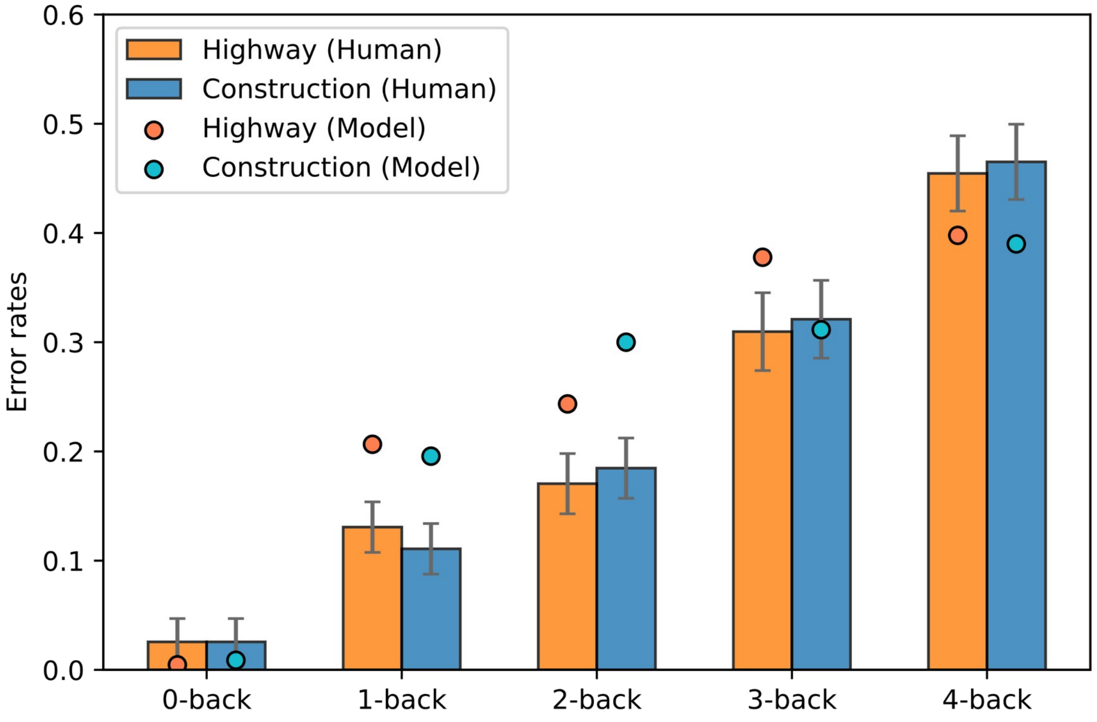
# Steering reversal rates

- revised model with a bottleneck in the imaginal module of ACT-R
- Decrease over n-back levels
- Higher steering reversal rates in the construction site



# Speed regulation errors

– The bottleneck in the imaginal module has no effect on speed regulation errors



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# Conclusion

- Model showed good predictions in the n-back task but initially wasn‘t able to transfer to driving performance
- We used behavioral data as well as results from brain-imaging research to revise the model
- final ACT-R model is able to show how both task compete for available resources
  - Central processing unit
  - Imaginal module
- Effect on driving performance by working memory load can be best explained by a bottleneck in the imaginal module, which is linked to parietal lobe activity

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# Thank you for your attention!

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