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How younger and older drivers' steering reversals change with cognitive distraction during both day and night-time driving

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DDI2024

Introduction

- Visual and cognitive distractions influence steering through the steering wheel reversal rate (SWRR): cognitive load prompts micro corrections, while visual load results in larger corrections (Markkula & Engström, 2006).
- However, human behavior in driving is influenced by a range of factors, including age (e.g., Horberry et al., 2006), driving style (e.g., Rong et al., 2011), and lighting conditions (e.g., Wood, 2020).

Introduction

- Expanding on prior research (Kountouriotis et al., 2016; Öztürk et al., 2023), this study explores how the following factors affect the steering wheel reversal rate:
  1) age
  2) lighting (day or night)
  3) cognitive load (n-back task)
  4) visual load (detection-response task, DRT), and
- To account for drivers' individual differences, we employ multilevel modelling.
- Part of the HAzards, ROad Lighting and Driving Project (HAROLD)

Method

Participants, design, and apparatus

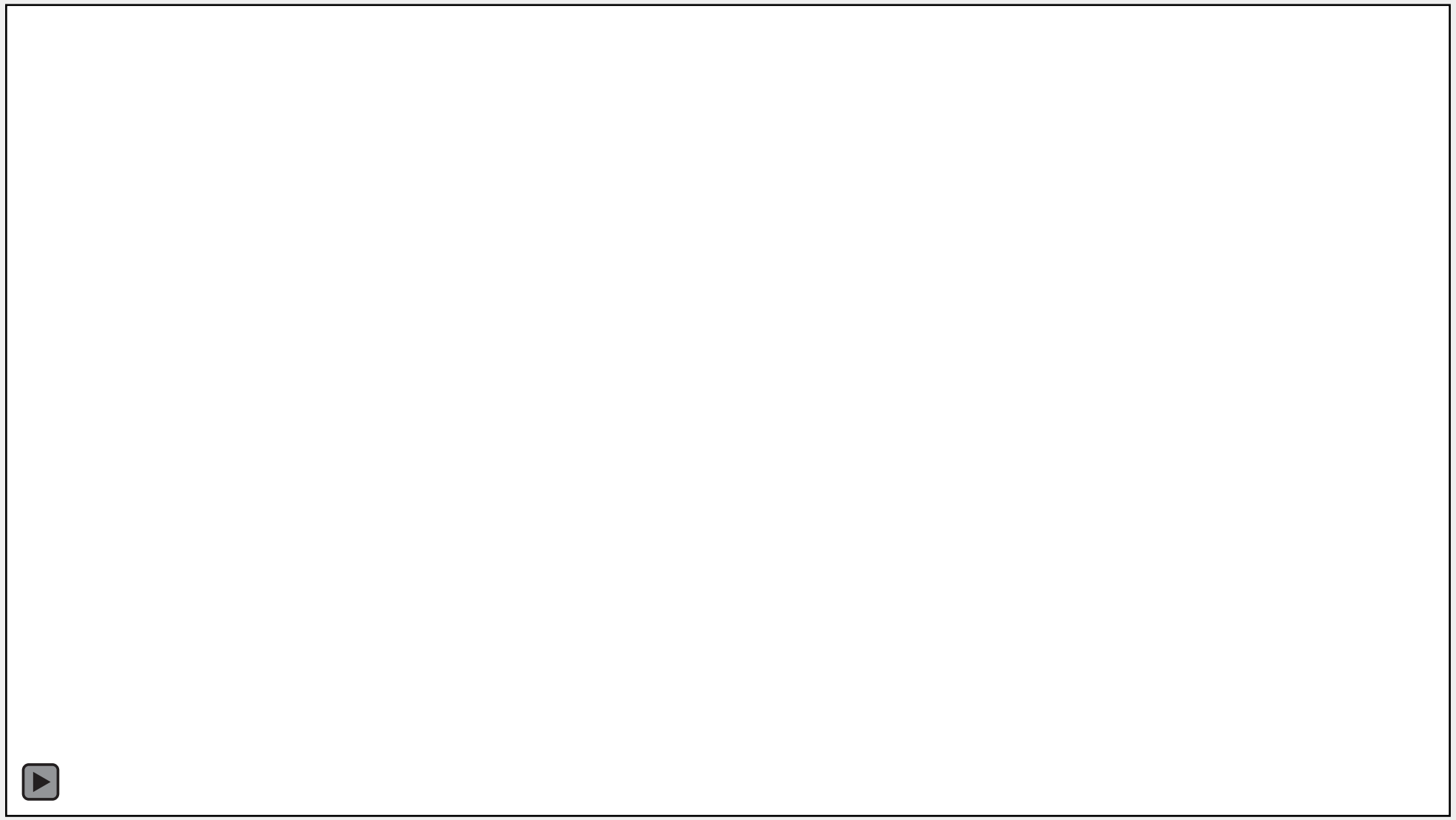
- 37 participants (20 younger: *M* age = 22.6, *SD* age = 1.2 and 17 older: *M* age = 65.8, *SD* age = 3.8)
- The study design was a 3 (cognitive task: no task, 1-back, 2-back) x 2 (lighting: day-time, night-time) x 2 (DRT: with DRT, without DRT) x 2 (age: younger, older) mixed factors design, with age as the only between-participant factor
- The study used the University of Leeds Driving Simulator, featuring a Jaguar S-type in a 4 m spherical projection dome with a 300° projection angle and 8 degrees of freedom motion system

Method

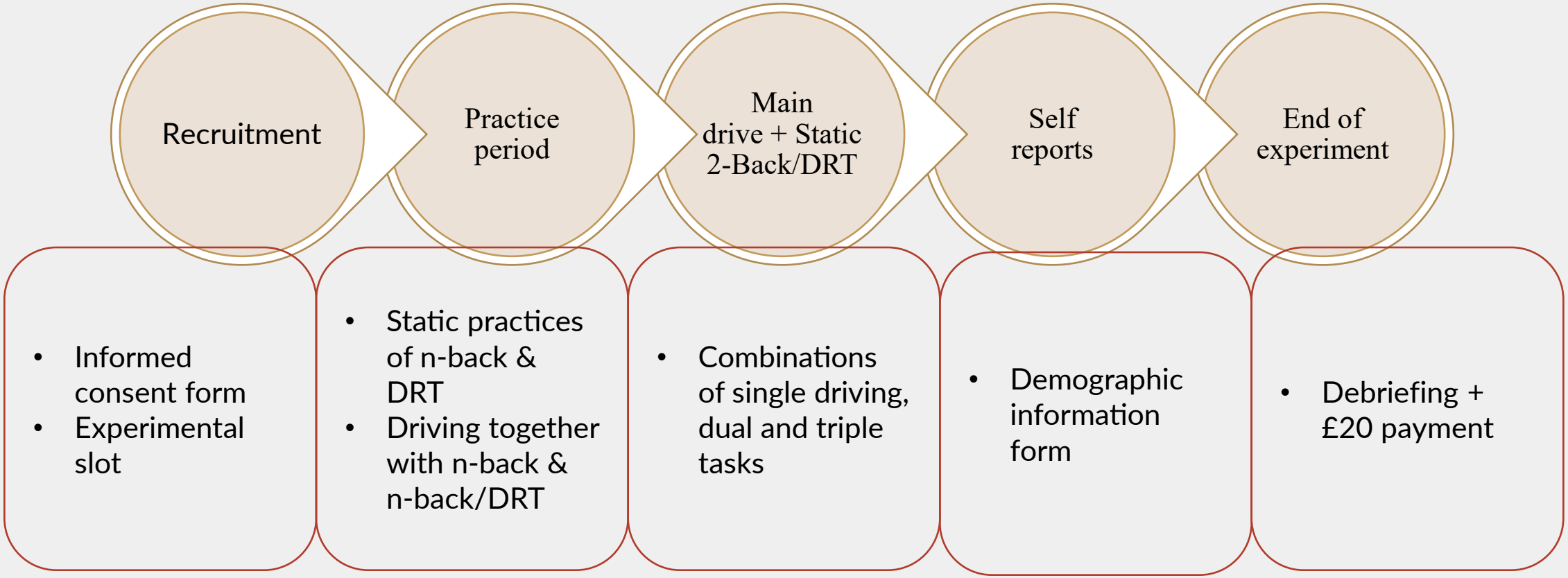
Driving scene, cognitive task, and visual task

- Driving scene: Two-lane contraflow, highway with a 60-mph speed limit
- Cognitive task: auditory n-back task (Mehler et al., 2011) with two difficulty levels (1-back, 2-back)
- Visual task: Detection-response task where the stimuli (a red circle) appeared randomly on the driving scene, presented every 3–5 seconds, remaining on the screen for one second (ISO, 2016)
  - 2° to 4° above the horizon and 11° to 23° to the left or right

Detection-response task



Method
Procedure



Each experiment lasted ~60 minutes

Analyses

- SWRR was calculated for 0.5 ° and 2.5 ° reversals per minute (syntax by Markkula & Engström, 2006)
- The 0.5 ° SWRR was conceptualized as small (micro) reversals and 2.5 ° SWRR as large reversals (Kountouriotis et al., 2016)
- In the following multilevel models, fixed factors include
  - age group (younger, older)
  - lighting (day, night)
  - n-back task (no n-back, 1-back, 2-back), and
  - DRT (not present, present)
- Each subject added as a random effect

Results

Small reversals – 0.5°

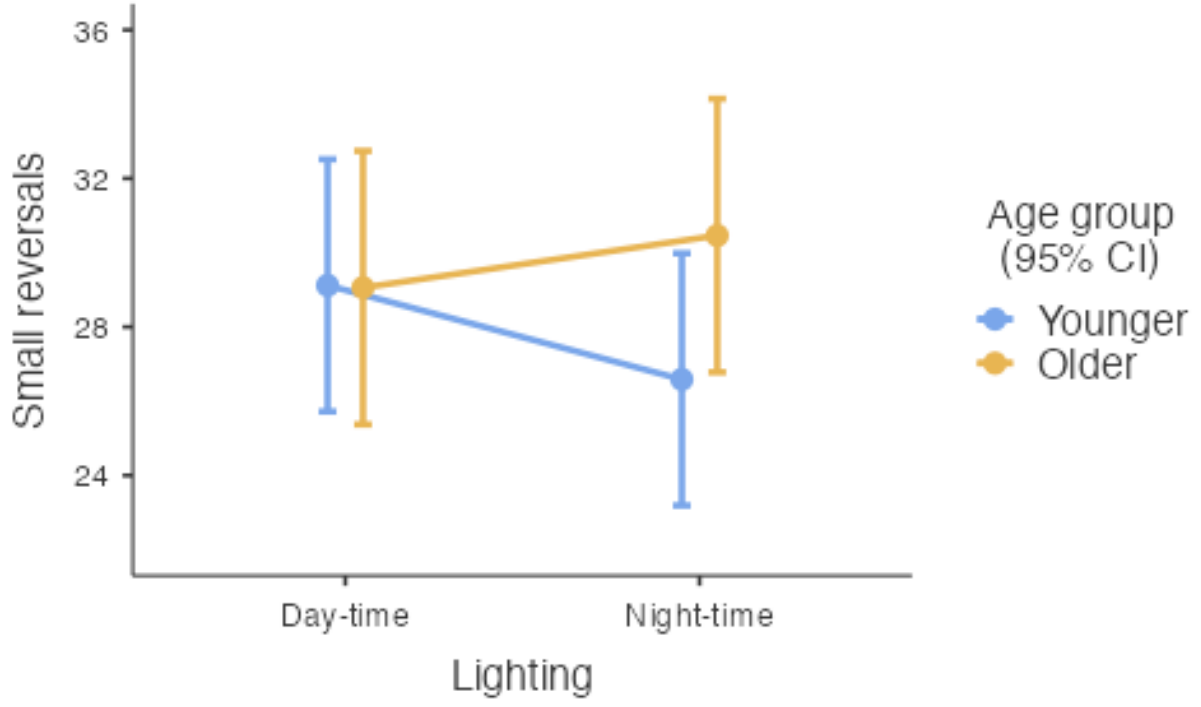
Visual load

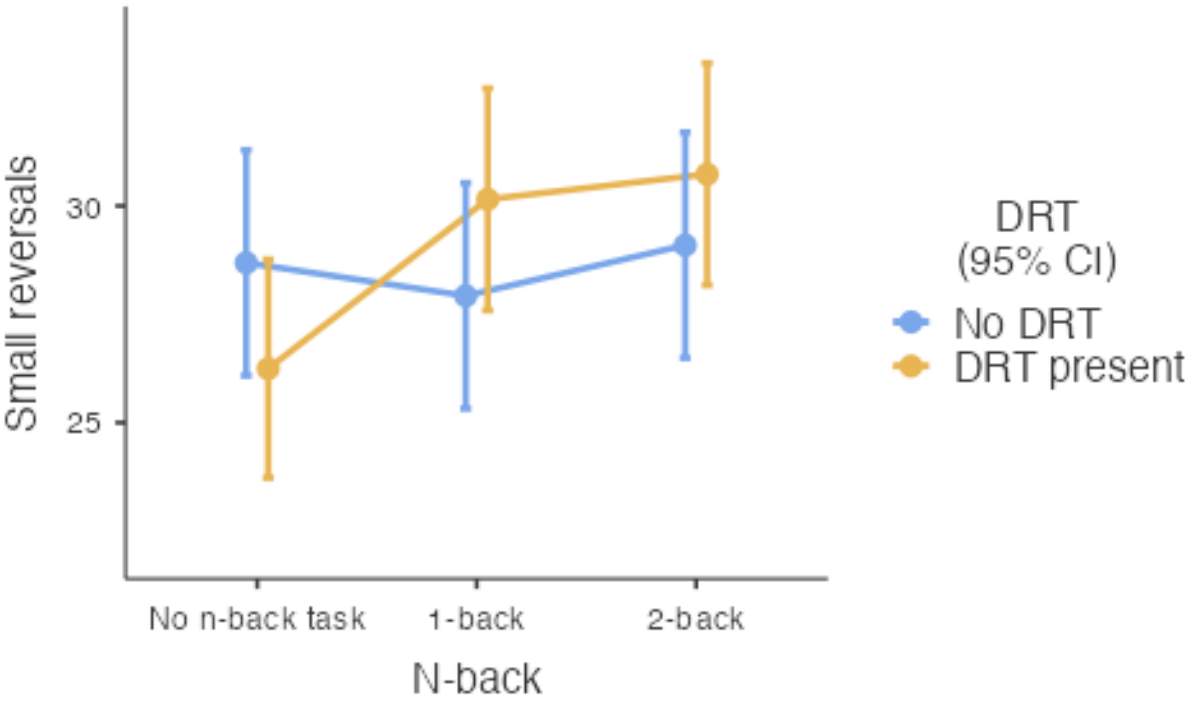
Cognitive load

Names	Effect	Estimate	SE	95% Confidence Interval		t	p
				Lower	Upper		
(Intercept)	(Intercept)	28.81	1.23	26.40	31.21	23.46	< .001
DRT	DRT present - No DRT	0.48	0.31	-0.12	1.07	1.55	0.121
Lighting	Day - Night	-0.56	0.28	-1.12	-0.00	-1.98	0.047
Age group	Older - Younger	1.91	2.45	-2.90	6.71	0.78	0.442
N-back 1	1-back - No n-back task	1.57	0.37	0.85	2.29	4.28	< .001
N-back 2	2-back - No n-back task	2.45	0.37	1.73	3.17	6.66	< .001
Lightning * Age group	Night – Day * Older – Younger	3.94	0.57	2.82	5.05	6.94	< .001
DRT * N-back 1	DRT present - No DRT * 1-back - No n-back task	4.67	0.74	3.22	6.11	6.35	< .001
DRT * N-back 2	DRT present - No DRT * 2-back - No n-back task	4.08	0.74	2.64	5.52	5.55	< .001

ICC = 67.2%

Results
Small reversals – 0.5°





Results

Large reversals – 2.5°

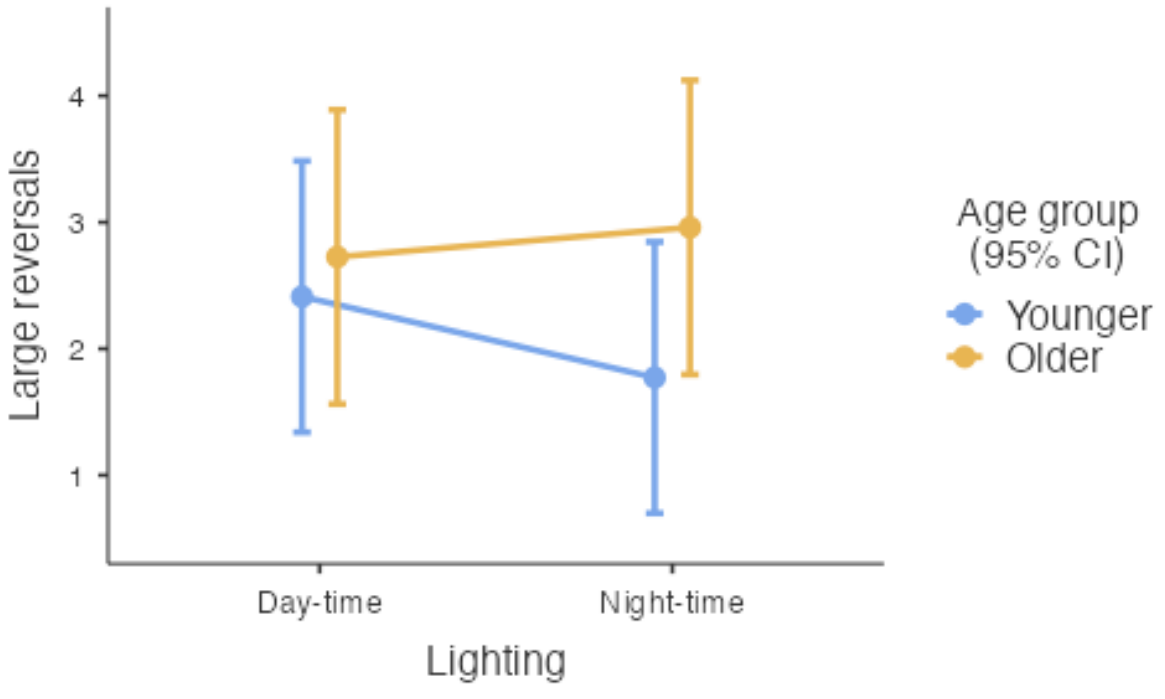
Visual load

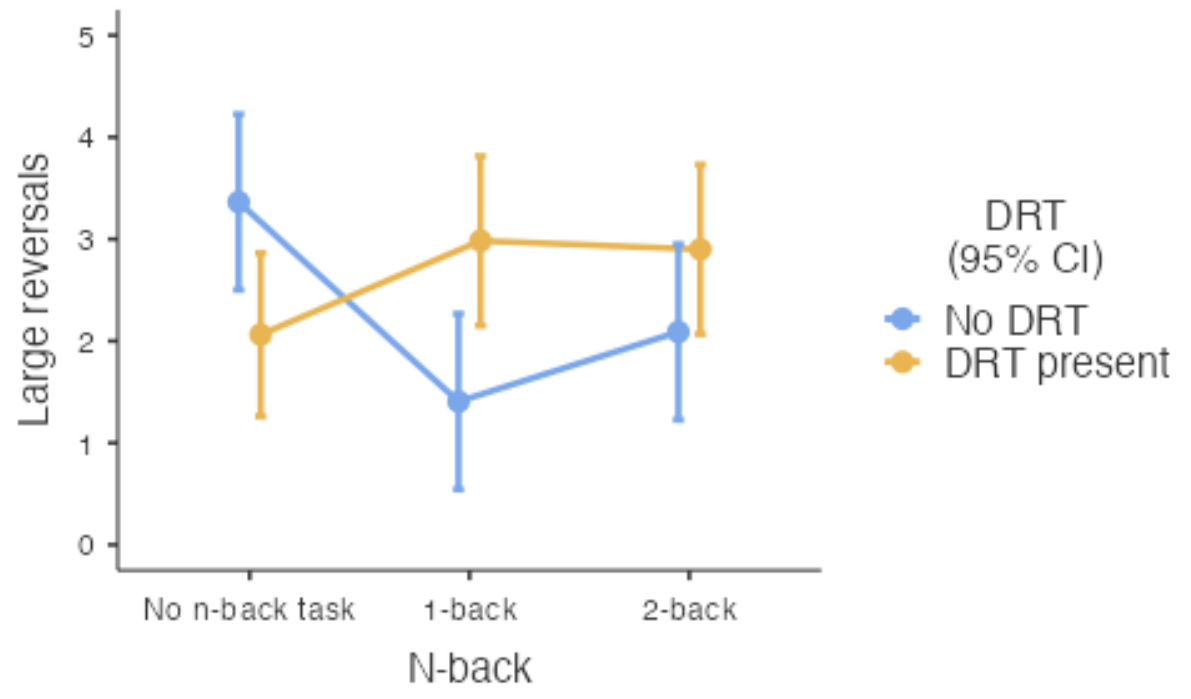
Cognitive load

Names	Effect	Estimate	SE	95% Confidence Interval		t	p
				Lower	Upper		
(Intercept)	(Intercept)	2.47	0.39	1.71	3.22	6.41	< .001
DRT	DRT present - No DRT	0.36	0.15	0.07	0.65	2.46	0.014
Lighting	Night - Day	-0.20	0.14	-0.47	0.06	-1.49	0.137
Age group	Older - Younger	0.75	0.77	-0.76	2.26	0.98	0.335
N-back 1	1-back - No n-back task	-0.52	0.18	-0.87	-0.17	-2.93	0.003
N-back 2	2-back - No n-back task	-0.22	0.18	-0.57	0.13	-1.24	0.217
Lighting1 ✻ Age group1	Night - Day ✻ Older - Younger	0.87	0.27	0.34	1.41	3.19	0.001
DRT ✻ N-back 1	DRT present - No DRT ✻ 1-back - No n-back task	2.88	0.36	2.18	3.57	8.11	< .001
DRT ✻ N-back 2	DRT present - No DRT ✻ 2-back - No n-back task	2.11	0.36	1.42	2.81	5.96	< .001

ICC = 45.9%

Results
Large reversals – 2.5°





Discussion
Main effects

- In small SWRRs, visual load did not significantly affect reversals, but cognitive load significantly increased them.
- In large SWRRs, visual load significantly increased reversals, while cognitive load decreased them.
  - The comparison between no n-back and 1-back significant, but the comparison between no n-back and 2-back was not significant.
- Result in line with e.g., Markkula & Engström (2006): cognitive load prompts micro corrections, while visual load results in larger corrections.

Discussion
Interaction effects

- Without the visual task, small SWRRs were at about the same level with increased cognitive load
- The presence of a visual task had a strong effect on large SWRRs, effectively counteracting the reduction in large reversals due to increased cognitive load.
  - The DRT effect aligns with the Active Gaze Model (Wilkie et al., 2008), indicating that tasks diverting eyes from the road center may result in an increase in larger steering reversals.
- These interactions should be further studied

Discussion
Individual differences

- High ICC values suggest that individual differences also significantly contribute to the variability in SWRR.
- Previous research has indicated that individual differences affect, for instance, in-car glance durations (Broström et al., 2013; 2016; Grahn et al., 2023) and occlusion times (Grahn & Taipalus, 2021; Grahn et al., 2023).

Conclusions

- SWRR appears to be sensitive to individual and environmental factors as well as to different levels of cognitive load.
- Furthermore, the effect of visual and cognitive tasks on SWRR varies and warrants further investigation.
- The change in the reversal rate of younger and older drivers during night-time driving is important for road safety to understand differences in behavioral adaptation to reduced visibility during night-time driving.
- A large effect of individual variability in SWRR was detected.

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Thank you!