# Driving Performance Deficits in Chronic Insomnia: Evidence from a Multi-Scenario Simulator Study


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# Introduction

“Before we begin…
I would like you to briefly think about this:

👉 Have you ever driven while feeling tired or not fully alert?”

# Introduction

- **Insomnia** is the **most prevalent** sleep disord worldwide and represents a major public health concern due to its impact on **physica health, psychological functioning, and daily performance.**

- Epidemiological studies estimate that approximately **10–15% of adults meet diagnostic criteria** for chronic insomnia, **whi up to 30–35% report insomnia symptoms**

# Introduction

**Chronic insomnia** is characterized by **persistent difficulty initiating or maintaining sleep or early-morning awakening** accompanied by **daytime impairment,** occurring **at least three nights per week for at least three months**

# Introduction

Beyond nocturnal sleep disturbance, insomnia has been associated with impairments in:

- attention
- executive functioning
- working memory, and emotional regulation
- reflecting underlying neurobiological mechanisms of hyperarousal

# Background

- Epidemiological studies suggest increased accident risk among individuals with sleep disturbance; however, experimental evidence isolating the specific effects of chronic insomnia on driving performance remains limited

- Moreover, little is known about whether insomnia-related impairments vary across different driving environments or under distraction

# Background

- Epidemiological studies have **linked insomnia symptoms with an increased risk of traffic accidents and safety-related incidents**
- However, observational research cannot fully clarify whether the elevated crash risk is directly related to insomnia itself or to other factors **such as medication use, comorbid conditions, or lifestyle variables.**

# Background

Simulator studies have reported increased lane position variability, reduced attentional stability, and altered speed control among drivers with insomnia compared with healthy controls (Perrier et al., 2015; Perrier et al., 2019).

Other studies have also demonstrated impaired hazard perception and increased cognitive interference during simulated driving tasks (Xu et al., 2022).

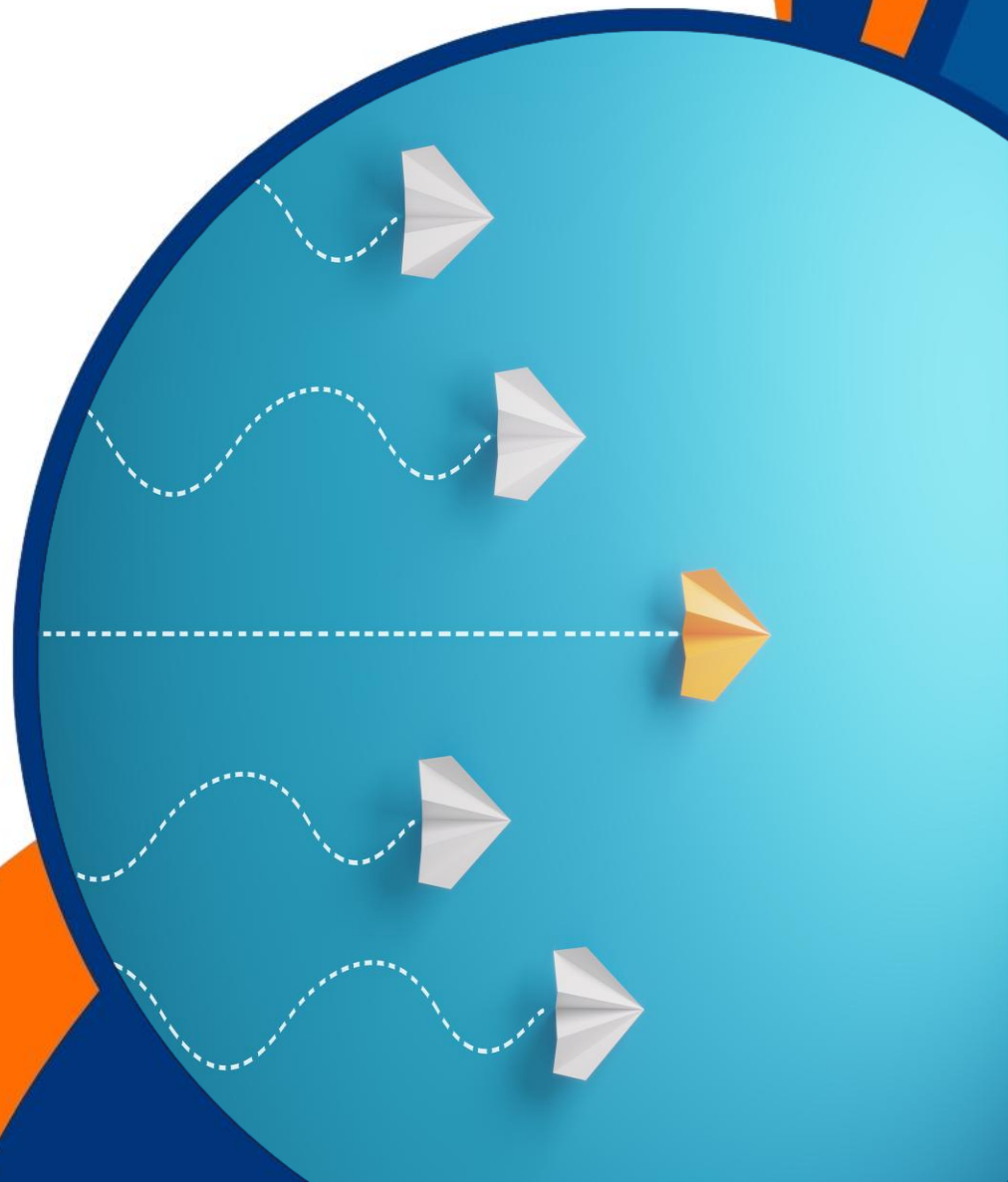
# Background

“If insomnia affects attention and reaction time…
what would we expect to see in driving performance?”

“This is exactly what we aimed to examine.”

# Objectives

- Investigate the impact of chronic insomnia on driving performance in a controlled simulator setting
- Examine whether performance deficits interact with environmental complexity and distraction



# Participants

- Fifty-one licensed drivers (25 diagnosed with chronic insomnia; 26 healthy controls), mean age 44,2 years participated in a high-fidelity fixed-base driving simulator experiment

Participants completed four driving scenarios varying by:

- Road type (urban vs rural)
- Distraction (with vs without conversational distraction)

# Driving Simulator Experiment

## 🚗 Procedure

Standardized protocol for all participants
15-min practice drive
Familiarization with simulator
Monitoring for simulator discomfort

## 🖥️ Simulator environment

Realistic traffic conditions
Functional mirrors

## 📊 Data recording

60 Hz sampling rate
High-resolution behavioural data

# Driving Simulator Experiment

- **Simulator**

FOERST driving simulator
170° field of view
Full vehicle setup


Figure 1,2 illustrates a digital environment of driving simulator in urban (a) and (b) rural scenarios.

# Scenarios

- Road type (urban vs rural)

Rural – no distraction
Urban – no distraction
Rural – with distraction
Urban – with distraction

# Questionnaires

Insomnia diagnosis was established according to DSM-5-TR and ICSD-3-TR criteria using structured interviews and validated questionnaires:

- AIS (Athens Insomnia Scale)
- ISI (Insomnia Severity Index)
- PSQI (Pittsbutgh Sleep Quality Index)

- Anxiety and depressive symptoms were assessed (HADS), and risk of obstructive sleep apnea was screened (STOP-BANG), and **sleep diary** (previous night)

# Data Collection

Primary outcome measures included:

- Reaction time to unexpected hazards
- Lateral lane deviation (standard deviation of lateral position)
- Mean driving speed
- Crash ratio (crashes per hazard)

Group differences were examined using regression models adjusted for age and gender and mixed two-way ANOVA to evaluate interaction effects between group and scenario

“Before I show you the results…
👉 What would you expect?

Would drivers with insomnia:
drive slower?
have more crashes?
or show more subtle impairments?”

“Let’s see what we found.”

# Data Collection

## Results (no differences)

Mean speed → no difference
Crash ratio → no difference :
“Performance deficits ≠ crash outcomes”

# Results

## Group Differences

### 💤 Insomnia group

↑ AIS ($p < 0.001$)
↑ ISI ($p < 0.001$)
↑ PSQI ($p < 0.001$)

### 🧠 Psychological factors

↑ Anxiety ($p = 0.005$)
↑ Depression ($p < 0.001$)

### 🫁 OSA risk

No difference between groups

# Results

- Drivers with chronic insomnia demonstrated **significantly poorer driving performance** compared to controls

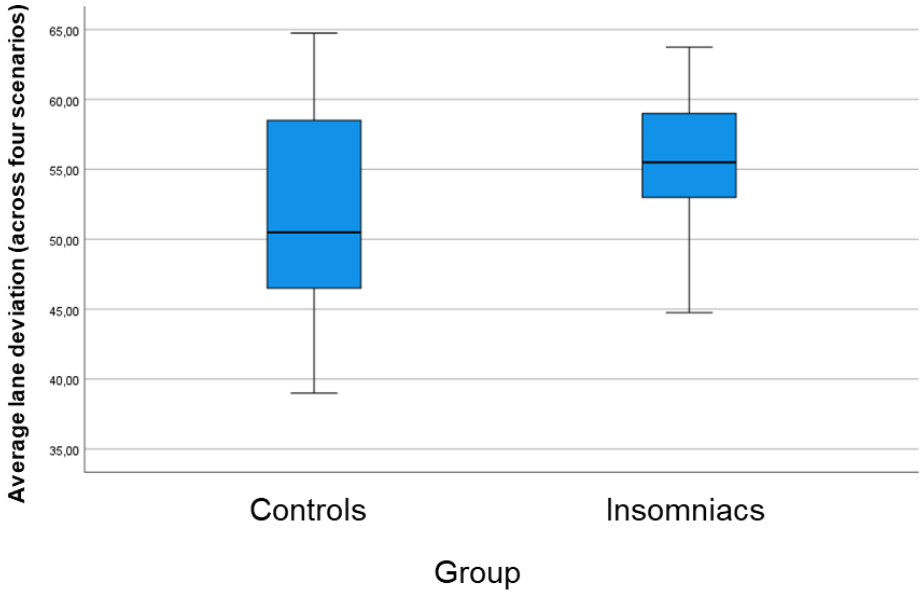
**Across scenarios**, the insomnia group showed:

- Greater lateral lane deviation ($p = 0.036$ overall)
- Significantly longer minimum, mean, and maximum reaction times (all $p < 0.001$)
- These impairments persisted after adjustment for demographic variables

# Results

- Mean driving speed did not differ between groups ($p > 0.05$), and crash ratios were not statistically different
- However, interaction analyses revealed that group differences in lane deviation and reaction time varied across scenarios, with larger effects observed in certain rural conditions
- Overall, reaction time deficits were present across all environments, indicating a largely generalized impairment rather than context-specific vulnerability

# Results

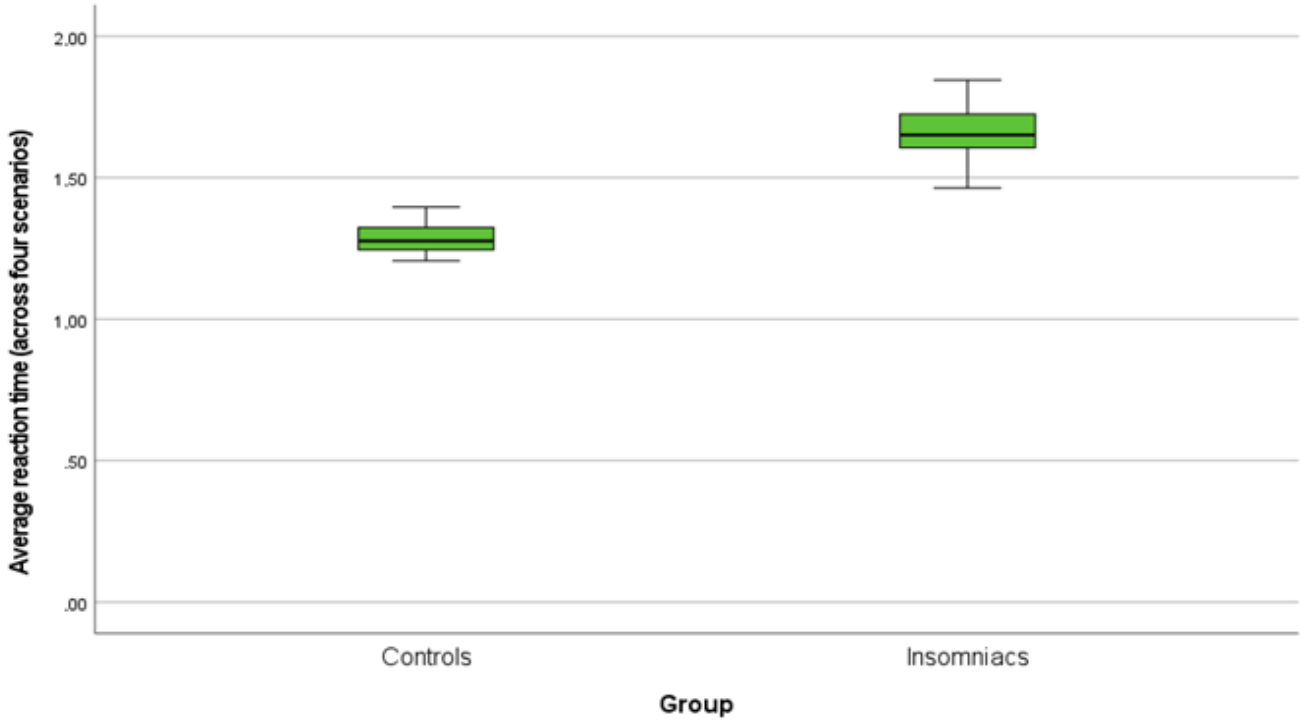



Average lane deviation in cm (across four scenarios) per group

**Figure 1** provides the average lane deviation (mean all four driving scenarios) for the two groups.

Insomniac drivers **showed noticeably higher median lane deviation compared to controls, indicating less stable lateral vehicle control.** In addition, the interquartile range is narrower for the insomnia group, suggesting higher group uniformity, but overall poorer lane-keeping performance, whereas the control group exhibited greater variability but generally lower lane deviation values.

# Results




Average reaction time in seconds (across four scenarios) per group

**Figure 2** shows average reaction time (mean of all four driving scenarios) for each group.

Insomniac drivers exhibited substantially longer reaction times compared to controls, indicating slower responsiveness to driving events.

The insomnia group also showed a wider spread of values, reflecting greater variability in reaction performance, whereas the control group maintained consistently faster and more stable reaction times.

# Results

## Interaction effects

**No interaction:**
Speed
Crash ratio
**Significant interaction:**
Lane deviation
Reaction time:
“Effect varies across scenarios”

# Results

## Sleep Diary (Pre-experiment)

### 💤 Night sleep (insomnia group)
↑ Sleep onset latency
↑ Night awakenings
↑ Wake time during night
↓ Total sleep time

### 😴 Daytime effects
↑ Sleep disturbance
↑ Fatigue
↑ Sleepiness

### ⚖️ No differences
Afternoon naps
Wake time deviation

# Discussion

- Chronic insomnia was associated with measurable impairments in simulated driving performance, particularly in hazard reaction speed and lateral vehicle control

- These deficits were evident across different driving environments and under distraction, suggesting that chronic insomnia compromises core attentional and psychomotor processes required for safe driving

# Key Findings & Implications

### 🚗 Driving performance

↓ Lane-keeping precision
↓ Reaction speed
Impaired attention & psychomotor control

### ⚠️ Crash outcomes

No difference in crash rates
→ Possible compensatory behaviour

### 🌍 Implications

Insomnia = hidden risk factor
Important for road safety awareness

# Limitations

### 📉 Sample
Relatively small sample size
Clinical population (sleep clinic)

### 🚗 Simulator
Controlled environment
May not fully reflect real-world driving

### 💤 Sleep assessment
Based on clinical measures
No objective sleep data
(e.g., actigraphy, polysomnography)

# Conclusions

- Although crash rates did not differ significantly, the consistent slowing of hazard response highlights a potential latent safety risk

- Given the high prevalence of insomnia, these findings underscore the importance of recognizing chronic sleep disturbance as a relevant factor in road safety assessment and prevention strategies

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# Conclusions

➢ **Compensation**

No crash differences

➡️ Possible explanation:

**Compensatory behaviour**

more cautious driving

adaptive strategies

⚠️ Not sufficient in real-world conditions

# Conclusions

**Rural vs Urban**
Stronger effects in rural environments

Possible explanation: lower stimulation reduced alertness

# Conclusions

## Implications

Insomnia = hidden risk factor

Important for:

- screening
- road safety
- clinical awareness

# Conclusions

## Take-home message

"Insomnia affects HOW people drive, not necessarily WHETHER they crash."

# Thank you for your attention!

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