In the blink of an eye:
The circadian effects on ocular and subjective indices of driver sleepiness

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Introduction

• Approximately 1,300 fatalities occur from the trauma of road crashes each year

• Strongest evidence (case-control data) suggests that 19% of all fatal and severe crash are due to sleepiness
  – Younger drivers are over represented

• Crashes often have multifactoral causes

• Self-awareness of sleepiness (i.e., subjective sleepiness) remains a critical component for mitigation of risk
Introduction

• There is low correspondence between subjective and physiological measures

• Subjective sleepiness evaluations are effected by extraneous activities
  – E.g., Verbal interactions or physical movements

• Variability in the ability to predict sleep onset when highly sleepy

• Physiological measures appear to have potential as a reliable measure of sleepiness
Introduction

• Ocular indices have some potential as a reliable measure of physiological sleepiness
  – blink rate, blink duration, blink amplitude, percentage of eyelid closure, eyelid closing/opening speed

• An advantage of ocular indices is that they can be recorded via non-contact methods

• Blink rate and blink duration have been associated with increases in sleepiness

• Increases in blink rate and blink duration also correlate with poorer driver performance indices
Circadian Rhythm Influences

- The circadian rhythm promotes alertness during the daytime and sleepiness during the night time.
Circadian Rhythm Influences

- The circadian rhythm promotes alertness during the daytime and sleepiness during the night time.
- A higher proportion of sleep-related crashes during the descending phase.
- Subjective measures have been found sensitive to the afternoon descending phase.
- Extensive evaluations of the circadian effects on blink rate and blink duration are lacking.
The Current Study

• Awareness of sleepiness is a safety critical aspect for sleep-related crashes

• Contradictory evidence regarding the relationship with subjective and physiological measures

• Extensive evaluations of blink rate and blink duration during the descending circadian phase are lacking

• This study aimed to examine the circadian effects on blink rate, blink duration and subjective sleepiness levels
Method

• Participants
  – In total, 26 participants (19 females and 7 males)
  – Mean age of 24 yrs ($SD = 2.46$; range = 20-28)

• Materials
  – Sleepiness Questionnaire
    • Assessed levels of sleep quality, daytime sleepiness, and awareness of sleepiness signs
  – Karolinska Sleepiness Scale (KSS)
    • Assess current levels of sleepiness
  – Ocular Indices of Sleepiness via EOG
    • Blink rate and blink duration
  – Driving stimulus: Hazard Perception task
Method

- **Procedure**
  - On testing days participants woke at 05:00
  - No caffeine or alcohol until completion of testing
  - Instructed to "**Stop when you think you would be too sleepy to drive safely on the road**"

- **Design**
  - Participants randomly assigned to the morning (09:00) or afternoon (14:00) start time

![Diagram]

- Baseline subjective sleepiness
- Simulated Driving Session (Hazard Perception test)
- Baseline recording of ocular indices (5 mins)
- Conclusion recording of ocular indices (5 mins)
- Conclusion subjective sleepiness
Results

• Examination of the between groups demographic and traffic-related demographic

  – No significant differences were found between the morning and afternoon groups for:
    • Age; $t(12) = 1.38, p = .18$
    • Gender; $\chi^2(1) = 0.19, p = .67$
    • Years licenced; $t(12) = 1.56, p = .13$
    • Km/year driven; $t(12) = -1.69, p = .10$
    • Driving duration; $t(12) = -0.44, p = .66$

  – The morning and afternoon groups were deemed to have similar demographic and traffic-related demographic characteristics
Results

- Examination of the between groups sleep variables
  - No significant differences were found between the morning and afternoon groups for:
    - Pittsburgh Sleep Quality Index; $t(12) = 1.14, p = .27$
    - Epworth Sleepiness Scale; $t(12) = -0.10, p = .93$
    - Sleep Timing stability score; $t(12) = -0.25, p = .81$
    - Signs of sleepiness; $t(12) = 1.48, p = .15$
    - Baseline KSS; $t(12) = -0.85, p = .41$
  - The morning and afternoon groups were deemed to have similar levels of sleep quality, daytime sleepiness, and awareness of the signs of sleepiness
Results

• The morning and afternoon groups were deemed to have similar levels of sleep quality, daytime sleepiness, and awareness of the signs of sleepiness.

• The morning and afternoon groups were deemed to have similar demographic and traffic-related demographic characteristics.

• The analyses can proceed without having to control for these variables.
## Results

### Time of Day of Testing

<table>
<thead>
<tr>
<th>Data Source</th>
<th>Morning (n = 13)</th>
<th>Afternoon (n = 13)</th>
<th>Significance test</th>
<th>Significance test</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Baseline</td>
<td>Conclusion</td>
<td>Mean Diff (p)</td>
<td>Baseline</td>
</tr>
<tr>
<td>Mean blink duration</td>
<td>96.80 (10.02)</td>
<td>117.11 (29.62)</td>
<td><strong>-20.31 (.01)</strong></td>
<td>108.98 (13.44)</td>
</tr>
<tr>
<td>Mean blink rate</td>
<td>129.15 (38.59)</td>
<td>138.46 (49.77)</td>
<td><strong>9.31 (.32)</strong></td>
<td>111.00 (54.54)</td>
</tr>
<tr>
<td>Subjective sleepiness</td>
<td>6.54 (0.77)</td>
<td>8.00 (0.41)</td>
<td><strong>1.46 (&lt;.001)</strong></td>
<td>6.77 (0.60)</td>
</tr>
</tbody>
</table>

- Blink duration increased in the morning only
- Blink rate showed no change whatsoever
- Subjective sleepiness increased in the morning and afternoon sessions
Discussion

• All participants were able to choose to stop driving before any unwanted sleep occurred.

• Both morning and afternoon groups stopped driving (on average) before 40 minutes had elapsed.
  – Well within the commonly promoted 2 hours of driving duration before stopping driving.
  – Only relatively moderate levels of sleep restriction.

• Simulated driving environment could have been a factor.
  – Laboratory condition can invoke lower arousal levels.
Subjective Sleepiness

• The subjective measure was sensitive to changes of sleepiness during the morning and afternoon sessions.

• Subjective perceptions of sleepiness might be less reliable when at extreme levels of sleepiness or when “fighting” sleep onset.
  – Potentially an effect of cognitive impairment or limited awareness of the signs of sleepiness.

• When participants are not “fighting” sleep onset, their self-awareness of sleepiness might be more precise.
Blink rate

• No changes were found for blink rate during morning or afternoon testing sessions
  – Inconsistent findings in the literature

• An effect from the perceptual demand of Hazard Perception test?
  – Successful Hazard Perception requires a high level of visual scanning of the road environment

• Increases in blink rate might only dramatically occur during high levels of sleepiness?
Blink duration

• A significant increase was found during the morning session, but not for the afternoon session testing

• Potentially due to baseline blink durations in the afternoon already affected by increased sleepiness

• However, baseline subjective sleepiness levels did not significantly differ between morning and afternoon sessions
  – An issue between the correspondence of subjective sleepiness and those of physiological measures?
Next steps

• Address limitations of current study
  – No driver performance measure
  – Young adult sample; what about more mature drivers?
  – Laboratory conditions

• Future research
  – Blink characteristics of mature drivers
  – The utility of other ocular indices (e.g., blink amplitude, eyelid closing speed, etc)
Conclusion

- Driver sleepiness contributes substantially to fatal and severe crashes
- Subjective sleepiness measures were able to detect increasing sleepiness during morning and afternoon testing sessions
- Blink duration was only sensitive to increasing sleepiness during morning testing sessions
- Further examinations of the utility of ocular indices seem warranted to determine its suitability as a physiological measure of driver sleepiness
Thank you for listening!

Comments or Questions?

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