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Can the preview of a curve mitigate the effects of cognitive load on gaze patterns of expert and non-expert drivers?

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KNOWN…?

- **Limited processing capacity** leads to performance decrements.
  (e.g., Broadbent 1958; Kahneman, 1973; Wickens, 1984)

- **Automaticity** frees up cognitive resources!
  (Durso & Dattel, 2006; Engström et al., 2017)

The amount of resources required to perform concurrent activities which take drivers' mind off the road is referred to as **cognitive load** (Engström, 2013).

Cognitive load

The Cognitive control hypothesis (Engström et al., 2017): **cognitive load does not affect automatized activities**.

KNOWN…?

- Cognitive load ↑ fixation **duration** and ↑ **concentration of gaze** towards the **road center,** particularly when **approaching** the curves.

(Lehtonen et al., 2012; Nilsson et al., 2020; Wang et al., 2014)

Expert drivers, who receive **extensive** and **deliberate driver training,** ↑ horizontal search.

(Crundall & Underwood, 1998; Crundall et al., 2003; Land & Tatler, 2001; Lappi et al., 2017; van Leeuwen et al., 2017)

Driving expertise

- Repeated experience leads to **automaticity.**
- **Mental representation** of the environment directs **visual search**.

(Crundall et al., 2005, Ericsson et al., 1993; Tuhkanen et al., 2019)

KNOWN…?

- Road signs might serve as implicit cues for **automatic vehicle control.**

(Charlton, 2004; Crundall & Underwood, 2001)

Curve warnings emphasizing **direction or severity of a curve** reduced driving speed even for **cognitively loaded drivers** (Charlton, 2004).

- Studies using eye tracking data show inconsistent findings.
  - the **number of fixations** and the **duration of fixations?**

(Babić et al., 2020; Fiolić et al., 2023)

… & UNKNOWN?

Long and short fixations?

(Leneman & Backs, 2018; Negi & Mitra, 2020)

Short fixations – Automatic fixations used to maintain lateral vehicle control.
Long fixations – Controlled fixations used to maintain longitudinal vehicle control.

Driving expertise?

(Crundall & Underwood, 2001; Wontorczyk & Gaca, 2021)

AIM & HYPOTHESES

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Does the use of a **road sign** that provides a **preview** of an upcoming curve alters **gaze patterns** of **cognitively loaded expert** and **non-expert drivers**?

H1

Cognitive load will decrease the number and duration of long fixations, and reduce drivers' visual search.

H2

The sign, compared to no-sign, will decrease the duration of short and long fixations and increase visual search of cognitively loaded drivers.

H3

Expert drivers' short and long fixations will be of lower duration and their horizontal and vertical gaze dispersion will be wider.

PARTICIPANTS

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- **Experienced non-professional** drivers (*n* = 18) .

(*Mage* = 38.05, *SD* = 5.77)

- All male
- Drove more than **15000 km/y**
- Had valid driving licenses for **more than 15 years**.

- Completed an **advanced driver training** and held a UK advanced driving permit for **at least 5 years.** (*M* = 11.79, *SD* = 6.73)
- Drove regularly during their work shift.

- **UK advanced police drivers** and **firefighters** (*n* = 14).

(*Mage* = 43.14, *SD* = 6.98)

STUDY ENVIRONMENT AND DESIGN

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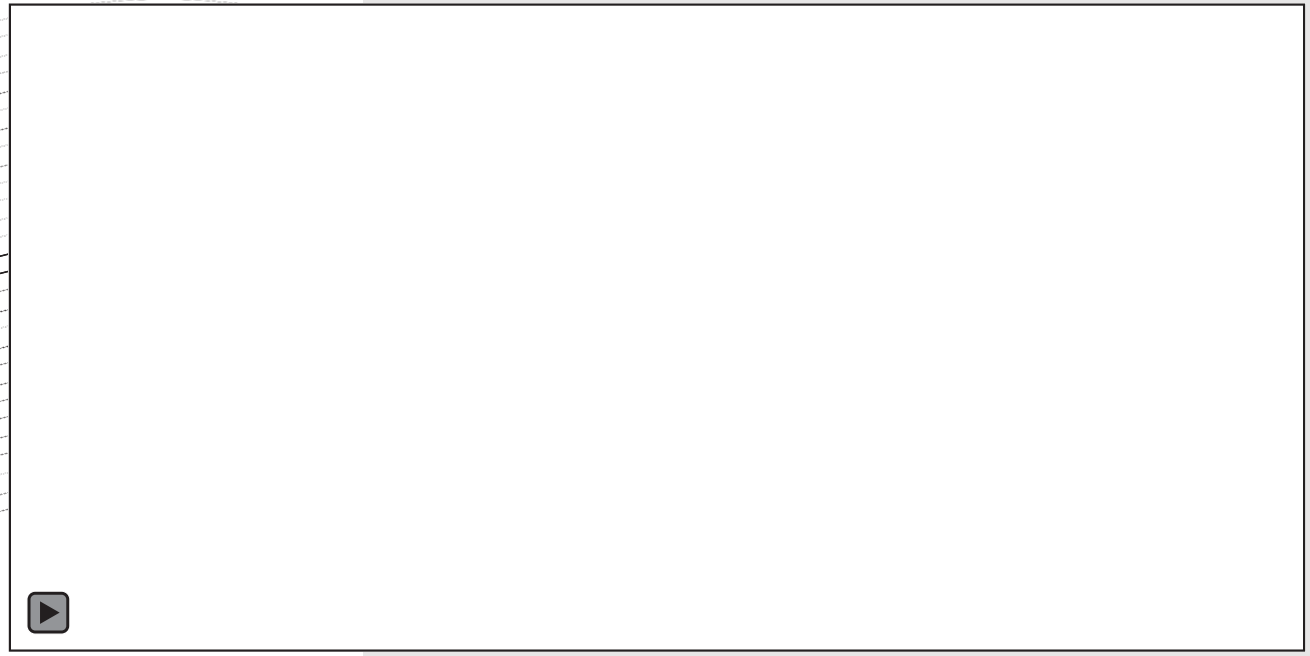

EXPERIMENTAL DESIGN

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- Mixed model design

COGNITIVE LOAD x ROAD SIGN x EXPERTISE

- 8 hairpin curves
- 70 MPH
- Counterbalanced order

Indicated curve direction and degree of the turn required.

1-sec long, presented 400 m before the curve entry.

EXPERIMENTAL DESIGN

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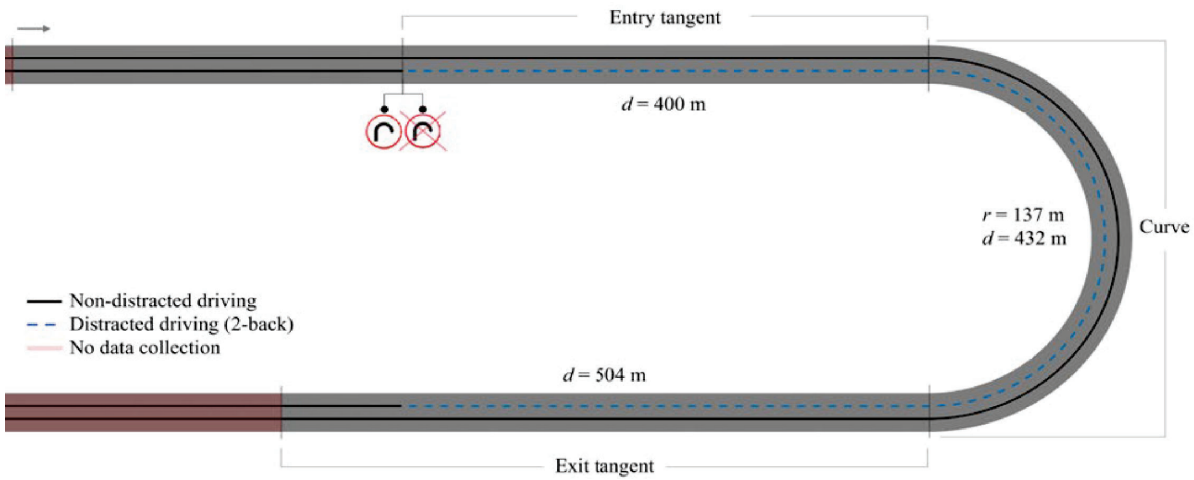
2-BACK TASK

The auditory-verbal version
(Mehler et al., 2011).

The task started 400 meters before the curve entry and finished 400 meters after the curve exit.



RESULTS

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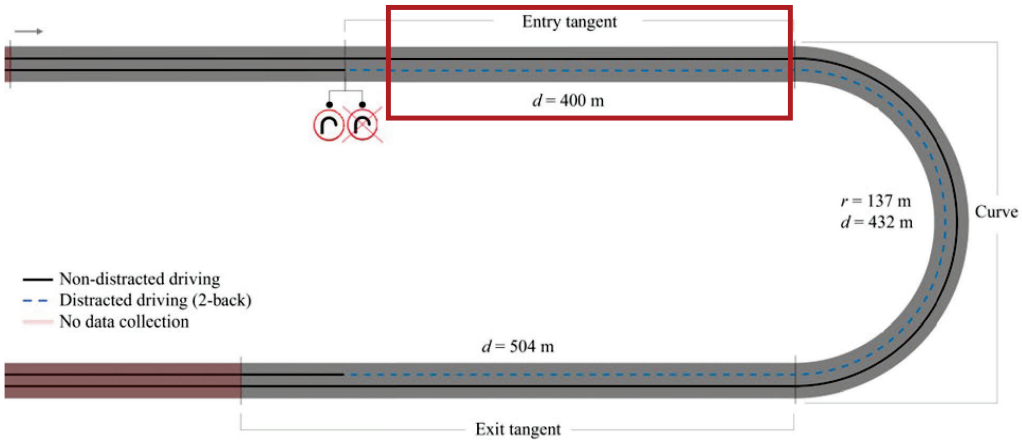
01 DATA SEGMENTATION

ENTRY TANGENT
(after the sign)
versus **CURVED SEGMENT**



RESULTS

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02 METRIC CALCULATIONS

- Number of fixations
- Mean duration of fixations
- Vertical gaze dispersion
- Horizontal gaze dispersion

Short fixations **< 250 ms**

Long fixations **250 – 1000 ms**

Standard deviation of gaze Pitch

Standard deviation of gaze Yaw

RESULTS

FIXATION COUNT

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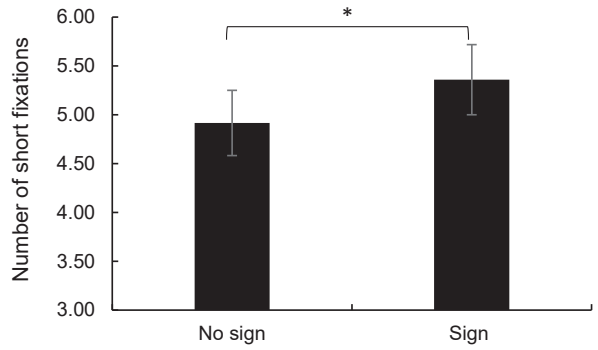

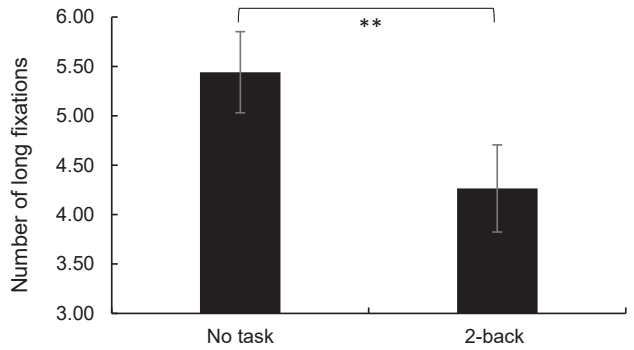

The road sign does not affect the number of long fixations but **increases** the number of **short** fixations.

The 2-back task does not affect the number of short fixations but **decreases** the number of **long** fixations.

The road sign supports ambient vision while the 2-back task deteriorates focal vision!

RESULTS

MEAN DURATION OF FIXATIONS

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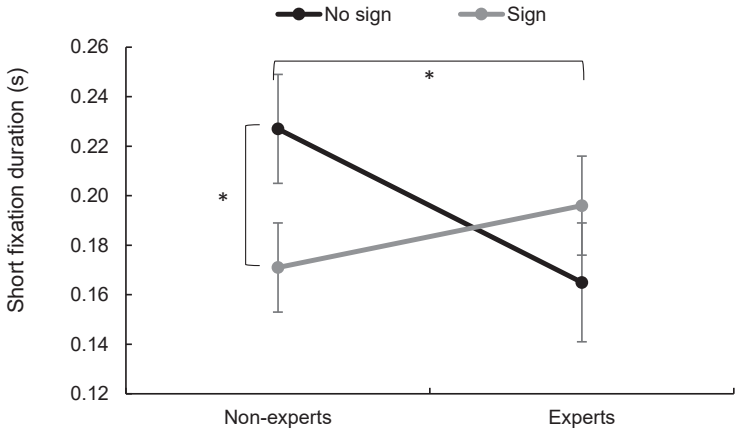

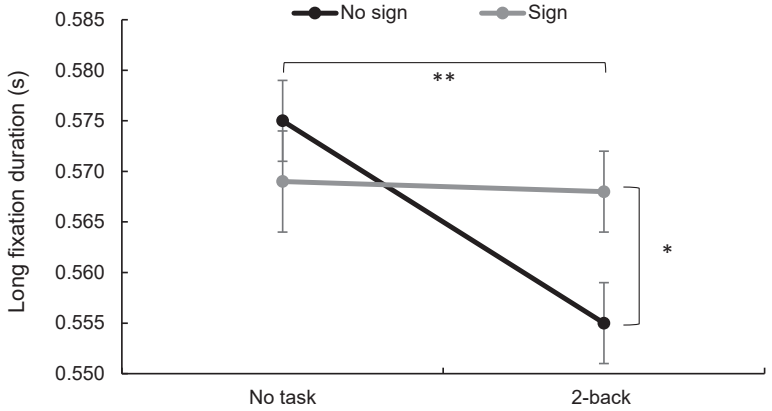

Road sign x **Expertise**
(p = .03)

Automatic processing is slower for non-experts?
The presence of the road sign **decreased** the duration of non-expert drivers' **short** fixations.

Cognitive load x **Road sign**
(p = .04)

Cognitive load affected controlled information processing?
The road sign **mitigated** the effects of cognitive load!

RESULTS

VERTICAL GAZE DISPERSION

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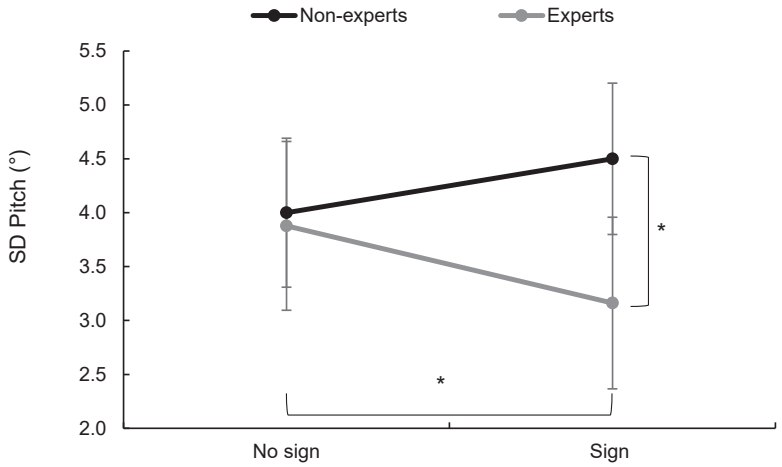

Road sign x **Expertise**
(p = .03)

The cue activated experts' mental representation of the curve?
The cue **reduced** experts' vertical visual search.

RESULTS

HORIZONTAL GAZE DISPERSION

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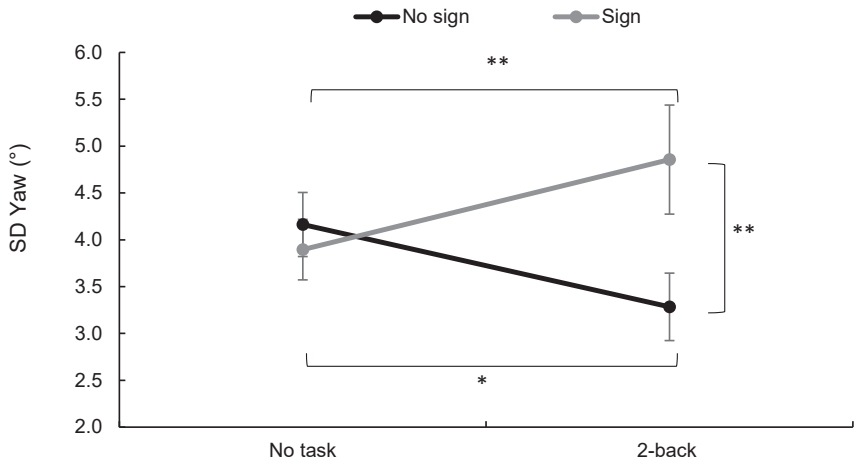
Cognitive load x **Road sign**
(p = .03)

Cognitive load reduces horizontal visual search, but only without the road sign.
The sign **mitigated** the effects of cognitive load!



RESULTS

Horizontal and vertical gaze dispersion for all drivers

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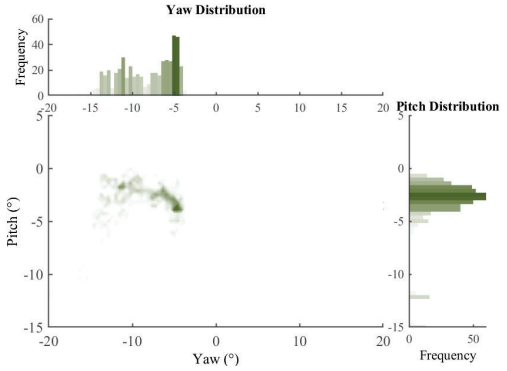
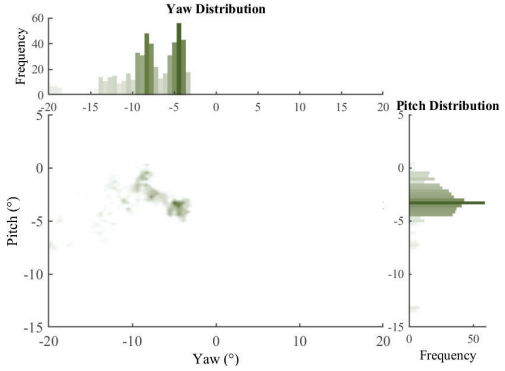
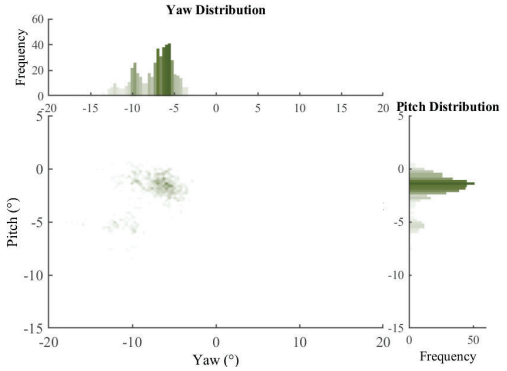
NO TASK; NO CUE



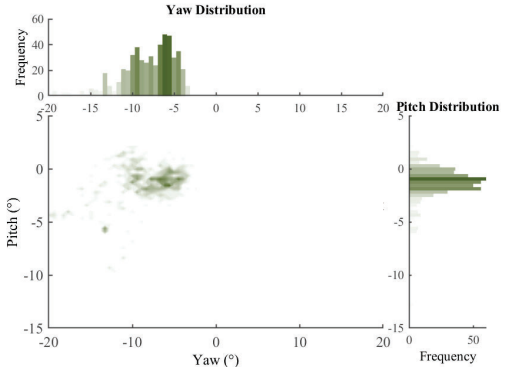
NO TASK; CUE



TASK; NO CUE



TASK; CUE



CONCLUSIONS

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Cognitive load **decreased** the number and duration of long fixations, and **reduced** drivers' horizontal gaze dispersion.

Road sign **decreased** the duration of short fixations for non-experts and **mitigated** the effects of cognitive load on long fixations and horizontal gaze dispersion.

Experts' short fixations were of **lower duration**, while the differences between experts' and non-experts' gaze dispersion were not obtained.

H1

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THANK YOU FOR THE ATTENTION!

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