SLEEP DEPRIVATION SYSTEMATICALLY CHANGES EYE MOVEMENT CHARACTERISTICS

Justine Winkler[1] | Ricardo Ramos Gameiro[1] | Daniel Aeschbach[2] | Peter König[1,*] | Christian Mühl[2,*]

[1] Institute of Cognitive Science, University of Osnabrück, Germany [2] Institute of Aerospace Medicine, German Aerospace Center, Germany * shared senior authorship

Presenting Author: Justine Winkler Presenter's E-Mail: juwinkler@uos.de

Deutsches Zentrum für Luft- und Raumfahrt

UNIVERSITÄT OSNABRÜCK

MOTIVATION

During our day-to-day life, sleepiness endangers our safety as well as that of others. Specifically, it impairs operator performance in security-related working environments, for example in aviation. To reduce the number and impact of sleepiness-related accidents, easy to handle monitoring methods are needed. Here, we investigate the relationship between gaze as a measure of visual attention and sleepiness.

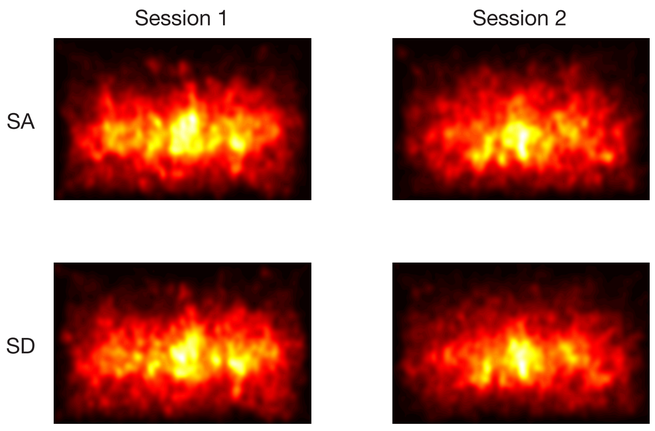
METHODS

After two days and two nights of adaptation in the sleep laboratory, we randomly assigned subjects to the treatment group with 24 hours of sleep deprivation (SD subjects). Control subjects were allowed to sleep normally (SA subjects). Before and the day after the treatment night we measured their eye movements during free viewing of natural images.

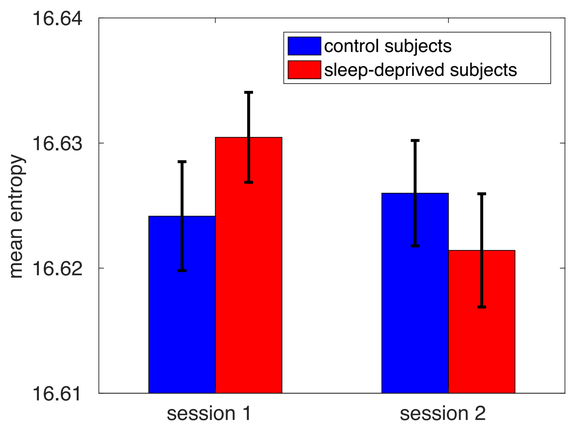
Experiment phases	Basis Night	Day 1	Treatment Night	Day 2
SD subjects	Sleep	Recording	Awake	Recording
SA subjects	Sleep	Recording	Sleep	Recording

RESULTS

Visual Exploration

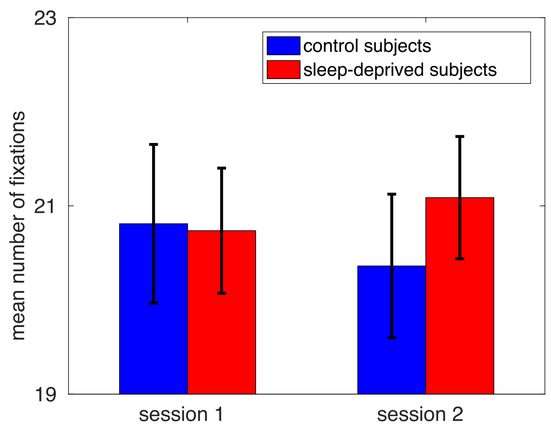


The effect of sleep deprivation on the spread of fixations, visualized by **fixation density maps**. The two upper FDMs represent 24 control or sleep allowed (SA) subjects without treatment in both the first (Session 1) and the second recording (Session 2). The two bottom FDMs represent 21 sleep deprivation (SD) subjects in the recording session before sleep deprivation (Session 1) and in the session after treatment (Session 2).



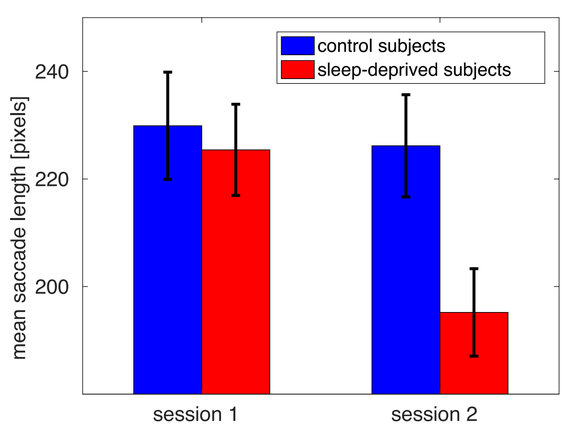
$F(1,43) = 7.156$, $p < .050$, $\eta^2 = .143$

The effect of sleep deprivation on **entropy** depending on the session. There was a **significant interaction**. Blue bars represent 24 control subjects without treatment, whereas red bars represent 21 subjects who had been sleep-deprived in the second session.



all $F <= 1.672$, all $p >= .203$, all $\eta^2 <= .037$

The effect of sleep deprivation on the **mean number of fixations** depending on the session. **No significant effects** were found. Blue bars represent 24 control subjects without treatment, whereas red bars represent 21 subjects who had been sleep-deprived in the second session.

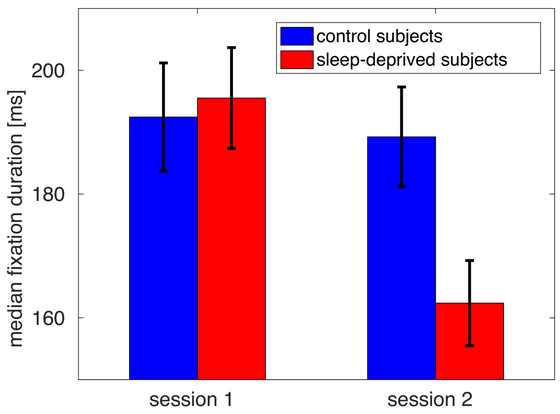


session*sleep: $F(1,43) = 11.946$; $p < .010$; $\eta^2 = .217$

The effect of sleep deprivation on the **mean saccade amplitude** depending on the session. There was a **significant interaction**. Blue bars represent 24 control subjects without treatment, whereas red bars represent 21 subjects who had been sleep-deprived in the second session.

Conclusion: Visual exploration behavior decreased in sleep deprived subjects.

Visual Exploitation



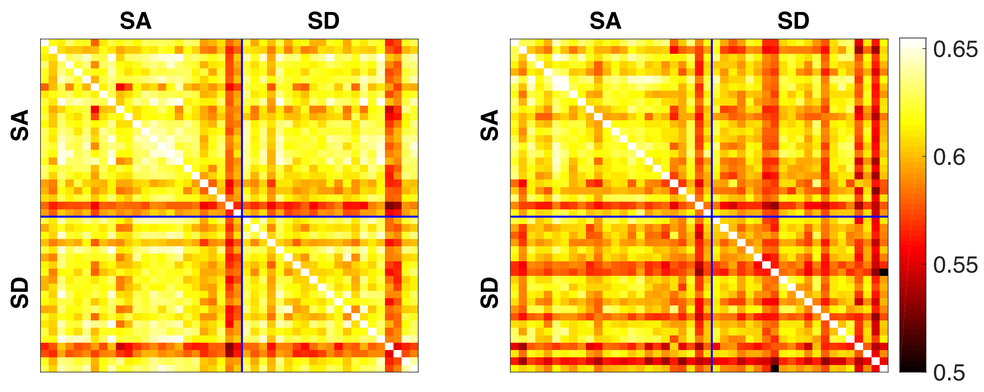
session*sleep: $F(1,43) = 20.065$; $p < .001$; $\eta^2 = .318$

The effect of sleep deprivation on the **fixation duration** depending on the session. Due to fatigue-induced data loss, we decided to compute the median for this parameter. There was a **significant interaction**. Blue bars represent 24 control subjects without treatment, whereas red bars represent 21 subjects who had been sleep-deprived in the second session.

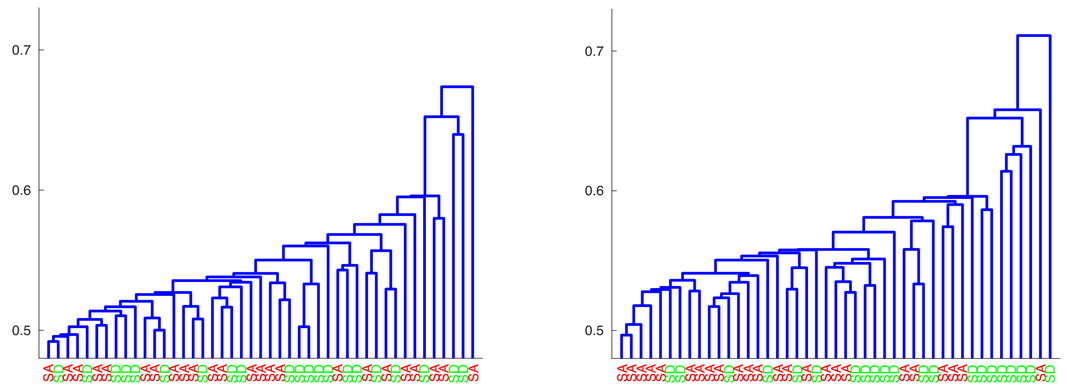
Conclusion: The fixations made by sleep deprived subjects took less time.

NOTE: All error bars in our figures represent the standard error of the mean.

Comparison of viewing patterns between single subjects



Similarity of viewing behavior between all pairs of observers in the first (left) and the second (right) recording session assessed by an **AUC value matrix**. The color indicates how well observers predicted the viewing behavior of each other. The higher the value, the better the prediction. A value of 0.5 (shown in dark red) denotes prediction at chance level, whereas yellow indicates a better prediction. Observers are sorted according to their groups: control or sleep allowed subjects (SA) and sleep deprivation (SD) subjects. The blue line in the matrix represents the border of the groups.



Dendrogram of **agglomerative hierarchical clustering** of the similarity of viewing behavior between observers in the first (left) and the second (right) recording session. The height of the edges indicates the difference in viewing behavior. Red labels represent control or sleep allowed (SA) subjects, whereas green labels represent sleep deprivation (SD) subjects.

Conclusion: For the change in viewing patterns after sleep deprivation, there is a high variance between subjects.

CONCLUSION

Sleep deprivation has a unique biometric fingerprint on our attention and eye movement behavior, leading to less exploration behavior when regarding an image. The degree of this change in viewing pattern varies across individual subjects.