Sleep loss and change detection: a driving simulator study

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Sleep and Driving

• Driver sleepiness is estimated to contribute to 15-30% of crashes (Connor et al., 2002; Williamson et al., 2011)
• Run-off-road crashes.
• Research focus on lateral vehicle control and out-of-lane events.
• Less is known about driving impairment leading up to run-off-road.
**Change detection**

**Change blindness**: failure (or delay) in detecting an obvious change to a visual object or scene

- during eye movements
- during brief disruption to visual display

**• Occurs for:**

- expected and unexpected changes
- simple arrays – letters, digits
- photographs
- real-world interactions

Change detection

• Five steps involved in change detection:

1. **attend** to location of target (i.e., object to change)

2. **encode** info about **pre-change** target

3. **encode** info about **post-change** target

4. **compare** pre- and post-change target info

5. **consciously recognise discrepancy** between pre- and post-change targets

(Jensen, Yao, Street, & Simons, 2011)
Change blindness

• In the person change paradigm, observers are more likely to notice the change if the person is an “in-group” vs. “out-group” member.

(Simons & Levin, 1998)
Change blindness paradigm
Previous findings

• Faster and more accurate change detection in rural vs urban scenes.
• Faster and more accurate change detection with greater safety relevance.
• Change detection accuracy is maintained when sleepy.
• When sleepy, drivers detected changes more slowly in urban images, but faster in rural images.

Beanland, Filtness, Jeans (2017) Change detection in urban and rural driving scenes: Effects of change target and safety relevance on change blindness. Accident Analysis and Prevention, 100, 111-122.


Filtness, Beanland (under review) Sleep loss and change detection in driving scenes. Transportation Research Part F.
Limitations of photo paradigm

Validity for driving.

- Distracting environment.
- Often one opportunity to detect change.
- Movement through environment (travel speed).
- Unexpected changes.
Method – Driving simulator

_Aim:_ Does sleep loss affect change detection when driving in urban and rural environments?

**Participants:**
- 21 experienced drivers (12 female),
- Aged 18-33 years,
- Regular 7-8h sleepers
- Regular drivers (at least weekly)
Method

Design:
Two 1h experimental sessions (counterbalanced)
- a normal night’s sleep,
- one night of sleep restriction to 5 hours

10.30am (8 participants), 12.00 noon (4 participants), 1.30pm (6 participants) or 3.00pm (6 participants). At least 3 days apart.

Prior sleep recorded by sleep diary and actigraphy.

Familiarisation drive (2 laps)
Driving simulator

- SCANeR™ studio software version 1.4
- 180° forward field of view from 3 projector screens
- Six degree of freedom (6DOF) motion platform
Road description

- 2 matched driving scenarios (order and timing of changes differed)
- 5 laps of a 11.3km circuit (45min driving)
- 50% urban Canberra 60km/h, 50% rural 100km/h
Sleep measures

• KSS before and after driving
• How much effort to stay awake? (7point scale)
• Sleep related eye symptoms¹

Change detection task

• Black simulator screen for 500ms
  - identical (change-absent)
  - changed (change-present)

• 8 change-absent trials per drive (4 urban, 4 rural)
• 12 change-present trials per drive (6 urban, 6 rural)

• Change targets regularly present
• Familiarisation drive included 8 blackouts (3 change-absent)
## Changes

<table>
<thead>
<tr>
<th></th>
<th>Low Safety Relevance</th>
<th>High Safety Relevance</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Urban</strong></td>
<td>- Parked cars change colour.</td>
<td>- Car travelling towards participant (head on-collision)</td>
</tr>
<tr>
<td></td>
<td>- Advisory road sign changes</td>
<td>- Cyclist moves from hard shoulder to driving lane (rear-end collision)</td>
</tr>
<tr>
<td></td>
<td>- Cyclist moves from the hard shoulder to the road (opposite side of road).</td>
<td>- Speed limit sign decreases by 10 km/h</td>
</tr>
<tr>
<td><strong>Rural</strong></td>
<td>- Parked cars change colour.</td>
<td>- Car travelling towards participant (head on-collision)</td>
</tr>
<tr>
<td></td>
<td>- Advisory road sign changes</td>
<td>- Tractor moves from hard shoulder to driving lane (rear-end collision)</td>
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<td>- Tractor moves from the hard shoulder to the road (opposite side of road).</td>
<td>- Speed limit sign decreases by 10 km/h</td>
</tr>
</tbody>
</table>
Unexpected changes

• Lead vehicle change colour (rural)
• Text signs change to German
## Sleep duration

<table>
<thead>
<tr>
<th></th>
<th>Normal night’s sleep (SD)</th>
<th>Sleep restriction (SD)</th>
<th>t test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean sleep duration (min)</td>
<td>473 (57)</td>
<td>300 (19)</td>
<td>$t(23) = 14.38 \ p&lt;.001$</td>
</tr>
</tbody>
</table>
## Subjective sleepiness

<table>
<thead>
<tr>
<th>Measure</th>
<th>NS M (SEM)</th>
<th>SR M (SEM)</th>
<th>t statistic</th>
<th>df.</th>
<th>Significance p (r)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heavy eyelids</td>
<td>2.00 (0.21)</td>
<td>3.33 (0.27)</td>
<td>5.10</td>
<td>18</td>
<td>&lt; .001 (.77)***</td>
</tr>
<tr>
<td>Difficulty keeping eyes open</td>
<td>1.48 (0.16)</td>
<td>2.57 (0.24)</td>
<td>4.11</td>
<td>20</td>
<td>.001 (.68)**</td>
</tr>
<tr>
<td>Difficulty focusing</td>
<td>1.86 (0.24)</td>
<td>2.95 (0.23)</td>
<td>3.75</td>
<td>20</td>
<td>.001 (.64)**</td>
</tr>
<tr>
<td>Eye strain</td>
<td>2.00 (0.23)</td>
<td>2.95 (0.29)</td>
<td>2.50</td>
<td>19</td>
<td>.022 (.50)*</td>
</tr>
<tr>
<td>Effort to stay awake</td>
<td>2.21 (0.29)</td>
<td>4.32 (0.34)</td>
<td>5.21</td>
<td>18</td>
<td>&lt; .001 (.78)***</td>
</tr>
<tr>
<td>KSS</td>
<td>3.73 (0.27)</td>
<td>5.75 (0.27)</td>
<td>7.18</td>
<td>20</td>
<td>&lt; .001 (.85)***</td>
</tr>
</tbody>
</table>

*Note.* NS = Normal Sleep; SR = Sleep Restriction; M = mean; SEM = standard error of mean; df = degrees of freedom. *p < .05, **p < .01, ***p < .001.
Accuracy did not differ between sleep conditions, $t(23) = 1.15, p = .262$. 
Greater accuracy in rural than urban environments $F(1,23) = 121.85, p < .001$. Interaction between sleep and environment not significant, $F(1,23) = 1.38, p = 2.52$. No main effect of sleep $F(1,23) = 0.05, p = 0.833$. 
## Unexpected changes

<table>
<thead>
<tr>
<th>Unexpected Change</th>
<th>NS</th>
<th>SR</th>
<th>McNemar’s test significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lead vehicle change colour</td>
<td>33%</td>
<td>24%</td>
<td>$p = .500$ (1-tailed) $n = 20$</td>
</tr>
<tr>
<td>Text signs change to German</td>
<td>76%</td>
<td>67%</td>
<td>$p = .500$ (1-tailed) $n = 20$</td>
</tr>
</tbody>
</table>
Conclusion

• Manipulation worked
  – Shorter sleep duration
  – Participants felt sleepier following sleep restriction, had sleep related eye symptoms.

• Accuracy is lower for change-present than change-absent trials
Conclusion

• Sleep restriction does not affect change detection accuracy.
• Change detection has greater accuracy in rural than urban environments.
Conclusion

• Accuracy results mirrored those of static images.

• Rural changes (less visual clutter) were easier to detect even with faster movement through the environment.
Note on the method

• Smaller number of changes possible than photo paradigm.
• Difficult to measure reaction time.
• Difficulties with scripting and consistency of events. Demanding programming and processing speed.
• Resource intensive.
Next steps

- Implications for safety relevance.
- Eye movements.
- Driving response (vehicle metrics).
Acknowledgements

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Questions?
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SLEEPINESS IS STRONGER THAN YOU
DON’T DRIVE SLEEPY!