International Symposium on Somnolence and Safety 2014 (SomnoSafe 2014)

Brussels, Belgium - 24-25 February 2014

Abstracts for SomnoAlert
INFLUENCE OF INTER-INDIVIDUAL DIFFERENCES IN CIRCADIAN FLEXIBILITY ON SUBJECTIVE AND OBJECTIVE SLEEPINESS MEASURES DURING 28-HOURS OF SLEEP DEPRIVATION.

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ABSTRACT
Inter-individual differences in the response to sleep deprivation exist and these differences can be important when evaluating sleepiness induced safety consequences. The current study explores the influence of individual differences in the circadian flexibility on sleepiness profiles, in response to prolonged wakefulness. Fifteen participants (11 women) enrolled in a 28 h total sleep deprivation study. Participants were selected on the basis of their circadian phenotype, assessed by the factor “Flexibility” of the Circadian Type Index (CTI) [1] and were divided in two groups: rigid types (CTI flexibility score < 17, 25th percentile; mean age 25.00 SD=6.19) and flexible types (CTI flexibility score > 27, 75th percentile; mean age=22.25, SD=6.50). Inclusion criteria were: age between 18 and 39 years old, good physical health (SF-20) [2], [3], absence of psychiatric disorders (MINI) [4], habitual sleep duration between 6.5 and 8.5 hours, good sleep quality (Pittsburg Sleep Quality Index; PSQI) [5], no excessive daytime sleepiness (Epworth Sleepiness Scale; ESS) [6], no extreme morning-eveningness scores [7], no previous detrimental neuropsychiatric reactions to sleep deprivation, no shift work, no current medical treatment or use of medicines or drugs (excluding oral contraceptives) influencing sleep. The Karolinska Sleepiness Scale (KSS) [8], the Psychomotor Vigilance Task (PVT) [9] and the Alpha Attenuation test (AAT) [10], were used to assess subjective, performance based and physiological sleepiness. Results showed an increase of sleepiness under conditions of extended wakefulness. No overall group differences were found in sleepiness measures, but significant interaction effects were found between all sleepiness measures over time and circadian flexibility. Flexible subjects displayed higher levels of sleepiness during the biological day, together with lower levels of subjective and performance based sleepiness during the biological night. Inter-individual differences in the behavioral flexibility of the circadian system were reflected in differential sleepiness profiles, suggesting that the circadian rhythm parameter of flexibility can be pivotal in evaluating sleepiness and sleepiness induced safety consequences. In line with the previous results of Di Milia and colleague’s [1] our findings suggest that the circadian rhythm parameter of flexibility may be an important factor in evaluating the tolerance to shift work and to other conditions associated with functioning during nighttime.


BRAIN DYNAMICS OF INHIBITION PROCESS IN EMERGENCY SITUATIONS DURING DRIVING

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Index terms— Inhibition, stop signal task, driving.

Efficiently dealing with an emergent situation is critical for a driver to avoid or minimize an accident in driving. Inhibition is one of the important processes involved in handling emergency situations. This study implemented the stop-signal paradigm on a dynamic simulator to explore the detailed EEG dynamics associated with inhibition process during driving.

In the designed experiments, the driving scene is a four-lane road with a traffic light positioned at every road intersection. Participants were instructed to drive on the road and follow the traffic lights. The task has a frequent “go” stimulus (70% of total trials) and a less frequent “stop” signal (30% of total trials). In Go-condition, participants are instructed to proceed when the traffic light turns green (i.e., go-stimulus). In Stop-condition, a car would suddenly appear in the path (i.e., stop-stimulus) and participants have to withhold their response to avoid a crash. Independent component analysis (ICA) and event-related spectral perturbation (ERSP) analysis were applied on 30-channel EEG signals to investigate spectral dynamics in emergency driving.

Compared to the results in the Go-condition, in the Stop-condition we found that theta (4-7Hz) and delta (1-3Hz) powers significantly increased in frontal and central regions during inhibitory motor control. Additionally, the delta band power in the central region was found to be a proper EEG index to distinguish a successful inhibition from an unsuccessful one. Consistent with previous findings, the pre-frontal cortex and the pre-supplementary motor area (pre-SMA) are associated with the inhibitory motor control. Our results further indicate that the pre-SMA plays a critical role in exerting control over inhibitory actions to avoid a crash. These results could serve as useful foundation for the development of EEG-based driver assistance system for real-life driving.
DAWN LIGHT SIMULATION AS A COUNTERMEASURE FOR CARDIOVASCULAR VULNERABILITY SURROUNDING SLEEP TO WAKE TRANSITION

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Index terms— Dawn light simulation, wake up, autonomic nervous system.

There is a large body of evidence that all major adverse cardiovascular events peak in the morning hours. Abrupt changes in sympatho-vagal balance, namely sympathetic surges during the transition from sleep to wakefulness may partly contribute to this morning accumulation of these adverse events. To prevent these abrupt sympatho-vagal shifts, we propose to reduce the gradient of the transition mimicking the biota wake-up conditions using a dawn-simulating-light (DSL) alarm clock.

After a 6-h sleep restriction night, participants were woken-up 2-h before their habitual wake time. We applied a habitual auditory alarm clock or a DSL starting 30 minutes (polychromatic light increasing from 1.2 lux, 1.9E+16/ m2*s, 1090K, 0.2 m-lux to -250 lux, 2.4E+18/ m2*s, 2750K , 620 m-lux) before scheduled wake-up time in a balanced cross-over design. In both conditions the participant remained in bed, in a supine position during the 30 min following the awakening. We compared the two type of wake-up episodes during 30 min of sleep in a still dark environment, 30 min of sleep during the gradual DSL exposure and 30 min of wakefulness after wake-up in a supine position in bed.

Seventeen healthy men (mean [SE] age 23.12[0.82] years sleep quality index (PSQI) 2.88 [0.27]; body mass index 22.86 [0.35] kg/m2 met the inclusion criteria. The R-R intervals (i.e., the length of time between the R peaks of consecutive QRS complexes) were calculated and checked for artefacts. Power spectral analysis of each consecutive 150 R-R intervals recording was performed sequentially with a fast Fourier transform based on a nonparametric algorithm. The cardiac sympathetic modulation was estimated by the power densities ratio LF/(LF+HF) [LF=0.04 to 0.15 Hz; HF=0.15 to 0.50 Hz]. During the transition from sleep to wakefulness, the classical alarm clock evoked a HR increase from 60.6+2.5 at to 89.7+3.7 bpm, while in the DSL condition, HR increased from 67.5+4.8 to 78.4+5.0, resulting in a significant gradient reduction (p < 0.05). This finding was corroborated by a significant increase of sympathetic modulation during the 30 minutes of sleep with a gradual DSL, that did not raise further during the following wakefulness.

Dawn-light-simulation before scheduled wake-up in the morning prepares cardiac physiology to awakening by “smoothing” the abruptness of sympathetic surge. This reduction seems to be due to a pre-stimulation of the sympathetic activity during sleep induced by DSL. These data indicate that DSL may have cardiovascular protective effect and counteract the usual “off/on” awake.
EVENT-RELATED ALPHA DESYNCHRONIZATION RELATED TO THE SCALING OF STEERING WHEEL CORRECTIONS

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Index terms—Driving, alertness, time-on-task fatigue, attention, alpha, event-related desynchronization/synchronization.

Previously we derived a new measure indexing the relation between the driver’s steering wheel responses relative to the velocity of the vehicle’s current heading. This measure we called relative steering wheel compensation (RSWC) is significantly lower immediately following an alerting stimulus compared to other periods of continuous driving and is detectable across 5-min intervals. In the present study, we investigate the neural substrates of these changes by examining the underlying oscillatory alpha power in sensorimotor areas which have been previously documented in the driving literature. Sensorimotor areas have consistently been shown to exhibit event-related desynchronization (ERD) in the alpha frequency band that occurs with the onset of corrective steering wheel maneuvers in response to vehicle perturbations. Here we hypothesized that alpha ERD in the sensorimotor cortical regions represent brain activity related to visuomotor transformation underlying responses to vehicle perturbations during a 45-min continuous driving task, and that these activations would change as a function of driving performance changes over a prolonged period of driving. To investigate this possibility we compared alpha ERSP of trials in which RSWC was low versus high. Interestingly, we find that low RSWC, which typically occur after the subject is alerted, is associated with less ERD than larger RSWC. In addition we demonstrate that these differences are not attributable to the amount the steering wheel is turned, nor the speed at which the heading is changing. This may imply that less cortical activation is utilized when performing corrective steering movements in non-alert states and provides an initial explanation for what these steering-related ERD patterns reflect with respect to driver alertness.
The terms sleepiness and fatigue are often used synonymously even though the causal factors contributing to the state may differ. The main determinants of sleepiness are the time of day (circadian rhythm) and the duration of previous periods of being awake and asleep (homeostatic regulation). Fatigue on the other hand may also be due to exogenous and endogenous factors such as monotony, task demand and task duration and may arise in the absence of sleep-related causes. Sleepiness and fatigue are intertwined and it is difficult to isolate one from the other.

A common approach when studying driver sleepiness is to use sleep deprived drivers. Usually, the drivers are in an alert condition during daytime and in a sleep deprived condition during night-time. One consequence of such a study design is that there is a confounding effect between the sleep-related factor day versus night (circadian effect) and between the factor alert versus sleep deprived (homeostatic effect). In addition, there is also an effect of fatigue-related factors such as time on task and boredom. The consequences of driving under this mixture of causal factors are heavily understudied in the research literature. For example is a driver more likely crash during the night-time compared to daytime, when the sleepiness level being experienced is the same in the two conditions? The consequences, in terms of line crossings, of different levels of self-reported sleepiness and long blinks will be investigated when the driver is sleep deprived (night) compared to not sleep deprived (day). The hypothesis is that high self-reported sleepiness (KSS 9) and long blink duration (>0.15s) will be less associated with critical events during the daytime compared to night time. The study is based on data from a driving simulator experiment with 16 participants driving during the day and during the night. The results show no differences in the percentage of line crossings during high levels of KSS (9) during daytime (33%) and night-time (40%). However, there was a significant difference between day and night time for the occurrence of line crossings while the driver had long duration blinks (4% during daytime and 35% during night-time). Despite these results the most promising predictor of line crossings was KSS with an OR of 5.4 with a starting point at KSS 5.
CALIBRATION OF OBJECTIVE (ELECTROENCEPHALOGRAPHIC) ALERTNESS SCALES

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Index terms— EEG, sleepiness, calibration, spectrum.

In spite of the extraordinary progress made by circadian and sleep science in the last decades, the measurement of sleepiness remains one of the most challenging problems. Earlier we demonstrated that simple scales for objective measurement of alertness can be constructed using the electroencephalographic (EEG) recordings obtained on 5-min eyes closed intervals of the Karolinska drowsiness test. The question arises of how such scales can be calibrated. On the one hand, we know with high confidence that self-perceived levels of drowsiness do not always correspond to the objectively measured levels, but on the other hand, it is also well-known that changes in sleepiness often dissociate from changes in objective performance measures and, hence, subjective assessments of drowsiness provide better gauge to sleepiness compared to these objective measures. Moreover, the reports on self-perceived alertness levels are always necessary to take into account on both starting and final steps of any such calibrating attempt. Thus, in order to establish validity of an objective scale of alertness, one is forced to somehow calibrate it using subjective scales. In the present report we tried to calibrate our earlier proposed EEG alertness scales through evaluation of the modulating influence of the circadian and homeostatic regulatory processes on the extent of dissociation between objective and subjective assessments of sleepiness. The resting EEG was recorded with 2-hour interval from frontal and occipital derivations during the last 32-50 hours of 44-61-hour wakefulness of 15 healthy study participants. We computed alpha-theta power difference for occipital derivation and scores on the 2nd principal component of the EEG spectrum for both derivations. Positive and negative values of the EEG indexes obtained for one-min intervals of 5-min eyes-closed EEG recordings were assigned to 1 and 0, respectively, and summed to score alertness on 6-point scales. Correlation coefficients between the time courses of scores on these scales and the KSS (Karolinska Sleepiness Scale) were found to be very strong (below -0.93), but evidence of systematic errors in both the mean and the calibration was also found. The correlation coefficients between the time courses attained values below -0.97 after correction of these errors. The results suggest that six consecutive points of the objective alertness scales (from 5 to 0) can be anchored to self-perceived levels of minimal, mild, moderate, marked, severe, and disabling sleepiness, respectively.
PRELIMINARY EVALUATION OF AN EXPERIMENTAL SOMNOLENCE QUANTIFICATION SYSTEM BASED ON IMAGES OF THE EYE

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Index terms—Somnolence, drowsiness, safety, accident, eye, ocular parameter, reaction time, driving.

Somnolence is known to be a major cause of various types of accidents, particularly on roads, and ocular parameters are recognized to be good and reliable physiological indicators of somnolence. We have thus developed an experimental (software) system that uses ocular parameters extracted from images of the eye to produce a level of somnolence on a continuous numerical scale. The ultimate goal of this system is to prevent somnolence-related accidents.

The aim of the study described in part here is to verify that, for a number of subjects, the level of somnolence produced by our system correctly reflects, on average, the level of performance of these subjects in the accomplishment of a task. The two tasks considered here are (1) a visual reaction-time (RT) test and (2) in-simulator driving.

We conducted two independent experiments. In each, the healthy, volunteer subjects were subjected to three tests over two consecutive days, and they were not allowed to sleep between the first and last tests. In the first experiment (involving 21 subjects), each test was a visual RT test, with duration of 15 minutes. In the second (involving 12 subjects), each test was a driving run in a simulator, with duration of at least 45 minutes.

During each test, we continuously recorded images of the right eye of the subject at a high frame rate. We then used our somnolence quantification system to produce a numerical value for the level of somnolence for each minute of test. For each such minute, we also obtained a relevant task-related performance parameter, i.e. either the mean RT (for the first experiment), or the standard deviation of the lateral position (SDLP) of the car on the road (for the second).

The results show that our system indicates an increase in the numerical level of somnolence when the mean RT increases or when the mean SDLP increases, as appropriate. In the first experiment, the mean RT increased from 0.385 ms for a low level of somnolence to 0.681 ms for a high level of somnolence. In the second, the mean SDLP increased from 0.417 m for a low level of somnolence to 1.204 m for a high level of somnolence.

In conclusion, the above experiments indicate that our somnolence quantification system based on images of the eye has significant potential for indicating the level of performance of a subject accomplishing a task, and thus, ultimately, for preventing accidents due to somnolence, in particular during driving.

Acknowledgements: IFSTTAR (for driving simulator), CETES Laboratory (R. Poirrier), LECIT Laboratory (A. Blavier).
A MULTI-CHANNEL EEG SIGNAL PROCESSING CHAIN TO DETECT MENTAL FATIGUE

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Index terms— EEG signal processing, CSP, filter, mental fatigue, detection.

An original 32 EEG channel signal processing chain is proposed to classify two levels of mental fatigue (low versus high).

Each EEG signal from the 32 electrodes is at first filtered in a given frequency band. Then, 15 electrodes are selected using a method based on Riemannian geometry. Next, a spatial filtering step is carried out using 6 common spatial pattern (CSP) filters. The filtered signals are linear combinations of the original signals, where specific weights are applied on the electrodes, to increase the discriminability of the signals in the two classes. Lastly, a binary classification is performed using Fisher’s linear discriminant analysis (FLDA). The features used are the log variance of the 6 CSP filtered signals.

Results are evaluated on data recorded on twenty healthy volunteers (9 females; age: M = 25 years, S.D. = 3.5) during their participation to a cognitive experiment. Its goal is to submit the participants to different levels of cognitive workload during a long time, to induce mental fatigue. EEG was recorded at 500 Hz from 32 electrodes positioned according to the 10-20 system. For each subject, 160 800ms epochs of signals were selected at the beginning of the experiment and at the end of the experiment and labelled as low or high level of mental fatigue.

The classification accuracy reached by the classifier per subject, using a 10 fold cross validation method, was used to analyze the discriminative power of different frequency bands: theta [4-8 Hz], alpha [8-13 Hz] and beta [13-30 Hz].

The performances obtained were excellent with respectively 95\%, 96\% and 100\% averaged accuracy (calculated on the 20 subjects) for theta, alpha and beta. The results were compared to those obtained with a more traditional signal processing chain where the averaged power in the given band was extracted from the same 15 selected electrodes using Welsh’s periodogram and used as input features to another FLDA. Results dropped to 78\%, 75\% and 84\% respectively for theta, alpha and beta.

Though the results obtained on 20 different subjects are excellent, the use of such a detector to monitor mental fatigue is impaired by its requiring a long training period. Thus, the perspectives of this research are to adapt the method to a subject-independent use, in which classifiers learnt on a pool of subjects could be applied on a new one, for instance by means of regularized CSP filters.
VIDEO-BASED OBSERVER RATED SLEEPINESS AND REAL ROAD DRIVING

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A recent trend in studies of sleepy driving is to carry out large-scale naturalistic data collections with instrumented vehicles. The advantage of these field operational tests is the possibility to study the extent to which signs of sleepiness contribute to safety critical incidents. However, such results depend upon the ability of an observer to accurately assess sleepiness based on video recordings of the driver’s face within a real life context. The extent to which this is possible is not clear. The aim of this study is to investigate and validate observer rated sleepiness (ORS) ratings using subjective self-reported sleepiness as a ground truth indicator of sleepiness (based on the Karolinska Sleepiness Score, KSS).

Forty raters assessed 54 one-minute video-clips. The video-clips were balanced according to day and night time conditions and on the sleepiness level (based on the KSS values).

The overall average percentage of correctly classified video segments was 41%. Since the ORS scale only has three levels, this is barely better than chance. ORS0 (alert) and ORS2 (very sleepy) were easier to score than ORS1 (slightly sleepy) and it was harder to rate the night-time drives. There was no significant effect of rater age on correct ORS classification. Inter-individual differences between raters were calculated as the average of the Pearson’s r correlations between all raters, and this was found to be 0.19. The rater’s confidence in their ratings also correlated poorly with classification performance.

The notion that it is possible to assess the emotional state (such as sleepiness) of a fellow human with a single glance is widely held, but, the results of the current study shows how extremely difficult it can be to rate the sleepiness level of a driver. Limitations in the study that may have influenced the results include rather poor (but realistic in a naturalistic driving sense) video quality, inexperienced raters, and the relatively short duration of the video clips.

In conclusion, the results of this study indicate that video based ORS ratings of drivers' sleepiness levels correlate poorly with the drivers' self-reported sleepiness. Further investigations should be carried out to investigate the reliability of ORS.
NON-IMAGE-FORMING RESPONSES TO LIGHT: EFFECTS OF A POLYMORPHISM IN THE CLOCK GENE PERIOD3

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Index terms—Non-image-forming visual system, melatonin, wakefulness, sleep EEG activity, clock gene polymorphism.

Background: Non-image forming (NIF) responses to light show maximal sensitivity at short-wavelength [460–480 nm (blue) light]. However, the extent to which NIF responses to light modulate human sleep and wake and its EEG hallmarks, and if these effects differ among individuals are unknown. Here we investigated if inter-individual differences in melatonin suppression, subjective and objective sleepiness, and sleep structure/EEG activity are driven by a clock gene polymorphism involved in human sleep-wake regulation.

Methods: Eighteen healthy young men homozygous for the PER3 polymorphism (9 PER35/5, 9 PER34/4) underwent two types of evening light exposure in a balanced crossover design during the winter. During each protocol, participants spent 1.5 h under dim light, 2 h under complete darkness, 2 h of light exposure (compact fluorescent lamps at 40 lux with 6500, blue-enriched or 2500K, non-blue enriched), followed by dim light for 45 min until habitual sleep time. Salivary melatonin and subjective sleepiness were sampled every 40 minutes during scheduled wakefulness. Hourly waking EEG activity was recorded during the Karolinska Drowsiness Test, during scheduled wakefulness. Sleep structure and EEG activity following acute light exposure were also analyzed.

Results: We observed a wavelength-dependent attenuation of melatonin secretion that depended on the PER3 polymorphism, such that melatonin decreased in PER35/5 but not in PER34/4 individuals. Blue-enriched light significantly reduced subjective sleepiness in a genotype-dependent manner, such that PER35/5 individuals were less sleepy than PER34/4. This subjective perception of sleepiness was mirrored by changes in waking EEG activity (theta range: 5–7 Hz), a correlate of sleepiness. Theta EEG activity was reduced during blue-light exposure only in PER35/5 individuals. Furthermore, blue-light exposure increased all-night NREM sleep slow-wave activity (1.0-4.5Hz) in the occipital cortex for the PER35/5 individuals, but not for PER34/4. Analysis of the time-course of NREM sleep SWA yielded increased occipital SWA throughout the sleep episode in PER35/5 individuals relative to PER34/4. In addition, PER35/5 individuals experienced light at 6500K as brighter, which was significantly correlated to their increased occipital NREM sleep SWA.

Conclusions: Our data indicate that humans homozygous for the PER35/5 allele are particularly sensitive to blue-enriched light, which suggests that light sensitivity may be modulated by a clock gene polymorphism also implicated in sleep-wake regulation. These findings may help to better understand individual variability of the NIF responses to light.
DETECTION OF EYE MOVEMENTS SPECIFIC TO DROWSINESS AND THEIR RELATION WITH SUBJECTIVE ASSESSMENT OF SLEEPINESS IN PVT: A COGNITIVE ERGONOMIC APPROACH

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Index terms—Cognitive ergonomics, PVT, eye movements, drowsiness, subjective assessment.

Drowsiness is one of the major factors explaining accidents, particularly in traffic accidents but also in work situations with serious consequences (e.g., medicine). The drowsiness may be assessed by diverse measures that vary from physiological and unconscious data (e.g., EEG) to subjective and conscious evaluation. In their daily life, people are used to evaluate their drowsiness by subjective assessment and research observes a great inter-individual variation in this evaluation. Moreover, the subjective evaluation is dependent on the situation and the risk perceived by the person (e.g., new versus usual situations, simple versus complex environments, etc.).

In this theoretical context, our purpose was to investigate the links between 1) objective performance (reaction time) measured by a psychomotor vigilance task (PVT), 2) data from eye movements and 3) subjective assessment of drowsiness (measured with Karolinska Sleepiness Scale, KSS). 12 persons, aged from 20 to 56, participated individually. They were asked to respect a 60% sleep deprivation during the night before the experiment and to not drink any energy drinks the day of the experiment. The experiment was conducted between 1 and 3 PM after a heavy lunch in order to increase the circadian effect. Moreover, the temperature of the room was 25° in order to increase drowsiness. Each participant was asked to perform 4 PVT. However, although 100% of participants performed the first two PVT, only 66% were able to perform the third PVT and only 33% of participants performed the fourth and last PVT.

Our results showed an effect of time on objective performance, eye movements and subjective assessment of drowsiness in PVT 1 and 2: significant increase of reaction time, increase of eye closure and perclos, reduction of pupil diameter and increase of subjective drowsiness estimation (KSS). Only the frequency and duration of blinks remained constant across time. In PVT 3 and 4, data from eye movements and objective performance (reaction time) did not vary anymore across the time. Only the subjective estimation of drowsiness (KSS) continued to increase.

Furthermore, subjective estimation of drowsiness was differently correlated with eye movements and objective performance across the PVT; it was significantly correlated with reaction time (PVT 1,2,3), blink frequency and duration (PVT 1,2,3), perclos (PVT 1,2,3,4), eye closure (PVT 2,3), pupil diameter (PVT 1,2,3,4). These results are discussed and integrated in an ergonomic approach in order to analyze the links between objective performance, eye movements and subjective assessment of drowsiness.
INATTENTION DETECTION IN PROFESSIONAL FLEETS USING A SMARTPHONE PORTABLE DEVICE SYSTEM BASED ON RESPIRATION SIGNAL VARIABILITY

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Index terms—Drowsiness, fleet, thoracic effort signal, respiration, inattention, fatigue, driving.

Investigations have demonstrated that professional fleet drivers as truck, bus or night guard drivers are more susceptible to have circadian phase disruptions caused by rotating shift work. These disruptions are associated with lapses of attention, increased reaction time, and decreased performance¹. Biomedical variables, as thoracic effort, related to autonomic nervous system provide direct information of the driver physiological state of attention² and anticipate risking situations while doing complex tasks³.

The aim of this work is to evaluate the level of attention while working with a driver’s fleet of 80 professional drivers by analyzing thoracic effort signal and the GPS route tracking (accuracy defined as the radius of 68% confidence), using lightweight signal processing algorithms integrated on a Smartphone in order to achieve a measurement of attention.

The attention state is evaluated with 5 stages that oscillate between green and red, being green the maximum attention state and red a dangerous inattentive state. Also the GPS tracking signal was acquired in order to relate the attention state with the route and the hour of the day. Only if the driver is extremely inattentive the Smartphone also sends a set of images of the driver to the server, in order to evaluate if the inattentive driver state is correct.

The experiment described in this paper shows the relation between attention state, thoracic effort signal variability and working environment of a driver’s professional fleet. Those results allow studying how the divers behave when they are struggled against falling asleep and how to decrease these effects managing the working hours and the routes.


Noelia Rodriguez, Biomedical Engineer at Ficosa International, Spain, earned her BSc in Biological Science from the University of Barcelona on 2005 and her MSc in Biomedical Engineering and Nanoscience and Nanotechnology from the Polytechnic University of Catalonia on 2007. Her PhD is focused on the detection of drowsiness in real drivers by physiological data processing in order to design an algorithm that alerts the drivers in danger of falling asleep to avoid car accidents.
STUDY OF SUPERVISED MACHINE LEARNING TECHNIQUES TO CLASSIFY SUBJECTS AS ALERT, DROWSY, OR OTHER BASED ON OCULAR PARAMETERS EXTRACTED FROM IMAGES OF THE EYE

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Index terms— Somnolence, drowsiness, machine learning, classification, artificial neural networks, support vector machines, ocular parameters, performance.

Drowsiness is a major cause of accidents in a variety of domains, e.g. on roads. The present work investigates (1) the potential of supervised machine learning techniques to classify people in one of the three states "alert (A)”, "drowsy (D)”, or "other (O)” (where “other” means neither “alert” nor “drowsy”) based on ocular parameters extracted from images of the eye, and (2) the performance of these techniques.

Twenty-one healthy volunteers took part in an experiment where they were asked to perform a total of three vigilance tests; each test had duration of 15 minutes; all tests were spread over two days. They had their usual hours of sleep before the first test, and were then deprived of sleep until the end of the last test. Prior to the classification experiments, we established the ground truth by labeling, via an independent process, each minute of test according to one of the three states A, D, and O. During each test, we recorded images of the eye of the subject at high frame rate. The values of a variety of ocular parameters (such as blink duration) were then computed for each minute of test. For each minute of test, we thus had a set of ocular parameters and the ground truth state.

We performed two distinct experiments. In the first, we built binary classifiers aimed at labeling each minute of test as A or D. In the second, we built ternary classifiers aimed at labeling each minute as A, D, or O.

For each experiment, we considered two types of classifiers: Artificial Neural Networks (ANNs) (Multilayer perceptrons) and Support Vector Machines (SVMs). For each type, we considered several settings of the parameters. For each setting of parameters, we built the classifier by 10-fold cross-validation.

The performances of the systems were measured in several different ways. In the case of the binary classifier, we also tested the system on the minutes labeled O. Indeed, an operational, binary classifier would need to make a choice (A or D) even on minutes that are in fact O. Among the many statistics obtained, let us simply say here that, for the binary classifier trained on a set of A and D minutes, and tested on another set of such minutes, we obtained correct classification rates of up to 90% for ANNs and 93% for SVMs (this over all the subjects and for the best settings of parameters). The statistics obtained show that subjects can reliably be classified as “alert”, “drowsy”, or “other” by using supervised machine learning techniques.
REAL DRIVING AT NIGHT – PREDICTING LANE DEPARTURES FROM PHYSIOLOGICAL AND SUBJECTIVE SLEEPINESS

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Index terms— sleepiness, driving, safety, subjective ratings, performance, EEG, EOG.

Very little data is available on physiological, behavioral and subjective measures of sleepiness during real driving at night and virtually nothing is known about how driving performance relates to physiological and subjective sleepiness indicators in such a context. The present study sought to provide such knowledge. A particular problem is how to measure driving performance (and risk) under sleepiness. Lateral variability works well in a driving simulator but less so in real driving. Here we wanted to evaluate “lane departures” (crossing the lane marker to the left or right), which has considerable face value and seems to relate to sleepiness in real driving on motorways.

33 volunteers drove for 90 minutes in an instrumented car on a two-lane, 9 m wide rural road during the afternoon and night (0130-0430h), while electroencephalography and electrooculography and lane departures (using a lane tracker) and other driving parameters were recorded continuously and subjective ratings of sleepiness were made every 5 minutes (Karolinska Sleepiness Scale - KSS). Data was analyzed using mixed models regression.

The results showed that unintentional lane departures increased from afternoon to night driving (0.001±.0001 vs 2.3±.007 per 5 minutes, p<.001), as did self-reported sleepiness (4.8±4 vs 7.9±3, p<.001) and long blink durations 0.10±.003 vs 0.13±.007 sec, p<.001). Lateral position moved to the left of the lane. EEG alpha or theta activity did not differ between conditions. Self reported sleepiness increased with time on task, as did blink durations. Unintentional lane departures were predicted by self-reported sleepiness and blink duration in the longitudinal analysis across time and by self-reported sleepiness in the interindividual analysis against mean lane excursions. Unintentional lane departures almost exclusively occurred at sleepiness levels of 8 and 9 on the KSS scale. The probability of a lane departure at night in the less sleepy group (KSS = 5.92±.12) was 0.06 per 5 minutes and 0.35 in the most sleepy group (KSS = 8.00±.10).

It was also demonstrated that removal of intentional lane departures, including short-cutting through curves enhanced the relation between self-reported sleepiness and lane departures.

It was concluded that lane departures, eye blink duration and subjective sleepiness are strongly increased during night driving and that sleepiness and to some extent eye blink duration are sensitive predictors of lane departures. Thus, awareness of sleepiness is high and linked to driving performance that may imply risk.
THE WAKE-UP BUS SLEEP STUDY: FALLING ASLEEP AT THE WHEEL IN 19 EUROPEAN COUNTRIES

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Index terms— Sleepiness at the wheel, accidents, European countries, epidemiology.

Background and objectives
Sleepiness is a major cause of road accidents. The European Sleep Research Society (ESRS) set up the European-wide Wake-Up Bus Project including a survey of drivers in different countries aimed at estimating:
- the prevalence of falling asleep at the wheel and its consequences;
- the associations between falling asleep at the wheel and country of residence, demographic characteristics and sleep-related problems.

Methods
Nineteen European National Sleep Societies (NSS), which are part of the Assembly of the NSS of the ESRS, participated in the survey: Austria, Belgium, Croatia, Estonia, France, Germany, Greece, Iceland, Italy, Lithuania, Netherlands, Poland, Portugal, Romania, Serbia, Slovenia, Spain, Sweden and Turkey. Data were collected using an anonymous questionnaire completed at the ESRS website. The questionnaire collected demographic data, driving behavior, history of sleepiness and its relation to road accidents, and sleep-related problems (Epworth Sleepiness Scale and the STOPBang questionnaire). Associations between sleepiness at the wheel and its determinants were quantified using multivariate logistic regression analysis (odds ratios and 95% confidence intervals).

Results
Overall, 12434 questionnaires were submitted. The median prevalence of falling asleep at the wheel in the previous 2 years was 17% (from 6.1% in Croatia to 34.7% in The Netherlands). After adjustment for individual characteristics, the odds of falling asleep were highest in Austria and The Netherlands and lowest in Croatia, Slovenia, Italy and Iceland. Among respondents who had fallen asleep, the median prevalence of accidents was 7.0%, highest in Italy and Estonia and lowest in Iceland. Of the 167 accidents reported, 13.2% involved hospital care and 3.6% involved fatalities. The most frequent reasons for falling asleep at the wheel were poor sleep in the previous night (42.5%) and poor sleeping habits (34.1%).

After adjustment for country of residence, age, gender and distance driven, falling asleep was associated with the following variables: younger age [odds ratio (95% CI), 1.68 (1.14-2.47) in drivers under 30 years]; male gender [OR 1.78 (1.61-1.98)]; driving 20000 km or more per year [OR 2.06 (1.79-2.39)], when compared to driving under 10000km; higher daytime sleepiness [OR 3.20 (2.75-3.65) based on ESS scores > 10]; and higher risk of obstructive sleep apnea [OR 3.52 (2.83-4.38) in men].

Conclusions
We found a high prevalence of falling asleep across European countries, the frequency of which was rather homogeneous across countries. The main determinants of falling asleep at the wheel include male gender, driving exposure, and obstructive sleep apnea risk.
1. INTRODUCTION
Sleep deprivation due to extended work hours has long been a concern in medicine (1). Emergency physicians (EP) commonly experience sleep deprivation in stressful situations (2). Regularly scheduled on-call duty is often 24 to 36 hours long. In addition, many trainees work more than 75 hours a week. Several studies in different domains have demonstrated the impairment of performance under sleep deprivation (3,4). In one well-known study, the effect of sleep deprivation after 24 hours of sustained wakefulness on a task has been shown to be equivalent to the effect of alcohol concentration of 0.10 percent (5). In medicine, although issues related to house-staff fatigue have been raised for many years (6,7), regulation have, until recently, been very limited. In 2010, Belgium adopted regulation that limit residents’ work hours.

2. OBJECTIVES
The goal of this study was to evaluate the effect of sleep deprivation on emergency physicians’ performance using the distinction between technical and non-technical skills. These non-technical skills are not directly related to the use of medical expertise, drugs or equipment. They encompass both social and cognitive skills e.g. communication, team working, leadership, situation awareness and decision making (ANTS) and have been shown as critical for crisis management.

3. MATERIAL AND METHODS
We used a full scale in situ simulator (Gaumard high fidelity HAL 3201) to assess physicians’ performance. After the approval of the ethical committee, 14 Emergency physicians from 2 hospitals have agreed to participate in the prospective multicenter study. We used 2 critical scenarios: the first one was a respiratory failure and the second was a severe bradycardia. Participants were randomized in 2 groups: Group A: scenario 1 before the night on call and scenario 2 after the night on call; In group B, the scenarios were reversed.

Before the experiment (2 nights before they were on call) the participants were asked some demographic data (sex, age, experience) and the average hours of sleeping. We used the Karolinska Sleepiness Scale to measure the subjective fatigue on a 10 points scale (from 1: extremely alert, 2:very alert, 3:alert, 4:rather alert, 5: neither alert nor sleepy, 6:some signs of sleepiness, 7: sleepy, but no effort to keep awake, 8: sleepy, some effort to keep awake, 9: very sleepy, great effort to keep awake, struggling against sleep, 10: extremely sleepy, falls asleep all the time.)

The emergency physicians’ performance during the simulations was recorded using an audio-video system. Each video has been assessed by two judges by consensus, using the ANTS grid (8), a behavioral marker system rating anesthetist’s non-technical skills. The physicians’ response latencies to the patient’s degradation during the 2 scenarios were also calculated.
4. RESULTS
We will present in details the impact of sleep deprivation on EP(s) performance using the distinction between technical (routine) and non-technical skills and comparing the participants through their level of experience.

5. REFERENCES
Driving During Alcohol Hangover: Lapses of Attention, SDLP, and the Interaction with Total Sleep Time

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Background: Reduced alertness and ability to concentrate are commonly reported during alcohol hangover. These symptoms are caused by excessive alcohol consumption, but also corresponding sleep loss due to staying up later than usual on the drinking occasion may exacerbate the severity of these symptoms. The purpose of this study was to examine the effects of alcohol hangover on simulated highway driving performance, and to examine the possible impact of total sleep time on performance decrement.

Methods: N=42 healthy volunteers conducted a 100-km simulated highway driving test the morning following an evening of consuming on average 10.2 (4.2) alcoholic drinks (alcohol hangover) and on a control day (no alcohol consumed). The driving test started when blood alcohol concentration (BAC) was zero. Standard Deviation of Lateral Position (SDLP, i.e. the weaving of the car) and lapses of attention were measured. A lapse was defined as a change of lateral position of >100 cm for at least 8 seconds. ∆SDLP (hangover – control) and ∆lapses were related to total sleep time.

Results: There was a significant increase in both SDLP (+ 1.9 cm, p=0.007) and the number of lapses (+2.4, p=0.019) during alcohol hangover. Total sleep time was significantly reduced in the alcohol hangover condition. Total sleep time had a moderating effect on ∆SDLP (hangover – control), in that subjects who slept less hours showed a larger SDLP difference between the hangover and control condition. This difference however was not seen for the ∆ number of lapses during alcohol hangover.

Conclusion: Driving during the hangover state is significantly impaired, despite that BAC readings are zero. A combination with reduced total sleep time further worsens driving performance.
INVESTIGATING SOMNOLENCE SELF-ALERTING BY TRUCK DRIVERS USING A NATURALISTIC DATA COLLECTION APPROACH

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Index terms— Somnolence, naturalistic data, truck, distraction, alert.

1. PROBLEM SCOPE
The link between drowsy driving and roadway crashes is well understood: when drivers become drowsy, reaction time slows, situational awareness decreases, and judgment is impaired [1], [2]. Drowsy driving can be a result of poor sleep quality/quantity and long work hours, which are conditions prevalent in commercial vehicle (truck) operations [3]. Recent data from the U.S. Department of Transportation indicate that approximately 1,000 people died each year in the U.S. in drowsy driving-related crashes, though this number may be significantly under-reported [4].

2. TRUCK STUDY RESULTS
A study by Toole et al. [5] used naturalistic driving data collected from truck drivers to investigate crash risk and mobile device use. The data set involved 100 truck drivers, each driving company trucks for approximately four weeks in normal revenue-producing deliveries.

Toole et al. [5] were interested in the risk of involvement in a safety-critical event, which includes crashes and near-crashes, relative to mobile device use for truck drivers. As identified by other studies (e.g., [6]), the risk associated with mobile device use is prominent with visual-manual components of the mobile device use task.

Toole et al. [5] also investigated the conditions during which truck drivers may engage a mobile device. In one analysis, mobile device was binned as a function of circadian lows and highs. The circadian rhythm cycle indicates the general times within a 24-hour period when people are more or less alert. Across the entire 24-hour period, mobile device use while driving occurred 10.4% of the time. Interestingly, the low morning bin (2 a.m. to 3:59 a.m.) was associated with 17.8% of all mobile device use, a 70% increase compared to the average.

3. DISCUSSION
This finding from Toole et al. [5] may be explained by the Yerkes-Dodson [7] curve, which demonstrates the relationship between performance and arousal. Performance on a task is low when arousal is either too high or too low, while optimal performance occurs at moderate levels of arousal. It is suggested that the truck drivers may have engaged in self-alerting via mobile device use as a countermeasure to the drowsiness associated with the circadian low.

This real-world finding underscores the need for somnoalert approaches that can seamlessly identify somnolence and provide effective alerts. Keys to success include: (i) The robust identification of somnolence in real-world conditions and (ii) Alerting approaches that are reliable and elicit the required response from the driver. Effectively meeting these two goals will be a challenge. However, as the crash data indicate, achieving these goals will have broad safety benefits.

4. REFERENCES


VALIDATION OF A DRIVING SIMULATOR WITH RESPECT TO DRIVER SLEEPINESS

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Index terms— Driver, simulator, real road, validation, driving behaviour, blink, subjective experience.

The aim of the study was to validate simulator driving against real road driving, with respect to driver sleepiness. The validation included subjective as well as objective sleepiness indicators.

Sixteen drivers (eight women) participated in the experiment. Each driver completed two driving sessions of 90 min on a real motorway: one during daytime and one at night. The same procedure was then repeated in an advanced moving base driving simulator (at another day), resulting in a total of four conditions: real road vs. simulator and day vs. night. The participants had a normal night of sleep before the experiment. The daytime condition was carried out in the late afternoon while the night-time condition took place after midnight, when the participants had been awake for at least 17 h.

Vehicle data, such as speed and lateral position, and physiological data (EEG, EOG, ECG and eye tracking data) was logged continuously during the driving sessions. In addition, the participants rated their sleepiness level on the 9-grade Karolinska Sleepiness Scale (KSS) every five minutes while driving. After each driving session, the participants were asked to fill in a questionnaire on their experience of the drive.

Four road segments, each four km long and separated by 14 km, were selected for analysis. Performance indicators included in the analysis were speed, left line crossings, right line crossings, blink duration, KSS and percentage road centre (PRC). The statistical analysis of the driving and driver behaviour involved a mixed model Anova with factors for session (day vs. night), segment (1-4) and study (real road vs. simulator).

The results showed that there were significant differences in KSS ratings, blink duration, PRC and speed between the simulator and the real road, while no such differences were found for left and right line crossings. The pattern of change with task progression was consistent between the simulator and real road for all investigated variables. Results from the questionnaire on subjective experience showed that the drivers found the real road more realistic and less boring than the simulator, and that it was more demanding to stay alert in the simulator. In conclusion, absolute validity was poor, but there was a relative validity with respect to driver sleepiness.
Drowsy driving is believed to be a major factor in many road crashes. Our aim here is to address some of the important issues about what drowsiness is, how it affects driving, and how its risks can be quantified under various circumstances. If we do not have a clear understanding of the nature of this problem, we cannot manage it successfully.

Drowsiness is the intermediate state between alert wakefulness and sleep. It is to be distinguished from fatigue with which it is often confused. Drowsiness is an unstable state which can fluctuate rapidly (in seconds) between different levels. It is associated with widespread mental and physical effects that portend and facilitate sleep onset. There is impairment of perceptual, cognitive and neuromuscular functions, including ‘dozing episodes’ when there is lack of awareness of the here-and-now, whether the eyelids are open or closed at the time. The dangers of drowsiness arise when it occurs involuntarily, at times when we should be alert, as when driving a vehicle.

Various subjective and objective methods have been used in sleep laboratories to measure what is often referred to as ‘daytime sleepiness’. However, all such measurements are partly situation-specific. They can seldom be relied upon to provide an accurate measure of a person’s tendency to doze off under different circumstances and at other times.

However, a driver’s level of alertness/drowsiness can be measured continuously while driving. There are several systems currently available or have been proposed for this. Some are based on EEG analysis, others on video cameras detecting eyelid closure. A new system uses infrared reflectance oculography to measure the velocity and duration of eyelid movements. These systems are described briefly. Currently there is no consensus about how drowsiness should be measured and who is too drowsy to drive.

The risks of drowsy driving can potentially be managed by better driver education and the judicious use of technology for monitoring the alertness/drowsiness of at least some drivers.