Tenth International Conference on Managing Fatigue: Abstract for Review

# Title: EEG analysis of local sleep and its relation to lane departures

Authors: *Christer Ahlström* (corresponding), Swedish National Road and Transport Research Institute, Linköping, Sweden, email: christer.ahlstrom@vti.se, tel. +46 709 218855

*Sabina Jansson*, Department of Biomedical Engineering, Linköping University, Linköping, Sweden, email: sabja199@student.liu.se

*Anna Anund*, Swedish National Road and Transport Research Institute, Linköping, Sweden; Rehabilitation Medicine, Linköping University, Linköping, email: anna.anund@vti.se

## Problem

Historically, sleep has been considered a passive state but later it was proven to be an active dynamic process. Until recently, sleep was also thought of as a global phenomenon, but it has now been found that regions of the brain, at the local level of cortical columns and other neuronal assemblies, go silent at different times. This is referred to as local sleep. Unlike microsleep, brief periods of local sleep may occur when you are still entirely conscious and functioning (Hung et al., 2013; Vyazovskiy et al., 2011). If local sleep is present in a brain structure that is currently needed to perform some task, this will have a negative impact on task performance. In a driving setting, the consequences of local sleep may be devastating.

The primary aim of this exploratory study is to investigate if local sleep (Ferrara & De Gennaro, 2011; Hung et al., 2013), measured via EEG theta power in the 5 – 9 Hz frequency range in source localized EEG recordings, can be related to lane departures and consequently to vehicle accidents. The question at hand is whether local sleep can provide an explanation as to why it is sometimes possible to stay on the road despite being severely sleepy while at other times it is not. Note that we do not envision our results to be used in a potential application as an operational countermeasure for several reasons, the most important being the requirement of an obtrusive high-quality multi-channel EEG. Instead, our long term objective is to gain deeper knowledge and basic understanding of the physiological effects underlying sleep related road crashes.

## Method

Thirty participants were randomly selected from the register of vehicle owners. Each participant drove in an advanced driving simulator at six different occasions, three occasions during daytime (between 12.30 and 21.15) and three occasions during night-time (between 22.00 and 06.15). Each occasion consisted of three driving sessions (rural daylight scenario, rural darkness scenario and urban daylight scenario). Every fifth minute during the 30-minute drives, the participants rated their sleepiness on the Karolinska sleepiness scale (KSS).

A 30-channel EEG was recorded during the trials, and the source localized brain activity was calculated using the standardized low resolution brain electromagnetic tomography (sLORETA) algorithm (Pascual-Marqui, 2002). The data were then bandpass-filtered in the 5 – 9 Hz frequency range to focus the analyses to the theta range which is of particular interest when investigating sleepiness after extended wakefulness (Hung et al., 2013).

Conditional logistic regression with matching was used to test whether increased time-localized EEG theta activity in a brain region increased the risk of having a lane departure. Here a lane departure is defined as each occasion when half the vehicle is outside the lane. The lane departures were matched with non-departures within the same individual to account for individual differences. To ensure that the lane departures were due to sleepiness, only lane departures when the drivers reported KSS = 9 were used. The lane departures and matching non-departures were used as a binary outcome variable and EEG theta content in eighteen brain regions were used as explanatory variables. A stepwise conditional logistic regression was used to derive a combined model relating several brain regions to lane departures.

## Results

The results are based on 135 lane departures matched with corresponding non-departures, all from drivers reporting a sleepiness level of KSS = 9. The regression resulted in a model with a significant simultaneous effect of the superior frontal cortex and the precentral cortex on lane departures relative to non-departures ($Likelyhood\ ratio\ test = 25.42, p = 3.023 \cdot 10^{-6}$). Including additional brain regions in the model does not improve its performance. The estimated $\hat{\beta}$ coefficients, the odds ratios, the standard errors and the z-scores are shown in Table 1. The estimated odds ratio for a lane departure relative to a non-departure was 1.48 in the precentral region and 1.60 in the superior frontal region. This means that for every unit increase in EEG theta power in these two regions, the odds for departing the road increase with 1.48 and 1.60, respectively.

Table 1: Results from the conditional logistic regression using the best combination of brain regions.

| Region | $\hat{\beta}$ | OR | SE $(\hat{\beta})$ | z | p |
|---|---|---|---|---|---|
| Precentral | 0.391 | 1.478 | 0.142 | 2.74 | 0.006 |
| Superior frontal | 0.468 | 1.596 | 0.206 | 2.27 | 0.02 |

## Discussion

Regions in which the EEG theta power increased significantly before a lane departure were especially the precentral and superior frontal cortex. The precentral cortex is associated with the primary motor functions and the superior frontal cortex integrates with the sensory system and regulates intellectual function and action, and is associated with motor planning, regulation and organization. This result intuitively makes sense, i.e. that an inability to stay on the road is related to motor function and movement organization. Analogous to the performance degradations associated with local sleep in awake rats (Vyazovskiy et al., 2011), our results indicate that an increased theta content in regions associated with motor control is associated with lane departures. This may explain why it is sometimes possible to stay on the road despite feeling sleepy, while at other times the same level of sleepiness leads to a lane departure. In both situations, it is obviously important to stop the vehicle and take a rest.

## Summary

The results indicate a relationship between lane departures and increased local theta activity in brain regions associated with motor function. However, the exploratory nature of this study, along with the fact that we have investigated the effect of local sleep rather than local sleep per se, prompts for further validation of the results.

## References

Ferrara, M., & De Gennaro, L. (2011). Going Local: Insights from EEG and Stereo-EEG Studies of the Human Sleep-Wake Cycle. *Curr Top Med Chem, 11*(19), 2423-2437.

Hung, C. S., Sarasso, S., Ferrarelli, F., Riedner, B., Ghilardi, M. F., Cirelli, C., & Tononi, G. (2013). Local Experience-Dependent Changes in the Wake EEG after Prolonged Wakefulness. *Sleep, 36*(1), 59-72. doi: 10.5665/sleep.2302

Pascual-Marqui, R. D. (2002). Standardized low-resolution brain electromagnetic tomography (sLORETA): Technical details. *Methods and Findings in Experimental and Clinical Pharmacology, 24*, 5-12.

Vyazovskiy, V. V., Olcese, U., Hanlon, E. C., Nir, Y., Cirelli, C., & Tononi, G. (2011). Local sleep in awake rats. *Nature, 472*(7344), 443-447. doi: 10.1038/nature10009