2009

International Conference on Fatigue Management in Transportation Operations:

A Framework for Progress

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Method and apparatus for generating an indication of a level of vigilance of an individual. US patent # 7435227

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Keynote Speaker: Senator Richard T. Moore, Massachusetts State Senator and Senate Chairman of the Committee on Health Care Financing

THURSDAY PROGRAM SCHEDULE

Closing Plenary Session: Cross-Conference Evaluation

Keynote Speaker: Michael Quinn Patton, Ph.D., Former President of the American Evaluation Association

FAA Modal Session

FMCSA Modal Session

Hotel Floor Plan

Conference Sponsors

back cover
Deborah A. P. Hersman was sworn in as the 35th Member of the National Transportation Safety Board on June 21, 2004.

Since her appointment to the Board, Member Hersman has been the member on scene at 13 major transportation accidents and has chaired a number of public events hosted by the Board. In October, 2008, she chaired a two-day public hearing on an accident in Victoria, TX involving a motorcoach that did not comply with the Federal Motor Vehicle Safety Standards. In September 2006, she chaired a two-day public forum on motorcycle safety. In July, 2006, she chaired a two-day public hearing investigating the February, 2006 fire on board UPS Airlines flight 1307. She also chaired a three-day public hearing in June, 2005, on the Jefferson City crash.

Member Hersman holds a commercial drivers license with passenger, school bus, and air brake endorsements. She successfully completed a motorcycle basic rider course and holds a motorcycle endorsement. Member Hersman is a certified Child Passenger Safety Technician. She has also completed the 40-hour HAZWOPER (Hazardous Waste Operations and Emergency Response Standard) training course.

Before joining the NTSB, Member Hersman was a Senior Professional Staff Member of the U.S. Senate Committee on Commerce, Science and Transportation from 1999 to 2004 where she was responsible for the legislative agenda and policy initiatives affecting surface transportation issues, including economic and safety regulation of railroads, trucks, buses, pipelines, and hazardous materials transportation. Prior to that appointment, she served as Staff Director and Senior Legislative Aide to Congressman Bob Wise of West Virginia from 1992 to 1999.

Member Hersman earned Bachelor of Arts degrees in Political Science and International Studies from Virginia Tech in Blacksburg, Virginia, in 1992, and a Master of Science degree in Conflict Analysis and Resolution from George Mason University in Fairfax, Virginia, in 1999. She is married and is the mother of three sons.
Fatigue Management and Individual Change
Enacting/Implementing Change (Track C)

Shift work, night work, irregular work schedules, unpredictable work schedules, and time zone changes continue to be commonplace. Clearly, challenges to the human circadian system within the transportation industry are here to stay. Effective strategies to reduce risk and improve safety partly involve change. This session includes presentations that describe some individual responsibility toward reducing at-risk behaviors.

Session Chair: Howard Leaman, M.D.
Intermountain Sleep Disorders Center

Dr. Howard Leaman is a physician specializing in the effects of sleep issues on alertness and performance at work. His focus is on primary sleep disorders, shift work, and circadian factors that have been shown to affect health, productivity and safety. He practices at the Intermountain Sleep Disorders Center in Salt Lake City, and has published on Commercial Driver sleep apnea issues and consulted with companies on fitness for work. Dr. Leaman is board certified in Sleep Medicine and in Occupational Medicine.
Objective Sleepiness predicts performance on a hazard perception simulator task.

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Objectives: Sleepiness is the major contributor to at least 20% of all road crashes. Sleepiness-related crashes are likely to be more severe, more often fatal, and more often involve young drivers, than other types of crash. Safe driving is a complex task, in which drivers require higher-order perceptual and cognitive skills to interact safely with the traffic environment. Hazard perception (HzP) is a critical driving skill. HzP requires scanning of the road environment, fixation on appropriate stimuli, and a ‘holistic’ interpretation of the salience of hazards. HzP latency is the time taken to detect and respond appropriately to a road hazard. Unlike vehicle control skill, hazard perception is reliably related to crash risk (see Horswill & McKenna, 2004 for a review), and a number of states now mandate a hazard perception test as part of licensing for novice drivers. Sleepiness can produce deficits in attention, vigilance and information processing. The impact of sleepiness on hazard perception skill is not known.

Methods: Two groups of 32 participants (aged 18-30) completed a 90-minute version of the Queensland Hazard Perception test (QHPT; a PC-based, real video, simulator task), a simple reaction time (RT) test and a hazard change-detection test on one of two occasions. One test session took place in the laboratory at 10am (low sleepiness), the other at 3am (high sleepiness). Subjective sleepiness was assessed by the Karolinska Sleepiness Scale at intervals throughout the test session. Objective drowsiness (eye-blink velocity) was assessed continuously with to provide a Johns Drowsiness Score (JDS; Optalert system) for each minute on the task.

Results: Participants were subjectively and objectively sleepier during the night-time test session. Mean JDS score was a significant predictor of mean QHPT score across the test period ($\beta=0.36, p=.005$). Driver experience (km/year driven), Epworth Sleepiness Scale, Pittsburgh Sleep Quality Index, Age, Gender and KSS at the start of the session were not significant predictors of performance. A significant correlation was found between simple reaction time and JDS score during the RT test period ($r=0.38, p<.01$). This relationship was not found for the hazard change detection task.

Conclusions: Previous studies have determined a relationship between sleepiness and simulator parameters such as lane excursion. This is the first study to demonstrate a relationship between objective drowsiness, indicated by an eye-blink velocity measure, and performance on a HzP task. The development of education and training interventions to improve HzP in drivers is critical. These data suggest that sleepiness can directly impact on HzP skill. As such, impairment of HzP when sleepy is clearly a potential contributor to road crash, particularly in the early morning hours. It may be important to develop specific sleepiness and fatigue management strategies for new drivers, and for these strategies to be incorporated with existing interventions designed to improve driving skills. The potential role of HzP training in reducing sleepiness-related driving risk remains to be determined. Interventions to reduce sleepiness in inexperienced drivers, and the potential of training to improve HzP skill, should be pursued.
Internet-Based Driving Tips for Commercial Motor Vehicle Drivers

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Rebecca L. Olson, Virginia Tech Transportation Institute, rolson@vtti.vt.edu
Santosh Gupta, Virginia Tech Transportation Institute (formerly), gupta.santosh@meddcl-i.com
Martin Walker, Federal Motor Carrier Safety Administration, martin.r.walker@dot.gov

Objective: The goal of this research was to develop a Driving Tips website to be used by Commercial Motor Vehicle (CMV) drivers and CMV fleet safety managers to highlight common large-truck driving errors and provide tips on avoiding such errors. The website is hosted on the Federal Motor Carrier Safety Administration website and is accessible to the public. The website is intended to be used as a supplemental driver training tool and is not intended to replace any of the classroom or on-road training methods that are currently being used. It contains real-world video clips of CMV drivers who were recorded making various driving errors through a naturalistic driving study conducted by the Virginia Tech Transportation Institute. The objective of the project was to provide drivers with compelling information to promote safe driving through the Driving Tips website with support from the real-world video clips.

Approach: Project tasks included a literature review to identify key elements necessary to develop effective driver training information that would be delivered via the Internet. Literature review topics included: website usability guidelines, driver error, driver training, and naturalistic data collection. The literature review resulted in information about specific driver errors along with preventive measures or driving tips. A focus group of subject-matter experts, including CMV fleet safety managers, who will be the end users of the website, was also conducted. The goal of the end-users focus group was to maximize the usability of the driving tips content. Based on feedback from the subject-matter experts, revised web content was developed that included key information such as the importance of each tip and “did you know” facts.

Results: The final Driving Tips website content includes seven main error categories and 27 driving tips. The seven error categories are: Too Fast for Conditions, Unfamiliar Roadway, Inadequate Surveillance, Driver Fatigue, Driver Distraction, Following Too Closely, and Inadequate Evasive Action. Within the error categories, there are 27 driving tips to help drivers avoid these errors. To support the driving tips, video from a heavy-vehicle naturalistic study is used to illustrate the errors. The final Driving Tips website is scheduled to “go live” in 2009.

Conclusion: It is important to note that the Driving Tips website is not meant to replace driver training material that is presently available. Rather, the purpose of the website is to support and supplement these other driver training materials primarily through the integration of naturalistic video. It is believed that the website, and the innovative approach of integrating naturalistic video, will resonate with CMV drivers and fleet safety managers and provide a compelling approach to teaching the importance of safe driving.
OVERCOMING BARRIERS TO COMMERCIAL DRIVER SLEEP APNEA SCREENING

Howard Leaman, MD,* Intermountain WorkMed, Intermountain Sleep Disorders Center, HowardLeaman@comcast.net
Gerald P. Krueger, Ph.D., Krueger Ergonomics Consultants, JerryKrueg@aol.com

Background and objective:
Obstructive Sleep Apnea (OSA) is a condition, under diagnosed in medical practice, which poses a significant hazard for commercial drivers and for public safety. Screening commercial drivers for OSA during their Commercial Driver Medical Examination (CDME) has been proposed to the Medical Review Board at the U.S. Department of Transportation Federal Motor Carrier Safety Administration (FMCSA). This paper outlines the steps taken to implement driver screening for OSA at Intermountain WorkMed, a 10-clinic Occupational Medicine Clinic Group in Utah that performs about 6000 CDMEs each year. This presentation will describe the experiences of the multi clinic group that began screening for sleep apnea in 2000; will describe barriers to OSA screening; and it will identify employer, and driver reactions to screening, results of screening, and effective solutions to barriers encountered.

Approach/Method
In December of 1999 a driver examined at one of the Intermountain WorkMed clinics was involved in a fatal crash in which the probable cause was that the driver fell asleep at the wheel. Accident information was collected, and Obstructive Sleep Apnea was identified as a likely contributing cause of the crash.

Medical providers were trained in identification of Obstructive Sleep Apnea, and a screening strategy was identified. All commercial drivers examined at 10 clinics were screened for OSA. The specific provider implementation issues, barriers, training, and screening strategies will be described and discussed.

Results:
The presentation will describe driver reactions and driver-medical provider conflicts in response to screening positive, and to being identified as having obstructive sleep apnea.
Resistance to screening from drivers’ employers will be described, as will steps taken within the community to promote awareness and acceptance of screening in this group. These steps included FMCSA provided outside support, employer education, and industry support.

Four different sleep laboratories were involved. Sleep physician and laboratory response to these patients was initially a significant barrier to diagnosis and treatment of referred commercial drivers. These issues and solutions will be detailed, and the outcome of polysomnography in 50 drivers referred to one sleep center will be presented.

Conclusion:
Obstructive Sleep Apnea in drivers of Commercial motor vehicles has already been identified as a significant risk to driver and public safety. Screening drivers for this condition is currently being considered by the FMCSA Medical Review Board. This paper presents results of a multi-clinic sleep apnea screening program from the perspective of medical providers, drivers, and employers, covers program implementation, barriers, and solutions experienced.
Addressing Obstructive Sleep Apnea in Commercial Drivers

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Obstructive sleep apnea (OSA) is a highly prevalent disorder in commercial drivers. It results in performance impairment. There are also substantial data, albeit in passenger car drivers, that it is associated with an increased risk of crashes. Since there is a simple, safe device available to treat this disorder in which compliance to therapy can be monitored, there is a simple intervention to reduce crash risk. Based on these data, an expert panel recommended to the Federal Motor Carrier Safety Administration that identifying and treating OSA in commercial drivers should be a high priority. The principles of the recommendations are: a) commercial drivers at high risk for OSA should be identified based on level of obesity (obesity is a major risk factor for OSA); b) identification of high-risk drivers should not be based on self-report which is unreliable; c) the goal of the strategy should be to identify and treat drivers for OSA in a timely fashion, rather than simply limiting their ability to work, except in certain limited circumstances; and d) once treated, making continued certification for driving dependent on documentation of compliance to therapy. These recommendations will address a common public health problem in commercial drivers that should not only impact on crash rates but other aspects of the health of the driver.
Panel: Fatigue Risk Management Systems (FRMS) Business Case
Model: Operation Healthy Sleep, Harvard Medical School
Evaluation of Fatigue Risk Management System Interventions (Track F)

A single fatigue intervention case, Operation Healthy Sleep, will be presented by Dr. Steven Lockley and colleagues from where Operation Healthy Sleep was an occupational screening and treatment program for obstructive sleep apnea implemented in a city police department. Following the presentation, an evaluation expert will engage audience participants in reviewing and discussing key evaluation issues illustrated by the case with particular attention to factors that can affect the use of evaluation findings, including implications for acting on the findings and further evaluation studies that, in aggregate over time, can affect policy and practice in an entire sector.

Session Chair: Michael Quinn Patton, Ph.D.
Former President of the American Evaluation Association

Michael Patton, Ph.D. is an organizational development and program evaluation consultant for Utilization-Focused Evaluation. He is former President of the American Evaluation Association and author of Utilization-Focused Evaluation (4th ed. Sage, 2008). He is on the faculty of The Evaluators’ Institute, George Washington University and conducts workshops and lectures around the world.
Objective: To present evaluation results and describe key design decisions that occurred during the occupational screening and treatment program related to fatigue levels of occupations involving shiftwork.

Summary: Operation Healthy Sleep was an occupational screening and treatment program for obstructive sleep apnea implemented in a city police department. Police officers work particularly demanding schedules as the need for 24/7 policing often requires frequent overnight shifts and long hours, leading to acute and chronic sleep deprivation in addition to misalignment of circadian rhythms. As police officers are predominantly male and are at increased risk of being overweight compared with age-matched controls, the research team hypothesized that they were at high risk for having obstructive sleep apnea (OSA). The intervention involved implementing a fatigue management program - ‘Operation Healthy Sleep’ - the central component of which was occupational screening for and treatment of OSA coupled with sleep health education. The overall goals of this program were to reduce the adverse consequences of fatigue on officers’ health, safety, and performance.

The impact of Operation Healthy Sleep was tested using a randomized controlled design; half of the districts in a major city police department were provided with the program and half were not. Districts were paired according to officer number and workload prior to randomization. Officers attended a 30-minute educational presentation on sleep hygiene, caffeine use and the symptoms, consequences and treatment of OSA. Following the presentation, officers who volunteered to be part of the study completed a survey which included an assessment of OSA risk. Officers with high OSA risk were then examined by a sleep medicine physician at a temporary occupational clinic and, if warranted, were further assessed using a portable device for two nights at home. Continuous Positive Airway Pressure (auto-titrating) therapy was offered to officers if their Apnea-Hypopnea Index (AHI) was >10/h or >5/h plus additional pre-defined symptoms.

Dr. Michael Patton, Mr. O’Brien and Dr. Steven Lockley will present the intervention’s evaluation results and illustrate the key decisions concerning the program’s design that were made along the way. Following the presentation, audience participants will be engaged in an interactive discussion. Dr Patton will discuss key evaluation issues portrayed by the case with particular attention to factors that can affect the use of evaluation findings. This will include implications for acting on the findings and further evaluation studies that, over time, can affect policy and practice in an entire sector. This session will provide audience participants with an inside feeling of what it is like to perform an evaluation in a real setting.
Cross Modal Fatigue Status and Unresolved Methodological Issues
Define and Measure Fatigue Problem (Track A)

This session will serve to introduce the Define and Measure Fatigue Problem track, review critical research issues affecting fatigue research, and report on the status of fatigue research in various transportation modes, with specific emphasis on Aviation, Ground, and Rail.

Session Chair: Carlos Comperatore, Ph.D.
US Coast Guard

Dr. Carlos Comperatore earned a Master’s Degree in Cognitive Psychology from Florida Atlantic University in 1982 and a PhD in Psychology from Florida State University in 1987. His work in basic and applied sciences includes the study of brain processes underlying alertness and attention, biological clock processes, the use of melatonin to prevent jet-lag and shift-lag, and the development and implementation of Crew Endurance Management strategies and techniques for Army aviation units, Coast Guard (CG) cutters, CG small boat stations, CG air stations, and commercial maritime platforms. His publication vita includes articles in the Journal of Aviation, Space, and Environmental Medicine, the International Journal of Aviation Psychology, The Pineal Gland Journal, NATO’s Advisory Group for Research and Development, Physiology and Behavior, and the Journal of Brain Research. In recent years, Dr. Comperatore served in the capacity of senior Human Systems Integration staff at Johns Hopkins University, Applied Physics Laboratory, and worked on DoD acquisitions teams in the capacity of Human Systems Integration analyst for the NAVY Technology Team. In 2007, Dr Comperatore joined USCG HQs and currently serves as operations risk assessment analyst in the Office of Safety and Environmental Health.
Methodological Issues Associated with Measuring the Operational Impact of Fatigue in Aviation

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Objective: In June of 2008, the National Transportation Safety Board (NTSB) recommended that the Federal Aviation Administration (FAA) develop guidance, based on empirical and scientific evidence, to manage fatigue in aviation operations. The request for corrective action was spurred by recent fatigue-related mishaps such as the crash of Corporate Airlines flight 5966, the end-of-runway overrun by Delta Connection flight 6488, the off-runway excursion of Pinnacle Airlines flight 4712, and the 26 nm airport overshoot by Go! Flight 1002. The recommendation that any interventions be based on empirical and scientific evidence has raised methodological issues. What single measure or set of measures can be relied upon to accurately reflect and thus monitor pilot fatigue.

Methods: The scientific literature and numerous other resources were searched to explore the impact of fatigue on aviation safety. In addition, the suitability of various methodological strategies for measuring 1) the detrimental effects of fatigue on pilot performance and 2) the adequacy of any proposed counter-fatigue interventions were qualitatively evaluated.

Results: Several reports were found in which pilots’ perceptions about fatigue were summarized, and several others were identified in which fatigue-related changes in electroencephalographic activity were described. In addition, papers detailing the effects of fatigue on in-flight psychomotor vigilance lapses and subjective fatigue ratings were found; and a variety of publications discussing the impact of fatigue on pilots’ abilities to perform scripted simulator flight profiles and various laboratory assessments were located. However, it was not possible to find a single report that presented the effects of pilot fatigue on the performance of routine operational flight tasks, nor was it possible to find a comprehensive up-to-date report of the numbers of fatigue-related incidents and accidents in Part 135 and Part 121 operations. Furthermore, there appears to be no consensus on the manner in which pilot fatigue should be managed or the way in which pilot fatigue and performance should be monitored.

Conclusion: Although there is consistent evidence of fatigue-related problems associated with modern commercial and military aviation operations, there is no clear consensus on the best methodological strategy or strategies to mitigate aviator fatigue or to assess pilot operational performance in actual flight contexts on an on-going basis. Such a consensus will be required before the NTSB’s recommendation to the FAA can be fully realized. Several options deserve consideration, among which are computerized fatigue-prediction models, wrist-worn sleep/wake monitors, and more comprehensive analyses of flight operational quality assurance (FOQA) data.
Fatigue in Trucks and Cars: Large Truck Crash Causation Study

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Objective: The Large Truck Crash Causation Study was conducted jointly by the Federal Motor Carrier Safety Administration (FMCSA) and the National Highway Traffic Safety Administration (NHTSA) to discover causal factors and reasons for crashes involving large trucks.

Methods: A representative national sample of 963 large trucks involved in fatal and A or B injury crashes was investigated over a 33-month period in 2001-2003. The 24 study locations in 17 States were NHTSA’s Crash Dataworthiness System sites. A trained NHTSA contract crash researcher and an FMCSA funded State truck inspector began data collection as soon as possible after being notified of the crash. Data collected was based on interviews, a post-crash truck inspections, scene diagrams, and official documents including police reports, hospital records, and coroner investigations. Crash results were coded at NHTSA’s two zone centers, the coding was reviewed by two crash experts, and disputes about conclusions resolved by a national review committee.

Results: The LTCCS concluded that thirteen percent of all large truck drivers were fatigued at the time of the crash. In crashes between a single large truck and a single passenger vehicle (cars, pickup trucks, vans, sport utility vehicles) eight percent of the truck drivers and fifteen percent of the passenger vehicle drivers were coded as being fatigued. For truck drivers fatigue was found less often than traveling too fast for conditions, being unfamiliar with the roadway, and inadequate surveillance among driver related crash factors. Truck driver fatigue was found more often than feeling under work pressure, making an illegal maneuver, being inattentive, following too close, being ill, and using alcohol or illegal drugs.

Fatigue was found to significantly raise the risk of being assigned the critical reason for a crash among truck drivers, and to raise the risk even higher among passenger vehicle drivers who collided with large trucks.

Conclusion: Truck driver fatigue was found to be more common than one would believe if examining NHTSA’s FARS database and less common than NTSB data shows. Fatigue is strongly linked to increased risk of having a crash. Attacking the problem must involve sound regulation, strong enforcement, responsible management, increased use of technology, and modifying human risk taking behavior.
The Fatigue Status of the U.S. Railroad Industry: A Preliminary Analysis

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Objectives: The objective of this research is to provide a statistically representative, comprehensive and scientifically valid picture of fatigue among those railroad workers with primary responsibility for the safe movement of trains. That segment of the workforce includes train crews (locomotive engineers and conductors), dispatchers, signalmen and maintenance-of-way employees. Of these four groups, only maintenance-of-way employees are not subject to the Hours of Service Law.

Methods: Three previously published surveys on the work schedules and sleep patterns of dispatchers, signalmen and maintenance-of-way employees (Gertler and Viale, 2006a; Gertler and Viale, 2006b; Gertler and Viale, 2007), as well as a recently completed survey of train crews provided data for this analysis. The surveys were random samples of the four employee populations and provide a statistically representative snapshot of their sleep characteristics and work schedules. The Fatigue Avoidance Scheduling Tool (FAST), recently validated by Hursh, Raslear, Kaye and Fanzone (2008), was used to calculate effectiveness scores (inversely related to fatigue) from the survey data. The effectiveness scores were used to construct probability density functions and cumulative density functions for each of the four employee groups and selected sub-groups. Each employee group and sub-group was also characterized by summary descriptive statistics (mean, median, standard deviation, interquartile range) and hinge plots. Unique work schedule characteristics of particular groups (e.g., shifts for dispatchers) were the focus of separate analyses.

Results: Of the four groups of railroad workers, third shift dispatchers were the sub-group most likely to be working at reduced effectiveness. Hursh et al., found that accident risk was elevated by 21% for those working at an effectiveness of ≤70 (very fatigued). The present analysis revealed that 31% of the third shift dispatchers’ work period is at an effectiveness of ≤70. Relief dispatchers and extraboard dispatchers, whose schedules may vary from day to day, worked at this level for 7.3 and 8.6%, respectively, of their shift. Train and engine crews worked at reduced effectiveness a similar portion of their work periods. Of the 21 train and engine service employees whose first quartile effectiveness was ≤70, nine worked a third shift job. Signalmen and maintenance-of-way employees, with few exceptions, work a regular daytime schedule. Their mean effectiveness exceeds 90 (not fatigued) and only a small fraction of the signalmen experience effectiveness levels of ≤70. Analysis of start time variability indicated that a third of relief dispatchers are subject to four or more shift changes per week. Train and engine service employees who work road freight jobs do not have a fixed start time and experience a median start time variability of 7 hr vs. 0.5 hr for those with a regular start time.

Conclusion: Congress recently mandated fatigue risk management in the railroad industry. Effective management of fatigue risk requires a measurement of fatigue across the industry and identification of the greatest risks. The analysis described here provides the first comprehensive assessment of fatigue risk in the railroad industry and offers a means to identify the groups at greatest risk of fatigue while at work.

References
Incidence and Predictors of Fatigue-Related Aviation Accidents

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Objective: Crew fatigue is often cited as a safety issue in aviation due to scheduling factors, extended duty periods, and circadian factors such as jet lag. In spite of the many studies that have been conducted to understand risk factors associated with crew fatigue, extremely little is known about how often it contributes to aviation accidents and incidents. The present study analyzed 20 years of United States civil aviation accidents to determine the incidence of fatigue-related accidents and to evaluate several potential risk factors for fatigue-related accidents.

Methods: Data for the study came from the National Transportation Safety Board (NTSB) Aviation Accident Database, a census of all United States civil aviation accident data dating back to 1962. During the 20-year period between 1985 and 2004, there were 44,380 accidents, most of which involved general aviation operations (88.6%). Overall, fatigue was noted as a cause, factor, or finding in 198 accidents, representing 0.45% of all accidents. Almost half of fatigue-related accidents were fatal (48.5%) and fatigue-related accidents were nearly four times more likely to result in fatalities than non-fatigue-related accidents (OR = 3.89, 95% Confidence Interval: 2.94 – 5.15).

Chi-square analyses were conducted to determine whether the following variables were related to the incidence of fatigue-related accidents: hours flown in the last 24 hours, hours flown in the last 30 days, gender, age, light condition, time of day, aircraft category (airplane, helicopter, or other), and phase of flight. Continuous variables were grouped into categories to facilitate the analyses.

Results: All of the variables were statistically significant with the exception of gender and aircraft category. Both greater hours flown in the past 24 hours (> 4 hours) and greater hours flown in the last 30 days (> 25 hours) were related to the incidence of fatigue-related accidents. Age was also found to be a risk factor, with the youngest pilots (< 35 years) experiencing the highest proportion of fatigue-related accidents. As expected, there was a higher proportion of fatigue-related accidents when skies were dark and during nighttime hours. Specifically, the hours between midnight and 6:00 am were most associated with fatigue-related accidents. Finally, there was an association between fatigue-related accidents and the accident phase of flight, with the highest incidence of fatigue-related accidents associated with cruise and approach/landing/go-around phases of flight.

Conclusion: Overall, the risk factors that were significantly associated with fatigue-related civil aviation accidents in this study are consistent with previous research in this area. Perhaps the most surprising finding was the small overall proportion (0.45%) of fatigue-related accidents in the sample. This is likely due to the fact that fatigue is notoriously difficult to evaluate in accident investigations since there are no definitive markers to indicate that a pilot was impaired by fatigue at the time of a crash. In recent years, NTSB staff members have established a standardized methodology for gathering and evaluating fatigue-related evidence, and there is work underway to evaluate the validity and usability of this methodology.
Planes, Trains, Boats, and Trucks: Supporting Technologies Across Transport Platforms
Supporting Technologies (Track D)

As researchers, we often focus on specific transportation domains. Whether that may be aviation, rail, marine or heavy vehicles, we sometimes lose sight of important and related new developments in other transportation modes. This session will highlight some key research across transport platforms. Presentations will be made for aviation, with a discussion of flight crew scheduling; in rail, to describe locomotive alerter assessment; in marine, to describe fatigue risk; and in heavy vehicles, to highlight a fatigue management survey of truck drivers.

Session Chair: Martin Walker, Ph.D.
Federal Motor Carrier Safety Administration

Martin Walker has been the Chief of FMCSA’s Research Division since 2002. He is responsible for developing FMCSA’s research agenda through the Agency’s unique program development methodology which combines stakeholder interests with Agency goals and priorities and translates them into projects to be funded annually. Martin has more than 24 years of experience as an Operations Research Analyst, 19 of which were in the Army.
Flight crew scheduling based on fatigue risk guidance

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Objective: In the interest of enhancing aviation safety, Jeppesen and Boeing have begun work with providers of fatigue modeling, airlines, and regulators with the objective of integrating bio-mathematical models of fatigue into flight crew scheduling software. The work is aimed at establishing strategies for reducing and controlling predicted fatigue in the planning phase, but also to build a closed-loop FRM component, of a larger FRMS framework, that complements and in the longer run enables replacement of prescriptive flight duty limitations.

Approach: For large airlines the process of crew scheduling and rostering is complex, requiring purpose-built optimization software. Historically, this software has included programmatic rules ensuring compliance with prescriptive flight, duty, and rest time regulations. These rules are considered along with economic and logistical factors for an optimal scheduling solution.

The approach in this work has been to integrate bio-mathematical models of fatigue into standard crew planning software in such way that fatigue and associated risk is considered throughout the optimization. The modified system has then been used to run simulations on various scenarios to investigate the effects from pricing fatigue along with all other objectives for the optimizer.

Results: The simulations have proven that bio-mathematical models of fatigue can be integrated into standard crew planning software in such a way that:

a) the average predicted fatigue in the final rosters can be reduced
b) actual risk from a task requirement, as well as from an individual perspective, can be targeted specifically and reduced
c) current flight time limitations can be replaced by limits on the fatigue index itself
d) various models can be technically integrated in a way that ensures coherent application across airlines
e) the underlying science, aimed at improving the models, can benefit from follow-up data systematically collected from real crew schedules
f) the trade-offs paid, in terms of productivity and other costs for the airline, for achieving the increase in safety can be measured and reasoned upon in detail.
g) vulnerabilities and excluded opportunities based on current flight/duty rules can be identified enabling regulators to adjust current flight time limitations but also for airlines/unions to improve their labor agreements.

Finally, leveraging available and anticipated future technologies for assaying in-situ fatigue in flight operations, a closed-loop FRM system is outlined to be built on top of the modeling/scheduling systems demonstrated. Such a holistic system could be used to develop FRM-based schedules, to provide safety assurance to regulators, and to advise individuals on healthy choices for personal fatigue management which should positively impact pilot wellness and systemic safety.

Conclusion: Bio-mathematical fatigue modeling combined with powerful flight crew scheduling optimization engines brings scientific FRM principles to application and allows for addressing safety in a much more nuanced and powerful way than today. One possible starting point would be to use these techniques for investigating vulnerabilities in existing regulations. These capabilities will be further enhanced as various models undergo rigorous validation in actual operations and can provide a key tool for scheduling within a comprehensive FRM system.
Locomotive Alerter Technology Assessment

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Objective: Virtually all US main line passenger and freight locomotives are now equipped with some type of alerter or deadman system. However, between 1996 and 2002, fatigue and alertness accidents occurred on average three times per year, approximately 70% of them in alerter equipped locomotives. Although PTC has recently been mandated for Class I railroads, we believe that technology improvements in locomotive alerters are still needed during the transition period to full compliance and also since crew fatigue management training and scheduling has not eliminated fatigue accidents, and single crew operations are being considered. A window for improvement will soon open as older locomotives are replaced with more fuel efficient models.

Approach: We review the technical history of locomotive alerter logic, the evolution of Federal alerter regulations, NTSB and FRA/CAWG analyses of fatigue/alertness accidents, recent UK and Australian and US assessments of potential new alerter technologies, Automatic Behavior Syndrome in sleep deprived individuals, industry stakeholder views of alerter performance problems, and the scientific, technical, operational, safety and cost issues defining the case for further improvements.

Results: The pre-emptive manual reset feature of conventional activity based alerters - not required by 49 CFR 238 - remains their most significant conceptual design flaw. This feature encourages the development of automatic pre-emptive resetting behavior, rendering the alerters ineffective in warning of micro-sleep onset.

Conclusion: We argue logic changes in software based alerters could greatly reduce pre-emptive automatic resetting behavior, and make the alerter function more reliably as a psychomotor vigilance probe, visual distraction detector, and as a job aid. There are important trade-offs to be made between system sensitivity and operational acceptability. Visual enunciators should be better positioned to promote outside vigilance. New logics should be evaluated by experienced engineers, initially in a locomotive simulator under realistic operational conditions.

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Objective: The navigation of large, high environmental risk vessels including LNG, crude oil, refined product, and chemical tankers to and from the Gulf of Mexico through the narrow channels of the Calcasieu Ship Channel to the ports on Lake Charles requires marine pilots who are not only skilled and experienced, but are also alert and attentive. The requirement that these pilots be constantly alert and attentive, and unimpaired by fatigue, is a challenge to achieve because of the round-the-clock, irregular and unpredictably-timed requirement for pilot-assisted vessel movements in the Port of Lake Charles.

Approach: Using the Circadian Alertness Simulator (CAS™), a scientifically-validated transportation operator fatigue risk model, the fatigue risks associated with the balance between the number of Calcasieu Ship Channel vessel movements per month and the number of available fully qualified pilots was investigated. A board scheduling algorithm BoardSim™ was used to assign pilots to each vessel movement by drawing pilots into vessel movement duty from the top of the board and adding each pilot when they finished an assignment to the bottom of the board. As each pilot was drawn into a duty period from the top of the board, all other pilots that were off-duty and hence on the board were moved up one position on the board so that the 2nd on call became the 1st on call, and the 3rd on call became the 2nd on call etc. This was designed to match the ‘board’ form of scheduling that is currently used by Lake Charles Pilots, Inc. To generate the pilot on-duty, off-duty schedules the board algorithm was run for the actual vessel movements of each month with a series of different pilot complements ranging from 10 pilots to 30 pilots. The smaller the pilot complement, the shorter were the average off-duty periods for each pilot between duty assignments. To determine the fatigue risk associated with each simulated pilot complement, the resulting on-duty, off-duty patterns for each pilot were analyzed using CAS. The parameters used to assess risk were the Unassigned Vessel Movements, Cumulative Fatigue Risk Score, the Percent Bridge Time in Mild Sleepiness, and the Percent Bridge Time in Significant Sleepiness.

Results: When the port was operating with 275 vessel movements per month a baseline plateau of core fatigue risk associated with nocturnal operations was reached with pilot complements of 17 or greater. However when the pilot complement was progressively reduced below 17 there was an exponential increase in the Percent Bridge Time in Significant Sleepiness reflecting the impact of shortened rest periods between vessel movements. This established 17 pilots as the minimum acceptable complement for fatigue risk management at this level of vessel movements.

Conclusion: The pilot complement level is an important determinant of fatigue risk which can be optimized by the use of fatigue risk models.
Objective. Identify best practices for managing fatigue in Teamster drivers.

Study Design. A survey instrument was developed and to achieve the goal in two ways: (1) by reviewing the experiences and practices of a large Teamster cohort of LTL drivers, and (2) by comparing fatigue management experiences and behaviors of the safest Teamster drivers who met MFCA criterion for having driven a million or more miles accident free (“MMs” who made up 27.6% of Teamster drivers in MFCA at the time of the survey), to the experiences and behaviors of the 72.4% of Teamster drivers who had not (yet) met this safety benchmark (i.e., “non-MMs”).

Survey Methods. The Truck Driver Fatigue Management Survey was an 11-page scannable survey mailed to 5741 Teamster drivers (2741 MMs and 3000 non-MMs). Sampling was adjusted to ensure proportional representation from each MFCA company, and responses from at least 1000 million milers (MM) and 1000 non-million milers (non-MM) drivers.

Results: A total of 2280 completed surveys were returned (1128 MMs and 1152 non-MMs). Stratified random sampling yielded weighted estimates of means and percentages. Half (49.8%) of drivers had a BMI in the obese range. 5.6% indicated being diagnosed as having a sleep disorder (89% sleep apnea; 67% treated). Proportionally more non-MMs than MMs reported driving at night and varied work start times. Most drivers (69%) recognized that daytime sleep was not as restful as nighttime sleep, and understood that disturbed daytime sleep was due to the circadian clock, along with light and noise. Only 26% of drivers used appropriate strategies for ensure good daytime sleep. MMs and non-MMs did not differ in sleep duration on non-work days (M=8.1h), but did sleep less on work days (M=6.9h). Depending on the fatigue symptom, 33%-66% of drivers reported experiencing fatigue that varied from a noticeable problem to a major problem, on half or more of their trips. The majority (63%) understood the risks posed by driving drowsy, and 51%-65% reported experiencing yawning, feeling drowsy, eyelids heavy and struggling to be alert while driving. Fewer reported serious drowsiness (e.g., nodding off/falling asleep [13%], having a near miss [9%], running off the road [6%], colliding with something [3%]). More non-MMs than MMs indicated experiencing serious drowsiness while driving. 89% of drivers identified “amount of sleep before the trip” as the most relevant factor to fatigue while driving. A majority identified 12 fatigue management strategies—6 involved activities while driving and 6 involved stopping. The primary reasons for stopping were bathroom (67%) and sleep (66%). The average driving time before a break was 3.7h and the average length of the break was 45min. MMs took a driving break sooner than non-MMs.

Conclusions: Teamster drivers reported the following practices as critical to their coping with fatigue from night driving and irregular schedules. Obtain adequate sleep before driving and on days off duty. Take rest breaks and naps to help manage fatigue and sleepiness. Optimize the sleeping environment. Recognize the warning signs and risks of drowsy driving. More predictable and regular work schedules are safer.

Acknowledgment: Study supported by Federal Motor Carrier Safety Administration and Motor Freight Carrier Association. We thank Bill Rogers for suggesting the study; the International Brotherhood of Teamsters for encouraging their members to participate in the survey; and the companies comprising the Motor Freight Carrier Association.
Luncheon Address

**Keynote Speaker:** Audrey Reichard, M.P.H.
*CDC/NIOSH*

Audrey Reichard is an epidemiologist in the Division of Safety Research at NIOSH. Her research activities largely focus on describing occupational injuries using surveillance databases. Much of current research efforts focus on emergency medical services workers. In addition to her research, she serves as Coordinator of the NIOSH National Occupational Research Agenda efforts in the Transportation, Warehousing, and Utilities (TWU) Sector. In this capacity she has contributed to the development and oversight of an agenda to prioritize research and activity goals leading to the reduction of injuries and illnesses in the TWU industries.
Pharmaceuticals for Sleep and Wakefulness: Impact on Worker Safety
Health-Related/Pharmacological Issues (Track B)

Pharmaceuticals (both prescribed and OTC) are widely used for their sleep- and
wake-promoting properties. In addition, many pharmaceuticals taken for other
purposes may negatively impact alertness. No industry should be more concerned
about the potential impact of pharmaceuticals on alertness and safety than those
with oversight of transportation services. We will explore some of the positive and
negative effects of pharmacotherapies as they relate to cognition and wakefulness,
in the context of transportation.

**Session Chair:** Dana L. Thomas, M.D., M.P.H.

*US Coast Guard*

Dana Thomas serves as a Commander in the US Public Health Service, where she
has been billeted to the US Coast Guard since July 2005. She is the Chief,
Occupational Medicine and the Program Manager for Occupational Health
(surveillance and evaluation) for more than 86,000 USCG Active Duty, Reserve,
Civilian and Public Health Service Officers. Dr. Thomas has had significant experience
working at the USCG’s National Maritime Center, in the Medical Evaluation Branch,
reviewing Merchant Mariners Physical Examination Reports. She currently serves as
the medical advisor to the Assistant Commandant for Marine Safety, Security and
Stewardship who responds to mariners’ appeals for credential denial based on
medical concerns.
Pharmacological Management of Fatigue

John Caldwell*, Fatigue Science, john@archinoetics.com

Objective: Operator fatigue associated with long duty hours, night work, and rotating work/rest schedules has been estimated to play a role in 15-20% of transport mishaps. Although a great deal of attention is now being focused on countering fatigue-related problems in operational contexts, the fact remains that most people require 8 full hours of sleep during every 24 hours in order to be optimally alert, and even employees who have been involved in shift work for years experience difficulties with night work and ever-changing sleep/wake cycles. Non-standard work periods challenge the basic physiological capabilities of humans. Shift workers not only experience difficulties remaining alert at night when nature intended them to be asleep, but they experience difficulties sleeping during the day when nature has programmed them to be alert. As a result, increasing homeostatic sleep pressure contributes to levels of fatigue that threaten both safety and productivity. At present, it appears that pharmacological interventions offer the greatest promise for overcoming natural biological/physiological limitations, and there is evidence that at least some of the currently available compounds should be more strongly considered for operational use. This is particularly the case with select short-acting hypnotics.

Methods: Several studies were reviewed to establish the utility of stimulants and hypnotics for the maintenance of wakefulness and performance in operationally-relevant settings. The studies on short-acting hypnotics received particular attention.

Results: The available data indicate stimulants can temporarily maintain wakefulness and performance despite significant sleep loss, and hypnotics can optimize sleep that otherwise would be compromised by environmental or circadian factors. Optimizing sleep quality with hypnotics often leads to safer subsequent performance by removing the sleep pressure that is a primary contributor to the fatigue equation. From a socio-political standpoint, there is significant resistance against the use of these pharmacological agents to manipulate human capabilities, but there is substantial evidence that artificially enhancing alertness poses less of an immediate safety threat than untreated fatigue.

Conclusion: There is sufficient evidence that select medications can temporarily sustain performance without adverse effects, and that the use of these medications is likely a better alternative than failing to treat the fatigue that results from forcing personnel to fight their basic physiological propensities unaided. Such medications should be included in comprehensive fatigue risk management systems, at least on a limited basis.
Stimulants, Hypnotics, Nutritional Aids, Medications, and Other Chemical Substances: Their Effects on Driving Alertness and Performance

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Background and Objective: Commercial drivers consume numerous chemical substances, including prescription and self-administered medications, stimulants, hypnotics, and a proliferation of nutritional aids, each of which singularly or in combination can affect driving alertness, fatigue, performance, and driver health. Our Transportation Research Board (TRB) Synthesis report, done for DOT’s Federal Motor Carrier Safety Administration, informs commercial truck, bus and motorcoach drivers, their safety managers, and public safety policy makers about the effects of a myriad of chemical substances on driver performance and health.

Approach/Method: In the TRB Synthesis study, we reviewed the scientific literature, conducted structured interviews, administered survey questionnaires to motor carrier officials and to medical providers who perform Commercial Driver Medical Examinations (CDME).

Results: In this presentation we will:

1. Highlight research findings on chemicals that affect driving alertness, increase the risks of performance degradation and to driver health. Review of numerous reports scattered throughout the literature attempts to discern what is known from historical and more recent stimulant and hypnotic drug research studies, to determine effects of nutritional aids on performance; and to assess medical research about prescription and over-the-counter medications, as they have potential to affect worker cognitive performance, alertness, fatigue, and other elements of performance of transportation equipment operators.

2. Outline what was found in terms of operational safety policies regarding chemical substances as adhered to in different modes of ground transportation.

3. Present information gained from surveys of motor carrier operational personnel in an attempt to outline roles of commercial driver managers, safety officers, occupational health, human resources, and highway safety enforcement personnel regarding truck and bus/motorcoach driver use of chemical substances.

4. Review information gleaned from questionnaires administered to a sampling of medical providers who perform medical qualification examinations of commercial drivers. Outline issues confronting these medical professionals, who are expected to examine drivers, and qualify (or not qualify the drivers) based on FMCSA rules and guidelines. As survey outcomes, identify educational, administrative and further research needs.

Conclusion: We will highlight the research questions that yet remain to be answered; and make research recommendations that scientific and safety administration officials should pursue regarding chemical substances to ensure healthy and safe performance on our roadways.
MEDICAL PROVIDER PRACTICES REGARDING DRUGS AND
COMMERCIAL DRIVER CERTIFICATION

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Disorders Center, HowardLeaman@comcast.net
Gerald P. Krueger, Ph.D., Krueger Ergonomics Consultants, JerryKrueg@aol.com

Background and objective:
Medical providers are frequently faced with decisions to qualify (or not qualify) drivers who admit to taking medications and substances, most of which are not covered in published guidance from the US Department of Transportation, Federal Motor Carrier Safety Administration (FMCSA). These medications are frequently associated with decrements in alertness or sleep disruption. Little is known about examiner practices as it relates to drivers’ use of medication and steps to qualify (or not qualify) the driver. This presentation reports survey work done for a Transportation Research Board Synthesis study regarding commercial drivers.

Approach/Method:
A survey of two groups of physicians, those who routinely performs Commercial Driver Medical Examinations (CDME), and another group who do not.

(1) Twelve classes of pharmaceuticals (and over the counter preparations), 69 different drugs were queried. On each drug, the medical provider was asked to identify what action they would take. The range of options were: Never approve; Approve (only with note from treating MD); Approve with objective testing; Approve with detailed history from driver; Approve only if prescription meds are taken 8 hours or more prior to driving; Usually/Always approve; I do not ever see this drug; or I am not familiar with this drug.

(2) In addition, providers were asked about their activities in advising drivers about medication and fatigue, sleep apnea screening, and employer communications (i.e. on medications or transferring the “Long form” to employer).

Results:
The results of the medical provider surveys will be reported, and medications classified.

Based upon these results, a medical provider education program can be developed which would cover pharmaceuticals as they affect alertness in driving, underlying disease state(s), relevant FMCSA guidelines, and involvement in accident(s) based on published roadway accident/crash records from various safety community sources.

Conclusion: Commercial Driver Medical Examiner practice in pharmaceutical and alertness management is relatively unknown, and has great potential impact on road safety. These practices were assessed in two groups of physicians in two Western U.S. cities. This study can form the basis for provider education on alertness management and pharmaceutical training for examiners of drivers of commercial motor vehicles. The linking of medications to actual road crashes, where possible, will add additional context to a training program.
Panel: Fatigue and Performance Modeling 101
Fatigue and Performance Modeling (Track E)

This panel session will provide a general overview of the “nuts and bolts” of fatigue and performance modeling, including a discussion of the uses of models, what different models measure and what they are being used to predict. The discussion will also touch on efforts to incorporate individual variability into models, and discuss some of the general limitations of fatigue and performance modeling.

Session Chair: David Dinges, Ph.D.
University of Pennsylvania School of Medicine

David F. Dinges, Ph.D. is Professor and Chief of the Division of Sleep and Chronobiology, and Director of the Unit for Experimental Psychiatry in the Department of Psychiatry at the University of Pennsylvania School of Medicine. Dr. Dinges has conducted extensive laboratory and field research for NIH, DOT, NASA, DOD, and DHS, on fatigue prevention, detection and mitigation. His findings have been used to advise Federal and private regulatory policies regarding duty hours and fatigue management. He has been the recipient of numerous awards including the 2004 Decade of Behavior Research Award from the American Psychological Association and the 2007 NASA Distinguished Public Service Medal.
Biomathematical Modeling of Fatigue: Basic Theoretical, Mathematical and Scientific Concepts

Hans P.A. Van Dongen*, Sleep and Performance Research Center, Washington State University, Spokane, WA, USA, hvd@wsu.edu

Objective: To introduce the scientific, mathematical, theoretical and technical concepts at the basis of biomathematical modeling of fatigue.¹

Summary: Biomathematical models of fatigue aim to describe and predict changes across hours and days in fatigue, alertness, cognitive performance, effectiveness, accident risk and/or safety. These models reflect endogenous biological processes and are rooted in the science of sleep and biological rhythms. A number of different implementations of these models are available, which have in common that they capture two key biological processes: a homeostatic process balancing wakefulness and sleep, and a circadian process tracking time of day. These two processes interact to determine fatigue, thereby modulating attention and cognitive functioning over time.

A variety of other factors that co-determine fatigue, ranging from transient internal states such as anxiety or illness to external circumstances such as workload or distractions, are typically not included in biomathematical models of fatigue. The predictions these models make are focused primarily on the biological processes normally driving fatigue, and must be interpreted with due regard for context. Duty hours are represented indirectly by their impact on the duration and timing of wakefulness and thereby of sleep. This is appropriate from a sleep/wake physiological point of view, but it does not account for the effects of time on task and rest breaks. (More research is needed to better understand how these effects interact with the homeostatic and circadian processes.)

When considering a biomathematical model of fatigue, it is important to define the nature (qualitative or quantitative, absolute or relative) and the metric of the predicted outcome variable. Metrics may vary from a global fatigue score to specific task performance to probability of error, etc. Any thresholds or critical ranges for evaluating fatigue predictions (e.g., “red zone”) should be documented with regard to origin, validity and generalizability.

Depending on the application, the effectiveness of a fatigue model is a function of its sensitivity (i.e., how well it predicts periods with increased fatigue, impairment or risk) and its specificity (i.e., how well it predicts periods with reduced fatigue, impairment or risk). In operational settings, model sensitivity and specificity determine the balance between risk tolerance and risk aversion, or between error/accident prevention and loss of productive work time. Confidence intervals or other statistical indicators of prediction error are necessary to evaluate predictions of fatigue in terms of accuracy and potential relevance. Accuracy is also a function of whether or not various modeling assumptions are met (e.g., about prior sleep/wake schedules).

Most currently available biomathematical models of fatigue make predictions for group averages. New methods have recently been developed to account for individual differences—these may be implemented in the near future.

¹ Research and development supported by the Air Force Office of Scientific Research, the U.S. Army Medical Research and Materiel Command, the Institute for Experimental Psychiatry Research Foundation, and NASA.
Technical Integration of Biomathematical Models of Fatigue into Systems: What Approaches are Valid and Feasible

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Summary: Continued refinement of biomathematical models of alertness and fatigue has resulted in numerous laboratory-validated models that explain systematic variance in neurobehavioral performance resulting from various modes of sleep loss and circadian misalignment. Integration of biomathematical models of fatigue into operational settings represents a critical step forward in the quantification and management of occupational fatigue-related risk.

Primary integration steps needing to operationalize biomathematical models as fatigue management tools involve indentifying: (1) The population of interest (e.g. group vs. individual performance, expert vs. novice operator, etc.); (2) Operational tasks and performance metrics; (3) data acquisition opportunities and technologies (closed loop feedback vs. open loop systems), and (4) target performance boundaries and consequences.

Systematic variance in the population can be captured in biomathematical models by including covariates (e.g. age, gender, I.Q.) while inter-individual variance can be captured by treating model parameters as random variables and applying Bayesian techniques for parameter estimation. Outcomes from critical operational tasks can be measured directly using embedded measures (e.g., tracking lane deviation) or indirectly using a sensitive behavioral measure (e.g., PVT). Biomathematical models may be implemented by way of open-loop simulations or closed-loop feedback systems that integrate schedule information, embedded task measures, brief performance tests, streamed data from sensors, or data manually entered by the end user. Performance targets may depend on economics, safety standards, industry specific regulation, and degree to which fatigue related performance failure contributes to catastrophe.

Completing model validation for a specific operational setting and applying appropriate integration steps may result in a powerful fatigue management tool to increase safety, productivity, and health. Especially, in settings where the risk of accident due to fatigue related mistakes is high and the impact catastrophic.
Use of Biomathematical Models of Fatigue: Safety, Liability, Confidentiality, Adherence, and Consequences

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Alertness Solutions, Cupertino, California

Objective: To explore issues related to operational safety, liability, confidentiality, adherence, and consequences of implementing biomathematical models in diverse work settings.

Summary: Biomathematical models of fatigue offer tremendous opportunities to address fatigue in actual operations across diverse work settings. Many of these opportunities will be highlighted from a scientific perspective and projected to provide a variety of operational advantages. Models that acknowledge the complexity of fatigue issues incorporate multiple known factors that could affect modeling outcomes. Similarly, the potential outcomes of implementation should acknowledge and address multiple operational issues that will affect whether modeling solutions provide effective real-world advantages.

Enhancing safety is the primary objective that drives interest in and application of fatigue models. There is a significant operational challenge to define safety in very specific terms. Once defined, it has to be amenable to measurement that allows the establishment of baseline safety levels and ongoing evaluation to objectively determine results. Operational definitions of safety, that can be measured, are critical to evaluating the effectiveness of model implementation. If safety criteria are not met, then liability issues will emerge when errors, incidents or accidents are investigated and fatigue models are found to have played a role in operational decision-making or actual schedule construction. Investigations usually focus on contributory and causal factors in an accident, in what way could a fatigue model be identified as one of these factors?

Confidentiality issues related to operational implementation of fatigue models is an area currently undefined but with potential implications for organizations and individual operators. What individual data will be used to determine safety or for further refinement of a fatigue model? How will this data be protected where appropriate? What if a model suggests one approach to a particular circumstance but in actual operations a different action is taken? What aspects of the model solutions, individual or organizational actions will be “public domain” vs. confidential vs. “discoverable” if there is a negative safety outcome?

Adherence raises a variety of issues as it relates to operational implementation of fatigue models. For example, what policy is used to determine whether a given modeling outcome is actually implemented or not? Is the modeling solution a tool, guide or required for implementation? Is the requirement to: a) “run” a model scenario or b) use it? If an organization identifies fatigue modeling as a component of an overall fatigue management program, what requirements will exist that involve adherence applied to policies and practices.

Consequences represent the “bottom line” in operational settings. What are the safety, operational, economic, practical, quality of life, policies, practices, and regulatory consequences of using a biomathematical model of fatigue? These will need to be explored and defined from both the perspective of advantages and limitations created by implementation of fatigue models into actual operations.
Eye Closure and Lane Change: Multiple Approaches for Real-Time Drowsiness Detection
Supporting Technologies (Track D)

The implementation of drowsy detection systems has taken different forms. This session highlights recent research that has implemented strategies for detecting driver drowsiness. The focus of this session will include both kinematic measures and ocular measures. Research will be highlighted that describes approaches that have utilized lane change maneuvering, eye closure, and a combination approach that integrates lane deviation and eye closure.

Session Chair: Richard Hanowski, Ph.D.
Virginia Tech Transportation Institute

Richard Hanowski is the Director of the Center for Truck & Bus Safety at the Virginia Tech Transportation Institute. He has specialized in transportation research since 1991 and has conducted many safety studies for government and industry. Dr. Hanowski has written over 125 publications and has experience conducting research with driving simulators, on test tracks, and on the open road, including collecting over 3 million miles of naturalistic heavy vehicle driving data and analyzing many crashes and near-crashes. Among his awards for his research and technical presentations is the 2008 SAE Lloyd L. Withrow Distinguished Speaker Award.
A Model based on Machine Learning approach to classify Lane-Change Maneuver as an indirect Measure of Fatigue

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Roberto Montanari, University of Modena e Reggio Emilia, montanari.roberto@unimore.it

Objective: The majority of accidents in transportation are due to human errors, rather than system failure, mechanical malfunctions or other factors. From accident analysis, fatigue – as manifested as drowsiness or hypovigilance – is a key contributor to human errors, since it reduces the availability of cognitive resources needed to assess the dynamic evolution of operational situations, aligning latent risk factors with problematic emerging conditions. Therefore, technology countermeasure to operator fatigue are really needed. The aim of this work is to develop a model to classify the Lane-Change (LC) manoeuvre. Lateral behaviour is known to be one of the major indicators to assess driving performance and therefore it can be regarded as a significantly step to detect wrong and risky driving behaviour, for example just due to driver’s fatigue (e.g. drowsiness).

Approach (or Methods): In order to recognise Lane-Change, we have followed a machine learning (ML) approach; in fact, for a classification problem, several studies from literature have demonstrated that these techniques can outperform the traditional, analytical methods. In particular, we have explored Support Vector Machines (SVM), Feed-forward Neural Networks (MLP) and Recurrent Neural Networks (RNN).

In order to train these models, we needed to collect data both as inputs and as output target. Therefore, we carried out some experiments at driving simulator, where 6 subjects were asked to drive on a pre-defined test-track (long 24km, including several scenarios) respecting road rules. In addition, they were told to perform the action indicated in a dedicated landmark: lane-change and car-following. The experimenter wrote down a flag 1 when maneuver was acted, while 0 meant no maneuver; these data constituted the target for the model training.

Results: We have tested different combinations of variables for the three models. In order to assess the best solution, we have used the Correct Rate (CR) index, which takes into account how many instances are correctly classified on a test dataset (never used before). In case of more models have the same CR value, we have also considered the computational time.

<table>
<thead>
<tr>
<th>Combination of model Input data</th>
<th>ML Technique</th>
<th>Model Parameter</th>
<th>CR Value</th>
<th>Computation Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>S, SA, DJ, TTLC</td>
<td>SVM</td>
<td>Polynomial Kernel: order 5</td>
<td>&gt; 99%</td>
<td>~ 3s</td>
</tr>
<tr>
<td></td>
<td>MLP</td>
<td>Number of Hidden Neurons: 30</td>
<td>&gt; 99%</td>
<td>~ 93s</td>
</tr>
<tr>
<td></td>
<td>RNN</td>
<td>Number of Hidden Neurons: 30</td>
<td>&gt; 99.5%</td>
<td>~ 1912s</td>
</tr>
</tbody>
</table>

Table 1: main results achieved. For all data we have used the Mean or the Standard Deviation. S = Speed; SA = Steering Angle; DJ = Deceleration Jerk; TTLC = Time To Lane Crossing

All models achieved a CR > 99% and RNN model even more, but the strong difference is in the computation time (as shown in the table).

Conclusion: We focused on the development and implementation of a model for LC classification. We have compared three different techniques and the best one has been the SVM classifier. Despite the excellent CR index we obtained, nevertheless further works are needed. Firstly, the test scenarios have to extended, in order to get more reliable statistics results. Then, we have to deal with multi-classification problem, since ordinary driving include many manoeuvre. LC classifier could be also installed on a prototype car, to evaluate it as a real-time system. Finally, by a theoretical point of view, we think that further investigations are necessary, about the precise correlation between lateral behaviour measurement (like ours) and the fatigue; however, we think that a method to detect driver’s intentions is essential to facilitate operating mode transitions or to monitor human state and act.
Drowsiness and distraction are among the major causes of vehicle accidents throughout the world. With safety as one of its core values, Volvo has been actively involved in developing and offering solutions to these problems. This presentation focuses on the efforts done by the company in these areas – from internal projects to national and international collaborations and cooperation. The importance of performing on-road tests for drowsiness and distraction detection systems will be elaborated. Lastly, an overview of the Driver Alert Support (DAS) system that was introduced to the market in 2008 will also be presented.
Driver fatigue is an issue in all 24-hour operations and is a leading cause of transportation-related fatalities. It is generally accepted that drowsy driving and fatigue-related microsleeps occur at a higher rate during specific times in the 24-hour period, and are related to the circadian phase of the driver. A novel vigilance recognition technology has proven to track drivers’ head position, eyelid closure, and eye gaze relative to the direction of the vehicle; and to recognize, video record and audibly warn against microsleeps, distraction, and lack of attention to the road.

**Objective:** To study round-the-clock long distance commercial driving and determine microsleep rates, time of day, concurrent vehicle speed, and GPS position on public roads.

**Approach (or Methods):** The ‘Driver State Sensor’ from Seeing Machines utilizes an in-cab camera system that does not utilize infra-red (IR) reflections or requires drivers to wear special glasses, and as a result, is able to operate during daytime and when prescription lenses or sunglasses are worn. The key data recorded includes: 3D head position and orientation, eyelid closure levels for each eye, time and date, the GPS location, heading and speed, and a long-term drowsiness metric based on eyelid movements. Two distinct types of fatigue were analyzed: an immediate measure that senses acute sleepiness, and a long-term sleepiness indicator (degradation of alertness before sleep or microsleep occur). The study involved one Class 8 truck, which works 24 hours per day, 7 days per week and has up to 22 different drivers of any 14-day period. Over the course of the study, the vehicle traveled 35,345 miles. The sensor was set to record microsleep events after 1.8 seconds and distraction events at 2.0 seconds.

**Results:** A total of 16 microsleep events and 2,814 distraction events were recorded during the study, which, when adjusted for mileage, result in 3.10 microsleep events per 10,000 miles, and 545 distraction events per 10,000 miles. Thirty one per cent of the microsleep events occurred between midnight and 6:00 a.m., 50% between 6:00 a.m. and 12:00 noon, and 31% between midday and 6:00 p.m. Nine of the 16 microsleep events were individual events (9 different drivers), with the remaining 7 attributed to 3 drivers who had 2, 2, and 3 microsleep events in succession. Drivers traveled a total of 88 seconds asleep and covered 3,400 feet or 0.64 miles, with an average road speed of 63.47 mph. All but one microsleep event occurred on Interstate Freeways, with zero accidents recorded.

**Conclusion:** For the first time, microsleep events have been recorded across the entire 24-hour period in commercial rivers during real-world long-distance operations on public roads. Scheduling and driver training are currently the main tools to manage fatigue. Clearly, technological advances in microsleep detection and two-way dispatcher/driver fatigue management procedures for immediate driver intervention could significantly reduce drowsy driving and increase safety on public roads.
An Innovative Approach to the Assessment of a Multi-Dimensional Driver Drowsiness Monitoring System (DDMS).

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Robert Carroll, (formerly) Federal Motor Carrier Safety Administration, robertcarroll@aol.com

Objective: The objective of this research project was to develop a robust prototype system that combines multiple drowsiness metrics (i.e., PERCLOS, lane position) to alleviate some of the reliability issues associated with single-measure devices.

Approach: The results of this on-road evaluation were used to assess the performance of the Drowsy Driver Monitoring System (DDMS) in terms of ideal functional specifications (e.g., accuracy and sensitivity) to determine the effectiveness of the multiple sensor integration approach. It is important to note that the on-road evaluation was not to test human behavior and performance, but rather, the evaluation focused on exercising the prototype system to determine its operational envelope (i.e., those operational conditions in which the system does and does not work effectively). Because the prototype system used a combination of eye closure and lane position sensors, the evaluation approach involved two participants simultaneously participating in the test sessions. One participant drove the tractor to perform consistent lane deviation maneuvers, which assessed the effectiveness of the lane position sensor. At the same time, other participants with varying physical facial features (e.g., skin complexion) and eyewear sat in the passenger seat and performed prescribed eye closures to exercise the machine vision-based eye closure sensor. This two-participant approach served as an effective and efficient method that allowed for multiple stimuli to be presented to the system simultaneously in a manner that was repeatable and safe for the research participants.

Results: The key finding of this on-road evaluation was that a multiple sensor integration approach provides a more robust method for assessing driver drowsiness.

Conclusions: Though there were limitations with each sensor, the combined approach performed more successfully than either sensor individually. Future research is necessary to (a) address the individual sensor limitations that were observed and (b) fully test the system’s algorithm.
Review of Fatigue Risk Management System Interventions
Evaluation of Fatigue Risk Management System Interventions (Track F)

Four papers will be presented describing fatigue interventions in the rail, airline, and ground transport industries from an evaluation perspective. These papers emphasize evaluation processes, outcomes, or impacts at the individual, organization, industry, or policy level. Each presenter will have 15 minutes to present their findings, followed by brief audience questions. At the conclusion of the presentations evaluation experts Harry Hatry and Dr. Jon Morell will further analyze and discuss the presented fatigue interventions.

Session Chair: Chris Coryn, Ph.D.
Western Michigan University

Chris Coryn, Ph.D. is an Assistant Professor in the Evaluation, Measurement, and Research program, housed in the department of Educational Leadership, Research, and Technology, and is also the Director of the Interdisciplinary Ph.D. in Evaluation at The Evaluation Center, Western Michigan University. His research and writing have focused primarily on evaluation of scientific research; evaluation theory, logic, and methodology; metaevaluation; peer review; quantitative, qualitative, and mixed methods; measurement; social justice; and structural equation modeling.
Injury Reduction with a Sleep Disorders Screening Program

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Objectives: To implement a sleep disorders and cardiovascular risk screening program in the road transport industry in Victoria, Australia. To evaluate the change in workplace injuries before and after implementation of the program.

Methods: A three year health screening and education program was run within truck yards, funded by government workplace and road accident insurers (Worksafe Victoria and the Transport Accident Commission). Companies were approached in conjunction with the Transport Workers Union. Education about fatigue, sleep disorders and cardiovascular risk factors was provided in the workplace. Nurses visited workplaces to provide confidential screening for sleep disorders, excessive sleepiness, cardiovascular risk factors and alcohol problems. Those with abnormal results were provided with written feedback, recommendations for follow-up of specific problems and referred for medical follow-up and treatment via their general practitioner. The screening included collection of the Epworth Sleepiness Scale (ESS), the Multivariable Apnoea Prediction Index (MAPI), sleep and work habits, cardiovascular risk factors (smoking, blood pressure, blood glucose, family history and cholesterol) and alcohol intake. The written feedback provided advice about the likely causes of sleepiness and specific advice about minimizing sleepiness based on this information. General practitioners were asked to sign and return a card indicating the conditions that were followed-up and a random telephone survey was undertaken of those drivers referred for follow-up but the card was not returned. Workplace injury data was collected for 12 months prior to and following the program from companies involved in the first six months of the program (800 drivers).

Results: Eighty-seven percent of 134 companies approached participated in the program. 11992 drivers participated in education sessions. 3975 drivers undertook individual health screening. 1868 drivers were referred for follow-up of medical conditions, with 215 drivers referred for urgent review. Nineteen percent of drivers had excessive sleepiness (ESS > 11), 24% were at high risk of sleep apnoea (MAPI > 0.5) and four percent regularly fell asleep whilst driving. Undiagnosed diabetes and severe hypertension were identified in three and five percent of drivers respectively. 59% of drivers attended for the recommended follow-up. New lost time injuries fell from 17.1 to 14.2 per hundred drivers per year following introduction of the program (p<0.05).

Conclusions: A large scale sleep disorders screening program was feasible with the assistance of union and industry support. Undiagnosed excessive sleepiness, hypertension, diabetes, and high risk for obstructive sleep apnoea were common. There was moderate compliance with recommended follow-up. There was a reduction in workplace injuries following the program, however it is possible that other factors contributed to the fall in injury rate.
Fatigue Risk Management Integrated within an Airline Management System

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(b) easyJet Airline Company Ltd, UK  (c) London City University, UK
(d) Integrated Safety Support, Australia

Background
The aviation environment is becoming increasingly complex due to rapid expansion of the low-cost market and significant pressures against airline profitability, due to rising fuel costs and market competition in the face of falling yields. These changes have produced a new set of challenges for effective safety oversight and has demonstrated deficiencies in the ability of flight time limitations (FTLs) to adequately control fatigue-related risk. FTL as a control, does not adequately account for airline rostering practices that require crew to sleep at less favourable times in the circadian cycle, individual differences and social demands on flightcrew. These factors can limit the quality and quantity of sleep obtained by crew and has direct impact on the acceptable level of safe performance on the flight deck.

Objectives
The objective of this paper is to demonstrate deficiencies in the ability of flight time limitations (FTL) to adequately control fatigue-related risk in commercial flight crew. Further, the application of an integrated Fatigue Management approach can result in significant systematic safety performance benefits (proactive and reactive, objective and subjective) derived from measuring and managing fatigue-related risks.

Approach
This paper is broken into five sections. The first outlines causes and consequences of fatigue-related risk in aviation and why the current controls are not adequate. The second section describes regulatory and commercial pressures that are increasingly advocating that airlines take a more sophisticated approach to managing fatigue-related risk. The third section describes the organisational elements for a Fatigue Risk Management System (FRMS) within a Safety Management System and includes 1) processes for investigation, 2) data control protocols, 3) risk management and 4) operational feedback. In section four we introduce easyJet’s FRMS and the framework for risk assessment (SIRA) that supports the FRMS. These elements are currently being enhanced with the support of an EU funded project called Human Interaction in the Lifestyle of Aviation Systems (HILAS).

Results
This fifth section takes the reader through the results from the analysis of actual FRMS investigations that focused on fatigue-related risk precursors such as elongated duties, duty transitions (early start to late start) and workload. This analysis has lead to the development and implementation of a Roster Evaluation Group at easyJet that balances safety criteria, from FRMS risk assessments, against operational criteria in pursuit of commercial objectives. This process implements evidenced based rostering rulesets and demonstrates that through detecting, measuring and analysing the effects of fatigue on performance, it is possible to improve rostering protocols that minimise operational risk to an airline.

Conclusion
This paper demonstrates the organizational and commercial benefits of a risk-based management system compared to FTLs as a fatigue control. Significantly, this includes how the analysis of fatigue-related risk events provides objectively and subjectively improved safety and operational performance to an airline through the establishment of a Fatigue Risk Management System.
Findings from International Railway Roster Studies - Moving Beyond Fatigue
Management Limitations of Current Schedule Design: a Three-Prong Approach

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Objective: This paper presents the methodology, findings and recommendations from five separate train driver roster fatigue risk assessments conducted in Ireland, United Kingdom, Australia and South Africa, where the assessment also included guards and train control officers. Driver study population was 1223.

A significant body of research into the determinants of alertness (including circadian rhythms, sleep duration and timing) facilitates assessment of the interaction of roster design elements with alertness. Applying specialised knowledge of shift work design and alertness determinants, and use of bio-mathematical software, numerous roster design practices were identified (many of these common across all operations) impacting drivers’ sleep duration and quality, leading to sleep deprivation and circadian desynchronisation, potentially contributing to fatigue impaired performance and inattentiveness. Such practices included: counter-clockwise shift rotation, consecutive early starts (including following days off), long consecutive work periods ending with late starts, and significant transition in start times between shift changes.

Methods: Analysis actions comprised:
1. Broad-based roster review applying roster design expertise to identify shift work design features and practices known to contribute to fatigue. Additionally, in South Africa, roster manager and driver interviews were conducted.
2. Bio-mathematical Modelling - Fatigue Index Risk Module (FIRM) assessed master planned rosters. Rosters were reformatted to integrate with FIRM. Fatigue risk was evaluated and quantified on a daily, transitional and cumulative basis. Aggregate fatigue risk was scored from Low, Significant, and High to Extreme Risk.
3. In South Africa, actual work patterns deviated considerably from planned rosters. Payroll data was collected to confirm actual work patterns and FIRM applied to quantify additional fatigue risk arising from deviation of planned work patterns.

Results: The assessments identified numerous roster features increasing fatigue risk. Applying 21 bio-compatible principles (alertness enhancing features) including: clockwise rotation, reducing consecutive work days, minimising early morning starts, reducing shift start time transitions and minimising consecutive work blocks, bio-rosters were generated demonstrating fatigue mitigation and capacity to protect operations, illustrating practicality and functionality of bio-compatible roster design.

Comparative FIRM analysis of current rosters was conducted. FIRM generated bio-rosters showing significant reductions in design-based fatigue risk. The importance of driver input to achieve functional bio-rosters supported by the end user was emphasized.

Findings revealed limited organisational knowledge or application of circadian principles and skills to produce bio-rosters. Use of prescriptive regulation did not address the biological basis of fatigue risk. Traditional roster design and roster management (organisational, union and employee based) contributed to unnecessary fatigue risk, poor quality of life for train crews, increased business costs, e.g. poor staff utilization, overtime payments and increased accident risk. Company and employee/union economic motivations generated excessive working hours exacerbating fatigue.

Conclusion: Bio-rosters showed substantial reduction in FIRM measured risk. In conclusion, a three-prong approach would improve alertness, QOL and safety:
1. Fatigue training certification for roster designers, plus union/staff education
2. Application of ergonomic biocompatible rosters
3. Defensive operational countermeasures, such as lifestyle planners, integrated into a Fatigue Management Program premised on organisational commitment, resources, responsibilities accountability, risk awareness, education, FMP auditing process and refinement.
Effects of a Fatigue Management Program on Fatigue in the Commercial Motor Vehicle Industry

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Objective: The goal of this study was to assess the feasibility of a company-wide approach to fatigue management and its impact on drivers’ fatigue, performance, sleep duration, and mood, as well as on company performance measures, scheduling policies, and practices. The fatigue management program (FMP) included an educational component and a sleep disorder screening and treatment component.

Approach: Three trucking companies (in Quebec, Alberta and California) participated in the implementation and assessment of the FMP. A total of 77 drivers participated in the FMP and in pre and post FMP data collection. The FMP included educational sessions which were offered to managers, dispatchers, drivers and their families. Participating drivers were screened and treated for sleep disorders. Drivers collected pre and post-FMP data using hand-held computers to enter data on sleep timing and quality and start and end of shift data on mood, and performance (PVT - Psychomotor Vigilance Task for 68 drivers only, close calls, nodding off at the wheel). Drivers also wore wrist actigraphs to obtain an estimate of sleep quantity and quality. Pre and post FMP data collection took place over a period of 10 days, including both duty and rest periods by drivers on their regular revenue-generating routes. In addition to driver measures, corporate performance measures were collected specific to each company (e.g. crashes, absenteeism).

Results: Of a total of 94 drivers screened for sleep disorders, 28.7% had no sleep apnea (RDI < 5), 39.4% had mild sleep apnea (RDI 5-14.9), 23.4% had moderate sleep apnea (RDI 15-29.9) and 8.5% had severe sleep apnea (RDI \( \geq 30 \)). RDI (Respiratory Disturbance Index) was significantly correlated with ANC (Adjusted Neck Circumference), MAP (Multivariable Apnea Prediction) and time below 90% \( O_2 \), but not with Epworth or SAQLI (Sleep Apnea Quality of Life Index). The 77 drivers included 36 without and 41 with treated sleep apnea (40 with CPAP and 1 with dental appliance). The analysis of sleep based on actigraphy revealed longer sleep duration and greater sleep efficiency during the post-FMP vs the pre-FMP condition for duty days. Sleep parameters remained stable during rest days. Significantly improved subjective sleep quality and more sleep per 24 hours were observed after the FMP intervention compared to before. Performance based on PVT scores, improved during rest days post-FMP vs pre-FMP in the severe ESS group and in the CPAP adherent group. There was an unexpected increase in PVT minor lapses at the end of duty days post-FMP vs pre-FMP. There were significantly fewer incidents of drivers reporting close calls while driving or nodding off post-FMP versus pre-FMP.

Conclusion: The prevalence of sleep disorders such as sleep apnea is high (71%) in this non-randomly selected CMV driver population. This contrasts with a somewhat lower prevalence (28%) reported in a large randomly selected group of CMV drivers (Pack et al., 2002) but comparable to that reported by Stooohs et al., (1995). ANC and MAP are reasonable predictors of the likelihood of a driver having sleep apnea. A comprehensive FMP intervention appears beneficial for improving daily sleep and reducing close calls while driving.

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Poster Session I
Prevalence of Fatigue in Serious Hazardous Material Truck Crashes:
A Database Analysis Approach

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Objective: The objective of this project was to further develop a hazardous material (HM) truck crash database with additional years of data and reevaluate previously established crash contributing factors and effect categories, including: vehicle, driver, package, infrastructure, and situational.

Approach: HM truck crashes in calendar years 2002 to 2006 were identified using the Motor Carrier Management Information System (MCMIS) and Hazardous Materials Information System (HMIS). All serious HM truck crashes (i.e., fatality, injury, or spill) in these calendar years were included in the analysis. A random sample of the remaining HM truck crashes was selected until the final sample included 5,000 HM truck crashes (one crash was removed due to insufficient data). The information from these 4,999 crashes was entered into the Final Hazmat Database. A total of 671 HM truck crashes in the final sample had both a MCMIS and HMIS crash file. These were merged and overwritten with information from HMIS as this was considered more detailed information. Police accident reports for each HM truck crash in the Final Hazmat Database were requested to validate the information in the database as well as add new information not included in MCMIS and HMIS. Moreover, each involved HM carrier was contacted to verify information and collect additional information on the HM driver, spill, and package. Quality control checks were performed throughout the data verification process and weights were applied to each HM Class to reduce bias. Several explanatory variables were identified to explore their affect on crash risk and outcome. Six types of explanatory variables were included for analysis in the current report: (i) Vehicle (Configuration, Cargo Body), (ii) Driver (Age, Condition), (iii) Infrastructure (Road Surface, Road Condition, Road Type, Trafficway, Access Control), (iv) Situational (Pre-Crash Condition, Dangerous Event, Vehicle Speed, Accident Type, Weather Condition, Primary Reason), (v) Packaging (Impact Location), and (vi) Driver Fault (Yes/No).

Results: 2.7 percent of the HM truck crashes were coded with a Driver Condition code of “fatigued” or “asleep”, while 5.5 percent of the HM truck crashes with a spill were coded the same way. Moreover, 6.8 percent of the at-fault HM truck crashes were coded with a Primary Reason of fatigued or asleep, while 9.5 percent of the at-fault HM truck crashes with a spill were coded the same way. This suggests that fatigue increased the severity of the HM truck crash (by resulting in a spill); however, without exposure data it is difficult to assess if fatigue increased the severity and/or frequency of HM truck crashes in the current study.

Conclusions: Learning about the circumstances and conditions involving fatigue-related HM truck crashes will inform the development of new technologies, enforcement and legislation, and safety management techniques to reduce these types of crashes. Interestingly, the prevalence of fatigue was slightly lower than reported in a naturalistic driving study involving large vehicles. For example, Blanco et al. (2008) reported that 9.4 percent of instrumented truck drivers were coded with a Critical Reason of fatigued or asleep during a critical event. This discrepancy might highlight the difference between the current crash database approach and the naturalistic driving methodology (which allows an accurate picture of what happened prior to, during, and after a crash or near-crash event).
Modeling Fatigue in Split Sleep Schedules with a New Biomathematical Model for the Homeostatic Effects of Sleep Loss

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Objectives: Split sleep schedules are common in around-the-clock transportation settings. Optimal scheduling (i.e., timing and duration) of split sleep is important to minimize fatigue and maintain performance, productivity and safety. Mathematical modeling is needed to track homeostatic and circadian influences on fatigue. In the context of a laboratory study of split sleep schedules, we examined predictions of a new biomathematical model of the homeostatic drive for fatigue (McCauley et al., 2009). This model encompasses recent findings on the cumulative effects of chronic sleep restriction.

Methods: We adapted the mathematical formulation of the new model to allow for inclusion of more than one sleep period per day. We then predicted psychomotor vigilance performance deficits across days in a laboratory experiment involving 10 days with restricted nocturnal sleep and a diurnal nap. These predictions were compared to the observations in the experiment (Mollicone et al., 2008).

Results: Both the experimental observations and the biomathematical model predictions showed fatigue building up across days, in a near-linear, sleep dose-dependent manner. The overall duration of the combined sleep periods per day was the predominant mediator of the experimental observations as well as the model predictions—the longer the combined total sleep time the better the performance. While the biomathematical model accurately predicted the magnitude of the effect of chronic sleep restriction with one consolidated sleep period per day, the effect of restricted split sleep was at first under-predicted. Adjusting a feedback parameter in the model dramatically improved the predictions for the split sleep schedules while preserving accuracy for consolidated sleep. The model predictions then suggested that there are subtle differences in the build-up rate of fatigue between schedules with the same total amount of daily sleep but different durations of the split sleep periods.

Conclusion: We refined a new biomathematical model of the homeostatic drive for fatigue to predict performance impairment across days of chronic sleep restriction in both consolidated and split sleep scenarios. This model may be useful to help select sleep/wake/work schedules to achieve optimal performance, productivity and safety in transportation settings.¹

References


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Objective: Driver drowsiness and fatigue is one of the main reasons for fatal collisions. Early detection and further prevention of drivers’ drowsiness is very important to enhance traffic safety. After reviewing the current technologies, we revealed that electroencephalography (EEG) has the potential to achieve better performance than other human cues. This paper was focused on developing EEG based driver drowsiness recognition and prevention technology.

Approach: Firstly, we try to find the EEG features that are more sensitive to driver’s drowsiness yet more robust to disturbances via experimental approach. Participants’ EEGs in alert state and drowsy state were recorded during a driving task that was performed in a driving simulator. Twelve EEG features were analyzed for their performance of distinguishing participants’ alert state and drowsy state. The result showed that using specific EEG features to recognize drivers’ drowsiness is feasible. Secondly, we build an EEG features based backpropagation neural network to recognize driver drowsiness. From the 12 EEG features, all possible combinations of 1 or 2 EEG features were found. The backpropagation neural network using different EEG feature combinations were compared in terms of recognition error. Last, we design the driver drowsiness prevention system. A prototype system was established, and experiments were carried out to test the prototype system. It was verified that the EEG feature and neural network based driver drowsiness prevention system can respond to drivers’ state in real time.

Results: We studied drivers’ EEGs in their alert state and drowsy state when they performed a driving task in a driving simulator. The results showed that EEG is a highly effective indicator of drivers’ drowsiness because many features of EEG in six locations are significantly different between alert state and drowsy state. It seems that the EEGs of the occipito-parietal and motor areas of drivers’ brains are more sensitive to drivers’ drowsiness than the EEGs of drivers’ other brain areas. The effective features of the six EEGs can be utilized to predict or recognize drivers’ drowsiness. The EEG experiments also verified that the performance of these EEG features in distinguishing drowsiness is highly affected by the locations where the EEG is measured. Therefore, using EEG features to detect drivers’ drowsiness involves not only the selection of EEG feature, but also the selection of the location of EEG electrodes. In addition, the EEG feature based backpropagation neural network can be employed to recognize driver drowsiness. We find it difficult to enhance its performance in driver drowsiness recognition by increasing the number of EEG features that the backpropagation neural network uses. However, the performance was improved by increasing the number of training samples. After being trained using a larger training sample set, the single EEG feature based backpropagation neural network achieved good performance in classifying drivers’ alert state and drowsy state. This neural network was employed to develop a driver drowsiness prevention system of which the mean of Alpha of C4P4 EEG based prototype system was tested by experiments.

Conclusion: The experimental result verified that the prototype driver drowsiness system can produce response to drivers’ alert state and drowsy state in real time. It is feasible to use an EEG and neural network based driver drowsiness prevention system to enhance the traffic safety.
Novel identification of optimal physiological indices for monitoring cognitive fatigue.

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Objectives: The objective of this study was to identify a sparse set of physiological measures that could be used to predict cognitive fatigue levels. PVT mean reaction time reaction time and lapses were used as a ‘ground truth’ measure of performance impairment indicative of reduced alertness.

Approach and methods: Six subjects were recruited for a continuous 37 hour sleep deprivation study. Subject physiologic data were recorded using commercially available, wearable, ambulatory physiological monitoring systems. These systems allow unbiased, non-invasive and continuous recordings of cardio-respiratory and activity measures. Subjects further performed the PVT every hour for the full study duration.

A suitable set of attributes that have relevant physiological meaning and compactly represent the original physiological data set was identified. This was based upon the demonstrated fact that there is a strong link between cognitive fatigue and autonomic nervous system activity. In particular, the fatigue state is associated with a shift of sympathovagal balance toward sympathetic predominance and reduced vagal tone. In addition, respiratory instability has been demonstrated to be a strong predictor of psychophysiological state. Initial feature selection focused on the inclusion of cardio-respiratory markers that could be used to infer autonomic activation, resulting in a large set of possible predictive features. These included indices of: heart rate, heart rate variability (HRV- several indices), tidal volume, breathing rate, respiratory instability (RI - several indices), motion, postural shifts and skin temperature. Features were extracted over a 3 minute quiet period preceding, during and following the PVT test.

When the number of predictors exceeds the number of training samples, the modeling problem is underdetermined, or ill-posed in the Hadamard sense. In this instance, it is desirable to find a model with significantly fewer predictors and in fact, the more sparse the model, the more likely that the predictors are causally related to the dependent variable. In order to achieve this for ill-posed data, the values of the regression coefficients can be constrained via a shrinkage function. We used the LASSO shrinkage and selection method, along with the least angle regression method for solving the LASSO, to create a sparse model and thus determine an optimal feature subset. The resultant subset should therefore consist of the most relevant predictors of cognitive fatigue.

Results: The LASSO only selected two variables: the normalized low frequency content of the HRV (LFnorm) and the tidal volume instability (TVI), which is an index of RI. These variables both indicate an increase in sympathetic arousal associated with attention toward a task.

Conclusion: The LASSO technique allows one to select en-masse, via a continuous subset optimization, a set of cardio-respiratory variables that together are effective predictors of operator alertness status. This technique combined with commercially-available, wearable physiologic monitoring systems will result in a system that can improve operational safety and effectiveness by accurately assessing cognitive fatigue levels during stressful day to day conditions.
Objective: Driving while drowsy is a significant contributor to motor vehicle accident deaths as drowsiness impairs a driver's reaction time and control over the vehicle. The primary goal of this research was to determine which, if any, driving performance variables are closely correlated with empirical measures of driver drowsiness. This effort was undertaken in an attempt to create the foundations for an innovative drowsy driver detection system based on driver performance metrics alone, or that may be integrated with other technological approaches. This research is the first known attempt at linking data from a closed-track study using electroencephalogram (EEG) with driver performance measures to examine the transition from an alert to drowsy driver state.

Approach: Nine sleep-restricted participants drove on a closed test track for a two-hour period during the late night or early morning hours. EEG data and various channels of driver performance data were collected continuously throughout the drive. These two datasets were then synchronized and compared to examine changes in driver performance as drivers transitioned from being alert to drowsy, and eventually, in most cases, falling asleep at the wheel. Video data of the driver and the forward view of the vehicle were also collected and used to code and perform an analysis of the drivers' behavior, validate the EEG data, and analyze differences in behavior between subjects.

Results: While no significant relationships between driver drowsiness state and driver performance were found in this study, this research is an important first step toward addressing this complicated problem, and provides insight and direction for future research.

Conclusion: While additional research should be done to make any specific claims, this research suggests that, due to large individual differences between drivers a within-subjects approach to using driver performance metrics to detect driver state may be more realistic approach than using a universal detection method, steering range and steering variability were found to have the strongest relationship to driver drowsiness and would be good variables to investigate in future drowsy driver research, and neither eye blinks nor EEG data are definitive measures for detecting drowsiness in drivers.
Objective: The purpose of the Hours-of-Service (HOS) regulations are to further improve commercial motor vehicle (CMV) safety by requiring motor carriers to provide CMV drivers with better opportunities to obtain sleep in order to reduce the incidence of drowsy, tired, or fatigued drivers and the crashes in which they are involved. As part of the HOS regulations, operators who obtain 34 consecutive hours of off-duty time can begin a new seven-day period, over which they can drive or be on duty a cumulative total of 70 hours (i.e., the seven-day "clock" is restarted by a 34-hour off-duty period). One of the main aspects of that off-duty allowance is for drivers to rest but, more importantly, sleep. Relatively little is known about the sleep of commercial vehicle drivers. However, a recent study conducted by Hanowski, Hickman, Fumero, Olson, and Dingus (2007) found that mean sleep quantity for commercial vehicle drivers, under the 2003 HOS regulations, was 6.3 hours. This increase in sleep quantity is not surprising since the revised HOS regulations provide drivers with two additional hours of off-duty time and drivers are using some of this additional off-duty time to sleep. Despite having a better idea of how much sleep CMV drivers are getting, there are limited data on the impact of sleep quantity on the occurrence of a safety-critical event (SCE; i.e., crash or near-crash).

Approach: This study takes advantage of actigraphy, research logbooks, and driving performance data obtained from a naturalistic truck driving study funded by FMCSA. The restart data for the CMV drivers show that the average duration of the restart period before an SCE was 53 hours (over the 34 hour minimum) every 5 days.

Results: No significant relationship was found between SCEs and the duration of the restart period. Potentially, other factors (e.g., traffic) closer in time to the SCE might be better predictors. Time since restart was not related to SCEs. However, the highest number of SCEs occurred during the first day after restart. Based on the actigraphy data obtained from the drivers, the average sleep was 6.5 hours during the 24 hours before an SCE compared to 7.0 hours during the restart period. Most of the sleep periods preceding an SCE were composed of a single period; however, some drivers obtained their sleep in up to four sleep periods (i.e., not all sleep in a continuous sleep period).

Conclusion: In summary, this study demonstrates that drivers are taking advantage of the restart period and sleeping more than after a regular day on-duty. However, the average sleep duration for CMV drivers was similar to the average sleep reported by the National Sleep Foundation for the 2008 Sleep in America Poll (6.7 hrs). No relationship was found between SCEs and amount of sleep or the duration of the restart period. An interesting finding of this study was that the first day after coming back to work had the highest frequency of SCEs. Future research will explore the potential cause of this first day effect.
Sleep History Effects Performance During Subsequent Sleep Restriction And Recovery

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Objective: Performance deficits from sleep loss have been described in the context of a two-process model (Borbély, 1998) with the homeostatic process as a simple reservoir in which performance capacity increases exponentially during sleep and decays linearly or exponentially during wakefulness. According to Johnson and colleagues (2004), this simple reservoir conception is accurate for describing and predicting performance with acute total sleep deprivation (in which recovery generally occurs after one night of recovery sleep), but not with periods of recovery following chronically restricted sleep. This notion is supported by findings from a sleep restriction study by Belenky and colleagues (2003) showing large individual differences in performance during sleep restriction and in rate of recovery, with sleep-restricted volunteers failing to recover to baseline levels with 3 recovery nights. One explanation for these findings is that volunteers were not entering the study in comparable states due to differing prior habitual sleep schedules. The aim of the present study was to examine if sleep amount prior to sleep restriction mediated subsequent performance and recovery rate.

Methods: Eleven males and 13 females [mean (SD) age = 25 (6.5) years] were assigned to either an Extended [10 hours time in bed (TIB)] (n = 12) or Habitual [Mean (SD) = 7.09 (0.7)] (n = 12) sleep group for one week followed by one baseline night, seven sleep restriction nights (3 hours TIB), and five recovery nights (8 hours TIB). Throughout Baseline, Restriction, and Recovery, the Psychomotor Vigilance Task (PVT) and computerized Mathematical and Serial reaction time (RT) tasks were administered to volunteers hourly each day (0800-1800). PVT lapses (RTs > 500 ms) and Math and Serial RT Throughput for each task (speed * accuracy product) was analyzed using mixed model ANOVA with fixed effects for sleep group, day, and time-of-day followed by post-hoc t-tests (Bonferroni correction).

Results: During restriction, PVT lapses increased in both groups, with faster declines for the Habitual group. During recovery, Extended group PVT lapses returned to Baseline after one recovery night; for the Habitual group PVT lapses failed to recover. Math and Serial RT Throughput improved for both groups during sleep restriction but more so for the Extended group versus the Habitual group during recovery.

Conclusion: One week of sleep extension improved resilience during subsequent sleep restriction and facilitated recovery thereafter, demonstrating that nightly sleep duration exerts long-term (days, weeks) effects. The work informs mathematical models by directly assessing the impact of prior sleep history on subsequent performance during sleep restriction and recovery and supports the notion set forth by Johnson and colleagues (2004) that a simple reservoir conception is not accurate for describing and predicting performance during sleep restriction and recovery. Indeed, these data concur with the assessment of a need for a modulated concept of the homeostatic process that includes its capacity as varying as a function of sleep history. In addition, these data may inform the development of optimal work schedules, especially with regard to predicting amounts and scheduling of recovery sleep.
Detection of driver drowsiness using EEG alpha wave bursts – comparing accuracy of morphological and spectral algorithms

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Objectives: Driver drowsiness is recognised as a contributing factor in motor vehicle accidents. It is important to develop technology and countermeasures to detect the onset of drowsiness that causes dangerous deterioration of driving performance. A number of features of electroencephalogram (EEG) in particular emergence of alpha wave bursts (8-13 Hz) have been reported to be associated with transition from alert to drowsy state. The aim of this study was to estimate accuracy of detecting onset of drowsiness by the EEG signal analysis algorithms based on identifying alpha bursts in a driver simulator environment and specifically compare an advanced pattern based approach versus conventional spectral techniques.

Methods: Forty-five multi-hour driving sessions on a ‘real car’ type driving simulator were conducted on individuals aged between 21-60 years including collection of physiological, video and driving performance data. A total of 177 episodes of transition from alert to drowsy state were scored using expert assessment of video images including driver’s face, steering wheel and driving scenery. Prototype algorithms were developed to detect transient increases in alpha activity in the frequency domain as well as the actual burst patterns using heuristic morphological rules. The latter approach had the advantage of yielding additional parameters such as the number of waves within the alpha burst, its magnitude relative to the background EEG as well as presence of higher frequencies and homogeneity of periods and amplitudes within the burst. Subsequently the algorithms for detecting drowsiness onset based on the alpha burst information for the central and occipital EEG sites were tested for different thresholds thus enabling estimation of sensitivities and positive predictive values (PPV) and modelling of receiver operating characteristics (ROC).

Results: The spectral algorithm has the following combinations of sensitivity/PPV values: <0.01/0.995, 0.07/0.99, 0.555/0.98. The best morphological algorithm was found to be more accurate with the respective values: 0.53/0.995, 0.61/0.99, 0.67/0.98. The most accurate algorithm used the minimum number of 4 waves in the alpha burst with numbers 3, 5 and 6 still achieving higher accuracy than the spectral approach. Using additional morphological parameters of relative alpha burst magnitude, absence of higher frequencies and homogeneity of periods improved sensitivity by 0.005, 0.021 and 0.002 respectively for the same PPV values.

Conclusion: The morphological algorithm for detecting alpha bursts enables higher sensitivity for identifying onset of drowsiness than the conventional spectral approach particularly for practically acceptable small rates of false positives. Overall the accuracy of the tested EEG based algorithms was found to be limited with at least 30% of drowsiness onset events undetected due to significant prevalence of people with suppressed alpha activity, effects of signal artefacts and occasional unreliability of observer drowsiness rating. The reported results justify further development of intelligent EEG processing techniques as well as less intrusive hybrid solutions for detecting driver drowsiness.
Gene Expression Changes in Response to 36 Hours Sleeplessness

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Objectives: Discover by microarray analysis genes that change expression levels over time in response to 36 hours of total sleeplessness. Genes found to change over time will be used to increase our understanding of the biology of fatigue and develop assays for use in forensics and improved regulations.

Methods: Air battle managers were recruited to participate in the study; total RNA was purified from four blood samples drawn from each participant at approximately 24-hour intervals to diminish circadian effects in our analysis. Samples were drawn beginning the day before the sleepless period began and ended about 22 hours after the sleepless period ended to measure recovery. The purified RNA was amplified and used as target material for Affymetrix hGU-133plus2.0 GeneChips(R). A test statistic estimating deviance from static expression over time ranked genes in order of greatest to least probability of differential expression, and gene lists were taken from the output for further analysis.

Results: The most stringent list contained genes considered most likely to be useful in development of an assay for fatigue. These will be targeted for further investigation by assays such as quantitative polymerase chain reaction in subject samples from this and other studies. This list is enriched for genes that play a role in hematological system development and molecular transport. A role for calcium in the response to fatigue is strongly implied by the presence of genes that bind and/or are regulated by this ion (annexin, PITPNM2, REPS2) and a fourth gene, PTPRJ, that controls intracellular calcium levels.

The biology of fatigue was investigated using a less stringent list. Genes involved in signaling through multiple pathways are represented in this gene list. Pathways represented include: B-cell, insulin, toll-like, LXR/RXR, and glucocorticoid receptors; GM-CSF, VEGF, and IL-12 extracellular effectors; ERK/MAPK as a mediator; and the NFk-B transcription complex as an intracellular effector.

Conclusions: From a research perspective, fatigue can be divided into two categories, chronic and acute. Chronic fatigue is defined as resulting from repeated cycles of reduced sleep where sleep debt accumulates over a period measured in weeks or months. Conversely, acute fatigue defines the sleep debt that arises due to total sleeplessness over some number of days. The results of this study increase our understanding of fatigue at the molecular level and are the basis of tests for fatigue that add to the aerospace medicine tool bag. These tests are under development for potential causal determination in accident investigation and will result in a real-time assay allowing for an on-the-spot determination of fitness-to-perform leading to decreased accident and incursion rates across the aviation and transportation industries.
Objective: Drivers' ability to react to unpredictable events deteriorates when exposed to highly predictable and uneventful driving tasks. Particularly, highway design reduces the driving task mainly to a lane-keeping one. Such a task provides little stimulation and is therefore monotonous. It contributes to hypovigilance and road crashes as drivers are often not aware that their driving performance is impaired. Monotony increases fatigue. However, the fatigue community has mainly focused on endogenous factors leading to fatigue such as sleep deprivation. This paper focuses on exogenous factors contributing to hypovigilance.

Approach: This paper reviews Intelligent Transport Systems (ITS) based interventions that model and predict hypovigilance due to monotony. Objective measurements of the effects of monotonous driving conditions on the driver and the vehicle’s dynamics is systematically reviewed with the aim of justifying the relevance of the need for a mathematical framework that could predict hypovigilance in real-time.

Results: Vigilance state could be assessed with oculography, skin conductance and driving performance (particularly in terms of lane positioning and steering wheel movements). Although electroencephalography (EEG) is one of the most reliable measures of driver’s vigilance, it is obtrusive. We show that Hidden Markov Models (HMMs), which have been extensively used to predict human behaviour, could predict driver’s hypovigilance. A HMM models the evolution of vigilance states with time and correlates these vigilance states (hidden variables) to the surrogate objective measures of vigilance states. This approach enables to accurately predict from observable variables the time when the driver is hypovigilant (i.e. without the use of an EEG).

Conclusion: Outlined is a vision for future research in the modelling of driver vigilance decrement due to monotonous driving conditions. A mathematical model for predicting driver’s hypovigilance using information like lane positioning, steering wheel movements and eye blinks is provided. Such a modelling of driver vigilance should enable the future development of an in-vehicle device that detects driver hypovigilance in advance, thus offering the potential to enhance road safety and prevent road crashes.
A Review of Fatigue Risk Management Systems and their Potential for Managing Fatigue within the UK Road Transport Industry

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Introduction: In 2008, the UK Department for Transport (DfT) commissioned a world-wide study to explore operators’, regulators’ and researchers’ experiences of Fatigue Risk Management Systems (FRMS) in the transportation industry. Based on the findings, the potential of FRMS to improve the management of fatigue risk in UK road transport was assessed and guidance provided on how FRMS could be adapted to the UK operating environment.

Approach: The research consisted of four tasks:

i) Literature review of materials on FRMS released by academic, regulatory and industry bodies;

ii) Survey of researchers, regulators, unions and operators with experience of FRMS;

iii) In-depth interviews with key individuals involved in FRMS, and

iv) Consultation with the UK Road Transport Industry and production of final report.

Results: Overall, the research concluded that FRMS, as an addition to prescriptive limits on driving and work hours, has the potential to meaningfully enhance protection against fatigue risk in road transport. The relatively recent advent of FRMS, plus the complexities associated with reliably assessing and demonstrating improvements in safety in operational environments, means that the effectiveness of FRMS has yet to be comprehensively demonstrated. However, feedback provided by regulators and operators involved in early research trials of FRMS and respondents who completed the survey and/or were interviewed, was mainly positive. The reported advantages of FRMS included enhanced safety, increased operational flexibility and increased awareness of fatigue as a source of driver impairment.

Among the reported problems associated with FRMS were lack of guidance material provided by the regulator and the challenge of moving from a prescriptive to an outcomes-based approach. Of note, several regulators and researchers from Australia commented that the recent introduction of chain of responsibility legislation, which extends the liability for driver fatigue and other offences up the supply chain, will be integral to effective fatigue management in their country.

Initial consultations with UK road transport operators and unions found support for FRMS, with some operators volunteering to be involved in future FRMS research. However, operators were concerned that any new requirements for fatigue management would not apply to European operators (based on the continent) and thereby contribute to varying levels of safety and competitiveness between countries.

Conclusions: The final report provided a number of recommendations, including initiating research on FRMS in the UK. Consequently, in 2009 a sample of road transport operators will be invited to trial FRMS and an objective assessment of the benefits and disadvantages for safety and productivity will be undertaken.
Analyses of Fatigue-related Large Truck Crashes, the Assignment of Critical Reason, and Other Variables Using the Large Truck Crash Causation Study

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Objectives: This presentation reports on a statistical analysis of data from the Large Truck Crash Causation Study (LTCCS). The study was undertaken to improve the Federal Motor Carrier Safety Administration’s understanding of the effects of work schedules on crashes. FMCSA is involved in a process of revising the “hours of service” (HOS) rules for drivers of commercial vehicles. Changes have been proposed and promulgated in a number of areas, including the maximum number of hours of driving allowed in a shift, the minimum number of hours off-duty between shifts, and the maximum number of hours of work allowed in multi-day periods (e.g., calendar weeks). Because prior studies were inconsistent or considered factors that might lead to fatigue or crashes in isolation, FMCSA searched for data sets that could be used for a more comprehensive study of the interactions among the factors its regulations might affect.

The Large Truck Crash Causation Study (LTCCS) constitutes a rich source of data on these factors, and had not yet been exploited fully. The LTCCS collected data on a random sample of approximately 1,000 serious crashes involving at least one large truck during 2001-2003. For each crash, investigators collected data on all vehicles involved. Investigators determined whether there was driver fatigue based on the driver interview and other information such as log-books. Investigators also determined the critical reason for the critical event, from which an indicator of driver critical responsibility can be derived.

Method: In this analysis we focus on the drivers of large trucks involved in these large truck crashes. We used logistic regression to investigate the relationship between driver fatigue and driver critical responsibility and several explanatory variables: hours of driving, hours worked on day of crash, hours awake, hours of last sleep, hours worked last week, time of day, number of vehicles involved, day of week, and truck type.

Results: Among the more striking findings are that sleep-related variables (including time awake, length of last sleep, and average sleep over the past week) are clearly related both to the chance that a large truck driver involved in a crash was fatigued and to the chance that the driver’s actions made a crash inevitable. At the same time, though driving extra long hours in a day or working overtime the previous week appeared to increase fatigue, there was no evidence that they increased the chance that a driver’s actions made a crash inevitable – that estimated probability was almost constant at the longer hours.

Conclusion: This data set makes it possible to explore several important issues related to fatigue, working and sleeping schedules, and responsibility for crashes that are impossible with more limited data. The analyses offered some support to the view that crash risks are greatly influenced by the amount of sleep drivers are able to get. They cast some doubt, however, on the effect of long hours of driving or working over a multi-day period on crash risks.
Comparing fatigue reports across road transport industry sectors

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Objective: Fatigue among short haul and light truck (SHL) drivers has received relatively little research attention compared to long distance heavy vehicle drivers. This paper compares reported fatigue experiences of SHL and long distance heavy vehicle drivers.

Methods: A survey of 321 light and short haul truck drivers was conducted in NSW, Australia. The participants were recruited through companies and were asked questions about their work and their experiences of fatigue and fatigue-related incidents. Responses were compared with those obtained on analogous questions in an earlier national survey of long distance heavy vehicle drivers (n=1007).

Results: The driver groups averaged similar work hours per week. SHL drivers worked predictable day shifts whereas long distance heavy vehicle drivers were much more likely to work at night. Nonetheless, SHL drivers were more likely than long distance heavy vehicle drivers to report that fatigue was a substantial personal problem and were equally likely to have nodded off or fallen asleep in the last year while driving for work. Common contributors to fatigue were identified by the two groups (e.g., long driving hours) but differences were also apparent. SHL drivers were more likely to cite traffic and early afternoon driving as factors contributing to fatigue, whereas long distance heavy vehicle drivers were more likely to cite waiting to load and dawn driving. There were also work-relevant differences in the effects of fatigue reported by the two groups. SHL drivers were more likely to report diminished traffic awareness and attention, and more near and actual collision events. Long distance heavy vehicle drivers were more likely to report vehicle control impairments and run-off-road incidents.

Conclusion: The results suggest that fatigue may be as much a problem for SHL drivers as for long distance heavy vehicle drivers, but the contributors and behavioural manifestations may be somewhat different for the two groups, reflecting differences in the nature of their work and driving environments.
Development of a Multi-Dimensional Scale for Driver Fatigue

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Objectives: Driver fatigue may be monitored using both psychophysiological and subjective indices. Different fatigue responses may have different safety implications, and so it is important to distinguish fatigue components in managing fatigue in transportation. However, development of a comprehensive subjective scale has proved difficult. The overall objective of the current research was to develop a new, comprehensive, multi-dimensional questionnaire for driver fatigue states. Data were collected using a driving simulator, in order to accomplish the following specific objectives:

1. To determine the factor structure of fatigue states during driving;
2. To determine the sensitivity of multiple fatigue dimensions to fatiguing simulated drives;
3. To determine whether fatigue responses to driving related to a validated measure of fatigue vulnerability, the Driver Stress Inventory (DSI: Matthews et al., 1997).

Methods: The various symptoms that may accompany driver fatigue were sampled systematically, on the basis of a comprehensive model of driver fatigue (Hitchcock & Matthews, 2005). Items related to physical fatigue (muscular fatigue, visual fatigue, sleepiness), tiredness-demotivation (exhaustion, boredom), cognitive-attentional symptoms (confusion, performance worries) and coping (avoidance, comfort-seeking, self-arousal). 288 participants (59% female), aged from 18-39, took part in two separate experimental studies, using a Systems Technology, Inc., STISIM Model 400 simulator. Drive duration and workload factors were manipulated within each experiment; this report, which focuses on scale psychometrics, is based on the pooled data from both studies. Participants completed the new Driving Fatigue Questionnaire (DFQ) before and after the drive. They also completed the DSI.

Results: Exploratory factor analysis identified seven correlated factors, corresponding to muscular fatigue, boredom, confusion, performance worries, comfort-seeking, self-arousal, and a single factor representing exhaustion and sleepiness. 6-item scales for each factor were acceptably reliable (αs ranged from 0.83 - 0.94). Fatigue scores were appropriately sensitive to the simulated drives. Performance worries showed the largest increase, and confusion the smallest, supporting the utility of differentiating multiple aspects of fatigue. The DSI includes a fatigue-proneness scale validated in studies of simulated and real-life driving, including a study of truckers. As predicted, the DSI fatigue-proneness scale was the strongest predictor of increased scores on the DFQ fatigue scales following the drive.

Conclusion: Multiple correlated dimensions of driving fatigue states may be measured reliably using the revised DFQ, comprising 7 scales of 6 items each. The scales are appropriately sensitive to the performance of fatiguing simulated drives, and correlate appropriately with a scale for fatigue vulnerability (DSI). The scales appear to provide a useful research tool for evaluating the multi-faceted fatigue responses that may be observed in simulated and real driving contexts. Additional research is needed to further validate the scale, focusing especially on real-life driving environments.

References

Fatigue Management and Culture Change
Enacting/Implementing Change (Track C)

Alternative approaches to prescriptive regulatory changes have recently gained both popularity and a record of success in some areas of the transportation industry. These approaches are shown to require significant change and maturation within the organizational and regulatory culture if they are to become successful in reducing fatigue-related risk. This session includes presentations that describe safety culture change and hard legislative action.

**Session Chair:** William Johnson, Ph.D.
*Federal Aviation Administration*

Bill Johnson is the FAA Chief Scientific and Technical Advisor for Human Factors in Aircraft Maintenance Systems, since 2004. In his 30 years in commercial industry he has worked for engineering companies specializing in industrial human factors and technical training. He has held FAA pilot and mechanic certificates for 40 years.
Objective: The objective of this study was to empirically evaluate organizational factors relating to fatigue in commercial aviation. Several high profile accidents in the late twentieth century brought considerable attention to the role of organizational factors and regulatory oversight in accident causation (von Thaden, Wiegmann & Shappell, 2006). When the issue of fatigue is brought for discussion, regulators, organizations, and individuals agree about its importance in aviation safety, but differ as to how to broach the issue of risk and fatigue countermeasures. According to Goode (2003) pilot scheduling factors have rarely been cited as a cause or a factor in Part 121 aircraft accidents, most likely due to the fact that there is no test for fatigue or the onset of fatigue. However, Goode provides robust scientific literature citing empirical relationships between work patterns and deteriorating performance.

Method: The Safety Culture Indicator Scale Measurement System (SCISMS) represents a four-factor model reflecting Organizational Commitment, Formal Safety Indicators, Operations Interactions, and Informal Safety Indicators which are correlated with the behaviors of the individual and their personal safety attributes (von Thaden, 2008; von Thaden & Gibbons, 2008). In a recent study of flight crews and maintenance technicians (n=2131) in 5 commercial (Part 121) airlines, von Thaden, Spain, and Woo (2008) discovered that fatigue was strongly and significantly related to a number of organizationally relevant variables and differed over organizations.

Results: Fatigue and risk are reverse-scored (such that higher scores indicate less fatigue/risk). Across organizations, self reported fatigue items had relatively high means for calling in fatigued and reporting for duty fatigued (M = 4.86, M = 4.62); with the exception of one negative item: scheduling [pilots] as much as legally possible with little regard for sleep schedule or fatigue (M = 3.52). Fatigue items correlated moderately strongly with frontline supervisors’ (r = .40, .16, and .32, p’s < .01) and organizations’ commitment to safety (r = .39, .14, and .50, p’s < .01). Additionally, the first and third items correlated moderately strongly with organizational risk (r’s = .24 and .26, p’s < .01) and safety behaviors (r’s = .13 and .26, p’s < .01). The mean of the fatigue items varied significantly over organizations (F = 49.70, p < .01), but did not vary significantly between flight operations and maintenance.

Conclusion: Organizational and supervisory commitment to safety were effective predictors of self-reported fatigue (R = .565), indicating organizational culture may play a role in the fatigue employees feel. Fatigue was also significantly related to self-reported safety behaviors, indicating that employees who feel fatigued are also likely to engage in other unsafe acts. Given that fatigue is likely under-reported, these correlates bear deeper consideration. Indicators of organizational safety culture must be specifically identified and clearly measured for any regulatory, procedural, or training changes to be introduced and accepted into an organization. Without identification and measurement of an organization’s safety culture, effective implementation of safe practices may be hindered by unidentified barriers (von Thaden & Gibbons, 2008).

References

Objective: Paper shall establish the clear case, with evidence/data, that fatigue is a significant challenge in aviation maintenance. The paper suggests that the science of fatigue has sufficient maturity for immediate application to reduce the risks associated with fatigue in aviation maintenance. It is the lack of will on the part of labor, management, and regulatory authorities that has been the primary obstacle to implementing programs to reduce fatigue risk in aviation maintenance. The presentation will demonstrate new training media that addresses fatigue issues in maintenance.

Methods:
Presentation shall use two primary sources to make the case that fatigue is a safety issue. The data include a substantial actigraph study, completed by the FAA from 1999 to 2001 and data from the NASA Aviation Safety Reporting System (ASRS). The actigraph data show that the workforce does not have adequate rest. The ASRS data show extensive self-reporting, by maintenance personnel, of events that appeared to be a direct result of fatigue.

With the case made that fatigue is a serious safety issue the author will then show portions of FAA’s Maintenance Human Factors Presentation System. The system combines animations and video with PowerPoint to provide relevant and interesting training that is adaptable to local use.

Results:
The paper/presentation will clearly show the challenge and the proposed solutions, individually mapped to the data. It will offer reasonable and concrete interventions centered on training at all levels of the maintenance organization.

Conclusion:
Evidence shows that fatigue has been a challenge in aviation maintenance for a long time. While it has been a topic of research and discussion it has not had the necessary industry-wide attention to mitigate the associated risks. The time has come to address this issue with greater resolve. A viable solution is demonstrated.

Paper Summary:
For over ten years the National Transportation Safety Board has listed worker fatigue on the list of “Most Wanted” challenges to aviation safety. While there is an abundance of data pointing to the fatigue risks there has not been a demonstrated industry or government will to address the challenge sufficiently. This paper and presentation will show the fatigue data from multiple sources. The paper will argue that there is plenty of proven science to address the challenges. It will map the risk data to specific solutions that can be applied immediately. It will also demonstrate one training solution.
The IOM recently estimated that fatigue-related crashes comprise almost 20 percent of all serious motor vehicle crash injuries in the U.S., a proportion that would account for 60,000 debilitating injuries and 8,000 fatalities annually. An estimated 7.5 million drivers in the U.S. admit to having fallen asleep at the wheel within the past month, with another 7.5 million drivers admitting to having done so during the prior 2-6 months, 33% of whom drifted into another lane or onto the shoulder, 19% crossed the centerline, and 10% ran off the road. Despite the scope of this public safety issue, only New Jersey law specifies that “driving a vehicle while knowingly fatigued shall constitute recklessness.” In this legislative vacuum, some drivers in Colorado, Maryland, Massachusetts, Michigan and Florida have been convicted of vehicular homicide (or similar offences) for negligent driving when impaired by drowsiness (as have drivers in Britain, Japan and Australia), whereas others have not even been charged with a crime. Among those convicted, some have gone to jail; others have received small fines.

Over the past 50 years, drinking and driving has become both illegal and socially unacceptable. Three years ago, the Sleep Research Society, the National Sleep Foundation and the American Academy of Sleep Medicine jointly endorsed model legislation in Massachusetts to: (1) educate drivers about the hazards of drowsy driving; (2) train police to recognize signs of drowsy driving; (3) collect drowsy driving information on state motor vehicle accident forms; and (4) establish the crime of falling asleep or being impaired by drowsiness or sleep deprivation while operating a motor vehicle. The operational definition for impairment included “drowsiness of which the person was aware or could reasonably be expected to be aware” or “evidence that the operator of a motor vehicle was awake for at least 22 of the prior 24 hours or at least 140 hours of the prior 168 hours.” As a result of these efforts, the Junior Operators’ Law in the Commonwealth of Massachusetts was amended in 2007 to: (1) require a public education campaign for student drivers and parents that includes information on the hazards of drowsy driving; (2) restrict junior operators from driving between 12:30 a.m. and 5:00 a.m.; and (3) establish a special commission to study the impact of drowsy driving on highway safety and the effects of sleep deprivation on drivers while operating motor vehicles.

Most people in drowsy driving crashes admit that they were drowsy before the crash. Moreover, 97 percent of drivers in sleep-related crashes admit to driving drowsy during the year before the fall-asleep crash. Like alcohol, drowsiness impairs judgment, increases distractibility and heightens risk-taking behavior. Yet, the sleep-deprived driver often continues to drive even after dozing at the wheel. For these reasons, education regarding the hazards of drowsy driving, law enforcement training, cleared rumble strips on state and federal highways and legal penalties for drowsy driving are critical to precipitating the cultural changes necessary to prevent this increasing public safety hazard.
Motor vehicle crashes before and after implementation of the Massachusetts Junior Operators License legislation

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Objective: Teenage drivers have the highest crash risk of any demographic group with motor vehicle crashes accounting for one-third of all deaths of 16- to 18-year-olds. The fatal crash rate for 16-year-old drivers is twice as high at night as it is during the day. On January 3, 2007, then Governor Mitt Romney signed into Massachusetts’ law H.5378, Driver Education and Junior Operators Licenses. The legislation increased education, supervised driving, and enforcement. As a result of the efforts of the Sleep Research Society Presidential Task Force on Sleep and Public Policy, several provisions in the legislation also target drowsy driving. All junior operators now have restrictions imposed when driving from 12:30am to 5:00am, a time of high risk of a motor vehicle crash due to drowsiness. Driver education programs for junior operators now include information about the hazards of drowsy driving. We aimed to assess the impact of the legislation on the number motor vehicle crashes involving teenage drivers in Massachusetts.

Approach: For the first stage of the analysis, we obtained from the Massachusetts Registry of Motor Vehicles motor vehicle crash data in which the driver was 16 or 17 years of age, over approximately a 2-year period. 19,470 records were retrieved, of which 17,972 were found to be complete and/or valid cases. We compared the total number of crashes occurring during approximately the 1 year period before implementation of the legislation to the equivalent time period 1 year post-implementation. In a separate analysis, we examined the number of crashes that occurred from daytime compared to nighttime. Compared to the pre-implementation period, during the post-intervention period we found approximately 30% reduction in the number of crashes occurring in the daytime and approximately 70% reduction in the number of crashes occurring in the nighttime. Compared to the pre-implementation period, there was approximately 50% reduction in crashes resulting in serious injury during the post-implementation period.

Results: Preliminary results indicate approximately 35% reduction in the total number of motor vehicle crashes in the post-implementation period. We then examined the number of crashes that occurred from daytime compared to nighttime. Compared to the pre-implementation period, during the post-intervention period we found approximately 30% reduction in the number of crashes occurring in the daytime and approximately 70% reduction in the number of crashes occurring in the nighttime. Compared to the pre-implementation period, there was approximately 50% reduction in crashes resulting in serious injury during the post-implementation period.

Conclusion: These results indicate that after the legislation was implemented, there was a substantial reduction in total number of motor vehicle crashes and number of crashes causing serious injury. In order to test whether these changes are likely to be attributed to the introduction of the legislation as opposed to a non-age specific decrease in the number of crashes, we plan to compare the crash data between different age groups over a longer time period. The greater reduction in number of crashes during the nighttime compared to daytime hours suggests that the provisions in the 2007 junior operator law aimed to reduce drowsy driving among teen drivers have been effective.
Predicting Accidents and Risk
Fatigue and Performance Modeling (Track E)

Historically, it has been very challenging to quantify the relationship between work schedules, sleep schedules and risk of involvement in accidents and incidents. However, recent research has begun to assess these relationships using biomathematical models and software. This work may eventually provide deeper insights into predicting accident risk or provide investigators with tools to help them to assess the role of human fatigue in accidents.

Session Chair: Tom Balkin, Ph.D.
Walter Reed Army Institute of Research

Thomas J. Balkin, Ph.D., is Chief of the Department of Behavioral Biology at the Walter Reed Army Institute of Research (WRAIR). He is also a Diplomate, American Board of Sleep Medicine; a Fellow of the American Academy of Sleep Medicine; and a member of the Sleep Research Society and the European Sleep Research Society. Dr. Balkin obtained his B.S. from Syracuse University in 1975, and his M.S. from SUNY Cortland in 1981. Upon obtaining his Ph.D. in Experimental Psychology from Bowling Green State University in 1984, he served as Assistant Director of the Sleep Disorders Center at the St. Louis University Medical Center for 14 months. In 1985, he joined the Department of Behavioral Biology at WRAIR, where he developed a research program to evaluate the efficacy and performance effects of sleep-inducing medications. In 1990 he was appointed Chief of the Human Psychopharmacology Branch in the Department of Behavioral Biology, and he was appointed Department Chief in 1995. With collaborators from the NIH and WRAIR, he has conducted and published studies of functional brain imaging during sleep and wakefulness, and is recognized internationally in the areas of sleep and performance (he is a coinventor on 7 current U.S./International patents in the area of sleep/performance modeling), functional neuroimaging during sleep, the psychopharmacology of sleep-inducing and stimulant medications, and sleep deprivation. He has been an invited lecturer and keynote speaker at national and international conferences, government research laboratories, and universities; and has served on a variety of panels addressing topics ranging from the measurement of sleep and performance in outer space to the impact of insomnia on quality of life. Recently, he chaired the Non-Advocate Review Panel for a proposal to study ground crew of the Phoenix Mars Lander project for NASA. He is an ex-officio member of the National Sleep Disorders Center Sleep Disorders Research Advisory Board (SDRAB); he is an Associate Editor of the journal Sleep, and he is Vice-Chairman of the Board of Directors (and Chairman-Elect) of the National Sleep Foundation.
Objective: Fatigue may be a major source of human error accidents in the rail industry. However, because there is no reported indicator of fatigue at the time of accidents, it has been difficult to determine the contribution of work schedules to fatigue and human factors accident risk. Biomathematical fatigue models permit the objective assessment of fatigue so that work and rest can be scheduled to minimize fatigue. Such a model could be used as a component of fatigue risk management and to determine the role of fatigue in accidents.

Approach: To be useful, a fatigue model must be validated and calibrated. Validation means that the model predicts fatigue-related performance errors, and calibration means that the model’s predictions can be related to specific levels of human error risk. A valid fatigue model should predict higher levels of fatigue (based on opportunities to sleep and an accident’s time of day) when there exists a greater likelihood of human factors accidents. By comparison, fatigue levels should have a weaker or no relationship to the likelihood of nonhuman factors accidents. The U.S. Federal Railroad Administration (FRA) completed a study to validate and calibrate a biomathematical fatigue model for use in the rail industry. The project examined 30-day work histories of locomotive crews prior to 400 human factors accidents and 1000 nonhuman factors accidents. A biomathematical fatigue model estimated crew effectiveness (the inverse of fatigue) based entirely on work schedule information and opportunities to obtain sleep.

Results: A reliable linear relationship existed between crew effectiveness and the risk of a human factors accident ($r = -0.93$); no such relationship was found for nonhuman factors accidents. This result satisfied the criteria for model validation. The risk of human factors accidents was elevated at any effectiveness score below 90 and increased progressively with reduced effectiveness. At an effectiveness score $\leq 50$, human factors accidents were 65 percent more likely than chance. Human factors accident risk reliably increases when effectiveness goes below 70 when accident cause codes indicated the kinds of operator errors consistent with fatigue, confirming that the relationship between accident risk and effectiveness was meaningful. Analysis of the material damage cost of human factors accidents showed a significant increase with decreased effectiveness or increased fatigue. Human factors accidents when effectiveness was below 70 were 2.4 times more costly than human factors accidents when effectiveness was above 90.

Conclusion: These results indicate that the fatigue model predicts both elevated incidence and severity of human factors accidents.

References

Modeling the Association of Hours-of-Service to Motor Carrier Crash Risk

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Objectives: This paper seeks to explore fundamental questions concerning the modeling of hours of service and motor carrier crashes. Among the factors reviewed are: effects of continuous driving; cumulative driving over multiple days; the effect of rest breaks; and, the effect of driver experience.

Approach: Previously unpublished analyses are conducted with crash and exposure data from 3 carriers collected in 2004. In addition, crash and exposure data from the 1980’s are used for comparison with the 2004 data and revisited to explore the effect on subsequent crash odds of being off duty for 34 hours or more. This analysis is intended to explore the implications of the 34-hour restart policy implemented in the U.S. as part of the recent series of changes in hours of service. Time-dependent logistic regression and survival theory models are constructed using data from both the 1980’s and 2004.

Results: The new analyses of the data sets yielded several findings of interest. Among the findings are:

- Crash odds increase with continuous hours driving. Additional analyses of data from the 1980’s and 2004 confirm the presence of the increase. This finding is at odds with results from the Driver Fatigue and Alertness Study (DFAS) and recent naturalistic driving experiments.
- There is persistent evidence of an increase in crash odds after more than 34 hours off duty. This effect is present in both the 1980’s and 2004 data sets. These findings raise a question about the efficacy of using a 34 hour “restart” policy without additional provisions.
- Rest breaks have a substantial beneficial effect in reducing crash odds. In models using logistic regression, rest breaks reduced crash risk by 9-50% compared to driving with no break. Survival models with a “transplant effect” to capture the influence of rest breaks found that 1-3 rest breaks during a trip significantly reduced the crash odds compared to a trip with no breaks. Specifically, the first rest break had a significant reduction in crash odds that persisted throughout the trip; the second break had an immediate reduction that declined over time, while the third had a marginal initial reduction that declined more rapidly than the second. These are among very few studies to quantify rest break effects. The limitations of the findings are their reliance on data from the 1980’s; the effect of a required 10 hour off-duty time along with other HOS changes implemented in 2004 and 2005 is not clear.
- Additional analysis of 1980’s data confirms a reduction in crash odds for drivers with more than 10 years experience at a firm. The magnitude of the odds reduction is nearly the same as the increased risk with 6 or more hours of continuous driving. This finding is consistent with those in an earlier paper published by the Transportation Research Board using a smaller data set.

Conclusions: The re-examination of old data and the analysis of data from 2004-05 (both involving crash and non-crash event comparisons) raise several questions with respect to recent hours of service studies which find little association between hours driving and crash odds. The paper discusses the implications of these differences and inconsistencies and how they contribute to a persistent uncertainty concerning the empirical basis for safety regulation. Aggregate analyses of yearly total crashes for fleets would seem of limited use as they are unable to isolate the effect of individual policies. Analysis of naturalistic driving data using crash surrogates offer unique opportunities for risk analyses as long as the data obtained are valid surrogates for crashes. One strong conclusion is that policies which discourage rest breaks should be carefully examined for their implication on crash risk.
A multidimensional research on train drivers sleep and fatigue: from predictive models to actual data

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Objectives. Hours of work of train drivers are known to be irregular and likely to induce fatigue that may impact safety and health. In 2007, the French railways company, initiated a comprehensive research on fatigue and sleep of train drivers. The research covers the various schedules typical of the SNCF operations: high speed, national, regional, freights and maneuver trains. The objective is to evaluate the impact of these hours of work on fatigue, health and safety and to figure out how fatigue could be prevented at different levels of the organization from the scheduling process to actual operations.

Method. The research covers 4 steps: (1) a chronobiological evaluation of specific schedules including the use of biomathematical models, the Fatigue Risk Index (FRI) and the Sleep Wake Predictor (SWP) (2) the analysis from existing reporting data on health and occupational accidents and from interviews of managers and occupational medical doctor of the drivers (3) a survey by questionnaire to investigate the impacts of hours of work on fatigue, health and social life (4) the measurement of sleep, subjective sleepiness (KSS), physiological alertness (EEG/EOG), and observation data on a sample of 25 train drivers on 42 trips. Results. The chronobiological evaluation shows that the freight schedules may induce the highest risk of fatigue because of frequent night duties and backward rotations of shifts. The analysis of the reporting data shows that fatigue is reported and investigated in very variable ways making difficult to evaluate precisely its contribution in safety and health data. This emphasizes the need for methodological guidelines to help safety analysts taking into account fatigue. The survey shows also a large variability of the train driver answers with respect to the impact of schedule. Morning shifts are associated with a negative impact on sleep quality and quantity. It is worth noticing that the drivers’ perception of the impact does not always confirm the predicted risk of fatigue by the FRI. This is mainly explained by the impact of the nature of the activity (TGV, freight,..) and the social aspects that are not taken into account by the predictive model. Finally, the field data collection on fatigue and sleep during shifts shows that night and morning shifts are associated with a significant reduction in sleep times and quality reaching in average 45% of the reported sleep need after night shifts. Sleep quality and quantity is also significantly impaired when rests are taken at the hotel compared to the rests taken at home. Sleepiness level is variable from one trip to another, some train drivers showing clear signs of microsleeps during the driving. These microsleeps resulted in significant changes of the driving behavior, especially on the breaking strategies and the use of automation. Results show that the SWP was able to predict well the sleep quantity and the subjective sleepiness at the end of the trips. Conclusion. Results are discussed regarding their impact on the scheduling process, in the light of the recent progress in Fatigue Risk Management Systems.
Transient Risk Factor Models for Fatigue and Human Factors Rail Accidents

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Objective: Transient risk factor accident models have been used with case cross-over epidemiological analysis to quantify and qualify the relative risk of rare event transient risks, as well as, identification and ranking of various accident triggering events, and short interval high risk environmental factors. When possible, case cross-over analysis can provide three distinct advantages (1) only data from the accident case is required, (2) subjects involved in the accident are their own controls, and (3) subject-level confounders can be easily controlled when used with the transient risk factor accident model. This type of experimental design and analysis can provide additional methodology for evaluating high risk intervals, environmental risk factors (weather, daylight, and obstructions), human factors (fatigue, health event, and distraction), accident onsets and triggers, and the relative risk of recurrent and rare accident events.

Approach: This paper describes the fundamentals of transient risk factor modeling and how it could be used to better analyze rail operations accidents and near miss incidents for rare events involving short high risk hazard periods and various types of triggering events. Short risk periods can be a few seconds to a few minutes. Each hazard period contains one or more triggering agents that can initiate an onset period resulting in an accident. If no accident results the model can represent a near miss incident outcome.

Results: Public access rail accident case databases do not contain all of the information and data needed to construct and analyze accurate transient risk factor accident or near miss incident models. However, the case information that is available does allow for preliminary subjective and count analysis presentation of what these models might look like in explaining how transient risk factor rail accident model prospective studies could be designed and used effectively to analyze accident risk factors, triggers, relative risks, and probabilities of outcome and severity.

Limited analysis of existing rail accident cases provides at least some idea of the possible components for this type of accident modeling. For example, in exploring the possible uses of the transient risk factor model, a retrospective analysis of 28 rail yard accidents cases for 1997 revealed 19 transient risk accident “triggers” for 28 rail yard accident case subjective reports for 1997. Both single and multiple triggers were identified The top six accident trigger causes were “fouling track”, “miscommunication or non communication”, “bell not sounded and/or headlight not illuminated”, “alcohol influence”, “exceeded speed”, and “failure to yield right of way to oncoming train”. There is presently insufficient public access accident and incident case information and analysis to fully construct transient risk factor models for each accident case. However, using the information that is available, a number of representative transient risk models are presented for examination and discussion.

Conclusion: This paper presents the major elements of transient risk factor case cross-over epidemiological method and suggests how it could be applied to the analysis of rail operations incidents and accidents. Examples from current research team efforts in industrial injury analyses as well as rail accident case information are used to illustrate how transient risk factor models and case cross-over analyses could provide a novel and more effective approach to identifying and evaluating short interval high transient risk environments, high risk time intervals, and triggering events in rail operations accidents. This methodology could provide more efficient and effective risk elimination and reduction intervention strategies based on an accurate hierarchy of relative risks for certain types of accidents and their outcome probabilities and severities.
Supporting Technologies for Testing, Detecting and Counteracting Drowsiness
Supporting Technologies (Track D)

There are several new and exciting developments in testing, detection and counteracting operator drowsiness across transport platforms. This session highlights some of this new work. Discussions will focus on fatigue impairment testing, shift work adaptation testing, work scheduling, and fatigue countermeasures.

Session Chair: Gregory Belenky, M.D.
Washington State University

Greg Belenky is Research Professor and Director of the Sleep and Performance Research Center at Washington State University. He leads one of the few laboratories in the world specializing in the study of human sleep and sleep loss and their role in performance, productivity, safety, health, and well-being. His laboratory and field studies support the emerging science of managing sleep in order to sustain performance, productivity, safety, health, and well-being.
Seeking A New Way to Detect Human Impairment in the Workplace

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Objective: Human impairment in the workplace can have various causes, including fatigue, alcohol and drugs, with fatigue being the leading cause of accidents in the transportation industry. Traditional fitness-for-duty screening mostly targets alcohol and drug abuse through testing of urine, blood, hair, or breath analysis. These traditional tests are expensive, invasive and don’t give instant results. They also require staff supervision and cannot be applied on a daily basis. However, newer concepts of impairment testing target fatigue and impairment, regardless of its cause, with instant results. Related development efforts include technologies based on cognitive and ocular measures. Here, we present a new cognitive impairment test. The BLT impairment test (developed by Bowles-Langley Technology, Inc.) is a brief, inexpensive, computerized shape recognition test (SRT) that requires the user to make a Yes/No decision about whether all items in a given screen are the same. After a series of 50 screens the resulting speed/accuracy-based score is compared to the user’s baseline. For refinement and evaluation of the SRT, three studies were conducted: 1) a stability trial, 2) a laboratory sleep deprivation trial, and 3) a workplace feasibility trial with emergency department doctors. The goals were to optimize test design, to assess validity, reliability and sensitivity of the SRT, to refine the scoring algorithm, and to evaluate feasibility and acceptability in a workplace situation.

Methods: 1) Stability Trial: A total of 100 healthy subjects (aged 21 to 60 years) completed ten SRT sittings of about 15 minutes each using all of 100 different shapes. During each sitting, the subjects were presented with 250 screens including identical and different shape combinations. 2) Laboratory Sleep Deprivation Trial: Fifteen subjects (aged 25-50 years) participated in a two-day sleep restriction trial with three hours of sleep in the morning before the second test day. On each test day, they completed ten bi-hourly test sessions (starting at 1200). Each test included several subjective alertness/mood tests (e.g., Visual Analog Scales, Thayer Activation-Deactivation Adjective Checklist, Karolinka Sleepiness Scale), performance tests (5-min performance vigilance task, 25-min driving simulation task, 50-screen four-choice reaction time test), and four SRTs. 3) Workplace Feasibility Trial: Twenty physicians of a medical emergency department participated in testing on ten consecutive work shifts. Test sessions were conducted before, during and after each shift and included subjective alertness/mood tests, four-choice reaction time test, and two SRTs. Participants also completed sleep diaries and daily operational performance questionnaires, and post-study operational feasibility questionnaires.

Results and Conclusion: Using Item Response Theory analyses, the stability trial helped optimize the test design by adjusting for item difficulty. The results of the ongoing analysis of the laboratory and workplace trials suggest some association between the SRT and circadian factors. Correlations between the SRT and other measures were used to refine the SRT scoring algorithm (adjust the impact of accuracy and speed, of correct and incorrect responses, and of screens with similar and dissimilar items). Based on the observed variability it is concluded that the current test version may be more sensitive to severe impairment rather than reflect gradual alertness changes, and further test refinements aim to increase validity, reliability, and sensitivity. The workplace feasibility assessment indicated that the majority of the participating emergency doctors would find routine impairment screening acceptable, and that they believe such testing may encourage other fatigue management actions by employers.

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Shiftwork Adaptation Testing System (SATS)

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Objective: As the transformation from a diurnal to a 24-hour society accelerates, and requires a greater percentage of the workforce to participate, the problem of individual shiftwork intolerance is emerging as a significant cause of human fatigue and health problems. However, no reliable methods for predicting shiftwork intolerance have yet been developed. Many studies have been focused on different physiological characteristics, such as 'Morningness/Eveningness', ‘Rigidity/Flexibility’, ‘Introversion/Extroversion’, and ‘Harm/Avoidance’, when looking for correlations between personality and night work adaptability. Because human beings are so complex, it is more likely that a combination of different biological, psychological, behavioral and sociological factors leads to adaptability/tolerance or non-adaptability/intolerance. This is clearly indicated by the large numbers of documented cases of shiftwork tolerant and non-tolerant people in any given industrial or transportation operation.

Approach: A web-based expert system (the Shiftwork Adaptation Testing System, SATS) was developed to predict how well an individual is likely to be able to tolerate shiftwork. SATS was designed to learn from existing case examples, building a database of positive and negative examples of shiftwork adaptation and using modern tools for classification and prediction such as Artificial Neural Networks (ANNs). The complete SATS comprises several components, including (1) a three part questionnaire, (2) a data base with data pre-processing and feature extraction, (3) a data classification module using Self-Organizing Maps (SOM) and (4) a shiftwork tolerance prediction module using Error Back Propagation Networks (EBPN).

Results: The Shiftwork Adaptation Testing System (SATS) was trained using absenteeism and questionnaire data of 36 employees with a shiftwork experience of at least 10 years. Preliminary results indicate a significant correlation between absenteeism and SATS score.

Conclusion: SATS is expected to find applications as a support tool in the hiring process for around-the-clock operations by predicting the adaptability/tolerance of potential recruits for night work, shiftwork and other 24-hur operations.
The Work Schedule Manager Credential: Development of a New Approach to Managing Worker Fatigue

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Objective: Non-traditional 24-7 work schedules have increased steadily in the past century with concomitant increases in social stress, health and safety risks. A significant body of research has substantiated that reduced work flexibility, extended workdays, and irregular work hours associated with 24-7 scheduling can dramatically increase the likelihood of work-related fatigue. One strategy for mitigating work-related fatigue is to improve the management of complex, multi-shift work schedules through education and training. Currently, no uniform training exists in the United States for individuals who are responsible for managing work schedule operations. The vast majority of supervisors and managers who perform shift work scheduling have no formal training in the human factors of fatigue, sleep disorders, circadian biology, scheduling best practices, or the health and social impacts of shift work. In addition, staffing and schedule management is often assigned as a collateral responsibility, secondary to other management, administrative, and technical duties. It is therefore considered crucial that those responsible for managing complex round-the-clock work schedules receive the training and tools necessary to properly perform this job.

Approach: Research is currently underway to provide evidence of the need to develop a credential for work schedule managers. The first phase in this process is to establish a comprehensive understanding of the job of a work schedule manager. To our knowledge, no published studies provide a detailed and thorough analysis of the job requirements, skills, abilities, and knowledge required to perform shift work scheduling. In fact, there is no entry for “work scheduler” or “shift scheduler” in the O*NET Occupational Information Database. Thus, the objectives of the current study include (1) conducting a job analysis to provide useful and complete job description criteria for work schedule managers, and (2) systematically assessing the gap between optimal work schedule management and current practices. These objectives are being met through interviews, surveys, and focus groups with subject matter experts (SMEs) in applied and academic settings, as well as with job incumbents in industries such as transportation, healthcare, manufacturing, and law enforcement.

Results: Initial interviews have confirmed the need for greater levels of expertise in shiftwork scheduling. Job incumbents overwhelmingly report that most of the scheduling training they receive is on-the-job, with little formalized instruction. SMEs have suggested that work schedule managers have knowledge of such things as the impact of work hours on performance, scheduling best practices, skill in problem solving, and the ability to balance conflicting demands.

Conclusion: This presentation will highlight ongoing research concerning the management of shiftwork schedules and present preliminary quantitative and qualitative results using a job analysis framework. The job analysis approach provides a useful, systematic process for defining job requirements and identifying training needs. The training and credentialing of work schedule managers may facilitate a new, effective approach to overall fatigue management, as well as safer and more efficient work schedule operations.
Fatigue Countermeasure Rebound: Temporary Alertness Gain from Caffeinated Chewing Gum Repaid as Excessive Sleepiness after Countermeasure Cessation

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Objective: Fatigue countermeasures either correct the underlying sleep debt (e.g. naps) or suppress the effects of the sleep debt (e.g. alertness stimulants). Since it is well established that the initial stimulation phase of illicit pharmaceuticals (e.g. cocaine, amphetamines, marijuana) is followed by a depression phase with excessive fatigue, we examined whether commonly used legitimate fatigue countermeasures might have a similar effect.

Methods: Six subjects (aged 20-30) participated in a two nights (one baseline night, one with fatigue countermeasure night) driving simulator study evaluating a caffeinated chewing gum fatigue countermeasure. The participants started driving at 10:00 P.M. after a day of normal activity and at least 16 h of continuous wakefulness. They had to complete seven monotonous driving sessions lasting 40 min. On the countermeasure nights, the fatigue countermeasure was applied in the third session (one stick of gum=low dosage), and in the fifth and sixth sessions (ad libitum use of chewing gum=high dosage). Electrophysiological signals (four EEG channels, two EOG channels, EMG, ECG) were continuously recorded throughout the experiment, and the subject’s face was video-taped during each driving session. In addition, driving performance data (Lane Deviation Variability, LDV, and Heading Error Variability, HEV), subjective sleepiness measures (Visual Analog Sleepiness Scales, VAS, and Thayer Activation-Deactivation Checklist) and Heart Rate Variability (HRV) were recorded. The data were first analyzed by two independent experts utilizing video camera and electro-physiological data for the occurrence of Micro-Sleep Events (MSE) during each driving session. Prolonged eyelid closures, nodding-off, driving incidents and drift-out-of-lane accidents (recorded as LDV and HEV), and MSE were also analyzed. MSE were also analyzed using a Neuro-Fuzzy Hybrid (NFH) System.

Results: An approximately 50% suppression of MSE was obtained with low dosage gum and an 80% with high dosage gum, as compared to non-countermeasure nights. In the seventh session, a MSE rebound with a MSE frequency 10% higher than during non-countermeasure nights was observed. This rebound was observed in all parameters, except subjective VAS scores.

Conclusion: This study suggested that alertness stimulants, while having short-term value as a fatigue countermeasure, should be used with caution.
Assessing the Effects of Extended Work Periods on Alertness and Performance
Define and Measure Fatigue Problem (Track A)

While the general emphasis of this session focuses on extended duty periods as contributory hazards in ground and aviation environments, two papers will also examine accident causation and fatigue monitoring technologies. One presentation will specifically examine fatigue as a contributory hazard to accidents. Another paper will discuss technology to detect unsafe driving and possibly sleep-deprived drivers.

Session Chair: John Caldwell, Ph.D.
Archinoetics, LLC

Dr. John Caldwell is the Senior Scientist at Fatigue Science in Honolulu. He sleep, psychophysiology, and pharmacology research and development aimed at improving safety and performance in operational contexts. He has conducted numerous studies in specialized laboratories and specially-instrumented flight simulators and aircraft. He has published one book, six book chapters, over 30 first-author peer-reviewed scientific papers, and more than 60 first-author articles in user-focused journals, conference proceedings, and government reports. He is a consultant for United Airlines, NASA, the Army, the Air Force, and the Marines. Before joining Fatigue Science, Dr. Caldwell was employed by the U.S. Air Force, conducting research, training, and consultations designed to enhance and sustain the effectiveness of the operational aviation community. Previously, he was in charge of aviation sustained operations research at the U.S. Army Aeromedical Research Laboratory at Fort Rucker, AL. In addition to his work with military soldiers and pilots in general, he has completed two assignments with NASA’s Human Factors Division at Ames Research Center in California where he focused on counter-fatigue research and applications.
Fatigue Accident/Incident Causation Testing System (FACTS)

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Objective: Fatigue is one of the most pervasive yet under-reported causes of human error-related accidents in transportation operations. Some studies have suggested that 25% - 30% of driving accidents are fatigue related, while others estimate that only 1% - 4% of human errors on the highway are attributable to the people falling asleep or being drowsy. One reason for this wide disparity is that there is no simple tool or objective way for investigators to collect the data needed to accurately investigate the role of fatigue in accident causation.

Approach: To bridge this gap, a Fatigue Accident/Incident Causation Testing System (FACTS) was developed, consisting of a diagnostic survey instrument, along with a weighted risk model based on Fuzzy Scalable Monotonic Chaining (FSMC), to help investigators readily determine the role of fatigue as a causal factor in driving accidents using standardized criteria. The “fuzzy” approach was chosen as a robust algorithm for probability calculations involving numerical and verbal attributes, particularly with the possibility of missing data and the relatively uncertain circumstances of an accident event.

Results: Fatigue probability results obtained from FACTS were compared with the National Transportation Safety Board (NTSB) 1995 analysis of 107 heavy truck accidents. In each accident the drivers survived and were able to provide information about the circumstances leading up to the accident. The NTSB was thus able to collect relatively good information about the driver’s duty/sleep pattern for the 96 hours prior to these accidents. Using the data gathered by the NTSB in its accident investigations, the case by case data was entered into FACTS. A high degree of correlation was found between FACTS decisions and the consensus of the NTSB safety board regarding the fatigue/non-fatigue cause of the accidents. The few accidents where a disagreement was found between NTSB and FACTS will be analyzed in detail.

Conclusion: The results suggest that FACTS can serve as a valid, expert tool for accurately determining the probability of fatigue as a causal factor in transportation accidents.

References

Sleepiness and driving performance: a simulator study of the effects of sleep loss and time of day

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Objectives: Sleepiness is involved in at least 15-20% of the road crashes. The aim of the present study was to identify sensitive indicators and combination of indicators of sleepiness when driving across a complete 24-hour period of wakefulness and during partial sleep loss.

Methods: The study included 14 (of which 7 were females) randomly selected, healthy, drivers that were examined during two conditions; baseline sleep (BS, 23.00 – 07.00h) and partial sleep loss (PSL, 03.00h – 07.00h). Each condition included 6 one-hour driving sessions. The driving sessions were evenly distributed across the 24-h day. In total, 12 hours of driving were recorded for each participant. The simulator includes a large moving base car (Volvo 850). During the experiment, EEG and EOG were continuously recorded and self-ratings of sleepiness (KSS, 1 very alert – 9 very sleepy) were given every tenth minute by the driver. Standard deviation of the lateral position (sd lat) was used as a metric for driving performance.

Results: KSS was significantly higher during PSL (p<0.001) and during nighttime (p<0.001), and increased across each driving session (p<0.001). Visually scored sleepiness (based on EEG and EOG recordings) and blink duration also increased during nighttime (p<0.05) and towards the end of the driving session (p<0.01). In general, the effects of sleep loss were relatively weak. Many participants reached extreme levels of sleepiness during late night hours. Sd lat showed a similar pattern as physiological sleepiness and increased during nighttime (p<0.01) and across the driving session (p<0.01). Another 15 variables were analyzed which showed weaker (often non-significant) effects of time of day and sleep loss. The results showed pronounced individual differences, in particular for driving performance and physiological indicators but less so for KSS. An analysis of the between-subject variation showed that the influence of individual differences was smallest for KSS, i.e. the fixed (manipulated) effects were clearly larger than the differences between individuals. The between-subject variation coefficient was at least 4 times larger for sd lat compared to KSS. The best objective predictors of incidents (lane departures) and severe subjective sleepiness were the standard deviation of the lateral position and the ratio between the blink amplitude and the peak closing velocity. Blink duration was also a good predictor of incidents and severe subjective sleepiness.

Conclusion: The results identifies subjective sleepiness, the standard deviation of the lateral position and variables related to eye closure as sensitive to manipulations of sleep loss and being awake at night time. However, individual differences are at least as important as the sleep loss manipulation and there is a need to identify the basis of such differences.

The study was sponsored by IVSS and carried out within the Swedish research project DROWSI.
Extended Flight Duty Periods: method to assess alertness-related flight safety

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Objectives: Because alertness and vigilance may reach unacceptably low levels when maximum permissible Flight Duty Periods (FDPs) are extended, crew augmentation together with in-flight relief are mandated by the authorities. To assess the effectivity of these regulatory measures in terms of alertness-related flight safety, field studies may provide useful information. In this context, a field study was performed on extended flight schedules involving 13-15 hr FDPs with augmentation of 1 pilot and in-flight rest facilities consisting of one row of 3 economy seats.

Method: During one complete duty roster and related days off pilots performed test sessions on a PDA and used an actigraphy device during home and in-flight sleep. Wake-up, pre-duty, pre-rest, post rest, top of descent (TOD), and post-duty test sessions involved completion of the 7-point Samn-Perelli scale (SP), 9-point Karolinska Sleepiness Scale (KSS), performance of a 5-min vigilance task (VigTrack-TNO), and questions about sleep, comfort, and operational conditions.

Results: 36 Pilots were included in the analysis. Mean FDP was 13:58 hr (range 12:45-15:55 hr), started on average at 01:22 pm, and ended at 03:20 am. The mean onboard rest period was 135 min. The mean in-flight sleep efficiency was 16% (subjective) and 37% as measured by actigraphy, while 42% of the pilots did not sleep at all. The majority of pilots reported that the crew rest facility was not comfortable, that ventilation was insufficient, and that sleep was disturbed by light, noise, and passengers. Compared with Pre-Duty scores, TOD scores during extended FDPs had significantly increased with 105% (SP), 100% (KSS), 32% (VigTrack - root mean square of tracking error), and 11% (VigTrack - reaction time). The longer the FDP on heavy crew duties was, the higher fatigue and sleepiness levels were at TOD, and the more vigilance performance was impaired. Pilots who reported longer sleep in the crew rest facility had lower fatigue and sleepiness levels at TOD. In-flight sleep efficiency was much lower than found in previous studies of in-flight rest, where sleep efficiencies ranged between 50 and 70% depending on the quality of the rest facility (bunk, business class seat, flight deck seat). Means and frequency distributions of scores of fatigue, sleepiness, and vigilance performance at TOD can be used to assess alertness-related flight safety.

Conclusion: It is concluded that the conditions related to the specific crew rest facility were not conducive to sleep. This indicates that measures should be taken to improve in-flight sleep quality and efficiency in these extended FDP operations. Although mean fatigue, sleepiness, and vigilance scores at TOD approached the risk zone, it was concluded that, on average, flying duty was permissible. However, frequency distributions of scores indicated that in 20% of the pilots the level of alertness was to be considered as insufficient to safely perform flying tasks. Criteria to assess alertness-related flight safety and recommendations to implement a Fatigue Risk Management System (FRMS) will be discussed.
Extended Driving Impairs Nocturnal Driving Performances

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Objective: Though fatigue and sleepiness at the wheel are well-known risk factors for traffic accidents, many drivers combine extended driving and sleep deprivation. Fatigue-related accidents occur mainly at night but there is no experimental data available to determine if the duration of prior driving affects driving performance at night. This study is the first one to use a dose-response design of duration of driving while controlling for effects of prior time awake, prior sleep time, and time of day.

Methods: Fourteen young healthy men (mean age [± SD]=23.4 [±1.7] years) drove 3 nocturnal driving sessions on an open highway for 2, 4 and 8 hours (3 – 5 am, 1 – 5 am and 9 pm – 5 am). Inappropriate line crossings (ILC) in the last hour of driving of each session, sleep variables, self-perceived fatigue and sleepiness were measured.

Results: Compared to the short (3–5am) driving session, the incidence rate ratio of inappropriate line crossings increased by 2.6 (95% CI, 1.1 to 6.0; P<.05) for the intermediate (1–5am) driving session and by 4.0 (CI, 1.7 to 9.4; P<.001) for the long (9pm–5am) driving session. Compared to the reference session (9–10pm), the incidence rate ratio of inappropriate line crossings were 6.0 (95% CI, 2.3 to 15.5; P<.001), 15.4 (CI, 4.6 to 51.5; P<.001) and 24.3 (CI, 7.4 to 79.5; P<.001), respectively, for the three different durations of driving.

After the long drive, fatigue scores were significantly higher than after the intermediate drive (Wilcoxon rank sum test = -2.989, P<.01). Fatigue significantly differed between the reference (11 pm) and the 3 nocturnal driving sessions (respectively, Wilcoxon rank sum test for the short drive = -2.731, P<.01; for the intermediate drive = -3.234, P<.01, and for the long drive = -3.298, P<.01).

Self-rated fatigue after the last hour of driving correlated with the number of inappropriate line crossing in the intermediate (Rho=0.527, P<.05) and in the long drive (Rho=0.478, P=.08 (tendency)).

Sleepiness before the last hour of driving differed significantly from the reference (9 pm) and the three nocturnal sessions with different durations of prior driving (For the short drive, Wilcoxon rank sum test reached = -3.077, P<.01; for the intermediate drive = -3.306, P<.001 and for the long drive = -3.317, P<.001). Before the last hour of driving, sleepiness was identical in the 3 nocturnal driving sessions. Self-rated sleepiness before the last hour of driving correlated with the number of inappropriate line crossing in the intermediate driving session (Rho=0.611, P<.05) and in the long driving session (Rho=0.608, P<.05).

Conclusion: The interaction of duration of driving at night with circadian clock time impairs driving performance and therefore road safety. This lends support to the legislative work on driving regulations, which tend to focus strongly on time at the wheel as a tool for improving safety. It also suggests that the public should be advised to limit the distance driven at night.
Fatigue Monitoring Technology Evaluation: Detection of Unsafe Driving Using Delphi’s DSM System

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Objective: Caterpillar Inc., a major producer of heavy equipment, has been working with the mining industry to try and understand ways to manage and monitor operator fatigue as well as to promote general fatigue awareness for workers employed in this 24/7 modern day mining industry. In the surface mining industry, 93% of haulage truck accidents are due to human error with a large portion being shown to be related to operator fatigue. Numerous technologies have been developed trying to provide a means for monitoring fatigue of drivers or automobiles, transport vehicles, as well as heavy equipment. Delphi has developed one such fatigue monitoring technology called Driver State Monitor (DSM). Caterpillar and Delphi worked together to evaluate this technology as part of a research effort to examine technologies for use in the large mining equipment such as Caterpillar’s large off-highway haul trucks.

Methods: The study consisted of two overnight driving simulation sessions. Volunteers arrived at the lab at 10 pm. After wire-up, checking logs and activity monitors, and retraining, experimental sessions started at 11:30 pm. There were eight experimental sessions, each one lasting one hour and the last session finishing at 8:30 am. Volunteers had a 1 hour break at 3:30 am. Each session included: 40-minutes driving session, 10-minutes CCT performance test, and 10-minutes PVT. Alertness self-assessment and Samn Perelli questionnaires were performed at the end of the driving task. KSS and brief alertness assessments were performed at regular intervals during the driving task, as well as before and after the task.

Results: For a general fatigue assessment the AVCLOS parameter of the DSM system was first averaged over the 40 minutes for each subject. The same was done with the VLD values. Afterwards the results of the single session averages were averaged again over all subjects. As expected, driving performance got worse progressively through the night resulting in an increase of driving errors. Correlations between VLD and DSM were performed, first overall (all volunteers, all sessions). The DSM shows an excellent correlation of 98% across this large time window. Nevertheless, fatigue states can change on smaller time scale such as 3-5 minutes. Correlations of session by session (all volunteers averaged) on a time scale of 2 minutes was performed. For the 8 sessions correlations were -2%, 34%, 72%, 78%, 71%, 95%, 92%, and 68% respectively. The worse correlations occur during the first sessions, while the best correlations occur in the later sessions when subjects are already considerably drowsy with frequent microsleep events.

Conclusion: In summary, DSM from Delphi shows overall strong correlations with driving performance expressed by Variation of Lane Deviation. However, correlation level varies by subject and session (time of day). There are cases when the volunteer commits accidents and drowsiness is not detected, or the volunteer commits no driving errors and the DSM detects drowsiness. It becomes very clear that the reliance on eye closure as the sole parameter to measure drowsiness is not sufficient. Drowsiness detection systems need to be effective across variations in inter-individual drowsiness level. The application of a data fusion concept is recommended.
Luncheon Address

Keynote Speaker: Marvin Dainoff, Ph.D.
Liberty Mutual Research Institute of Safety

Marvin Dainoff, PhD, CPE is Director, Center for Behavioral Sciences at the Liberty Mutual Research Institute for Safety in Hopkinton, MA; a position he has held since August, 2008. Previously, he was Professor of Psychology and Director, Center for Ergonomic Research at Miami University, Oxford Ohio. He is a Past-President of the Human Factors and Ergonomics Society and is a Director of the Board of Certification in Professional Ergonomics.
Receptivity, Diagnosis and Treatment of Sleep Disorders
Health-Related/Pharmacological Issues (Track B)

This session will focus on the impact of sleep disorders on transportation operations, and on clinical and policy interventions aimed at diagnosing and treating sleep disorders. Potential barriers to the implementation of sleep disorders screening programs at the individual and organization levels will be discussed. New assessment technologies facilitate may identification of those with sleep disorders in the occupational setting.

Session Chair: Lawrence Epstein, M.D.
Sleep HealthCenters

Lawrence Epstein, MD, is the Medical Director of Sleep HealthCenters, a Sleep Medicine specialty group in Boston. He is board certified in Internal Medicine, Pulmonary Diseases, Critical Care Medicine and Sleep Medicine. Dr. Epstein is an Instructor in Medicine at Harvard Medical School and is the Program Director for the Sleep Medicine fellowship training program at Brigham and Women’s Hospital. Dr. Epstein was the President of the American Academy of Sleep Medicine from 2005-6. He is the co-author of the Harvard Medical School Guide to a Good Night’s Sleep.
Objective: Fatigue is a common issue in the trucking industry because of the sleep deprivation related to irregular and night work hours. Those challenges are compounded for those individuals whose sleep is also disturbed by an untreated sleep disorder. Obstructive Sleep Apnea (OSA) is one of the most frequent sleep disorders. It consists of episodes of interrupted breathing during sleep, resulting in sleep fragmentation and increased sleepiness. As a consequence, OSA results in increased risk of driving accidents and health problems. However, OSA can usually be treated effectively. An elevated prevalence of OSA has been documented in the trucking industry. CIRCADIAN has developed an OSA screening and treatment program for shiftworkers that includes education, pre-screening, case management and patient counseling. We report here the results of the screening program in a US trucking company.

Methods: Employees received a package containing basic information about sleep apnea and the pre-screening questionnaire and returned the completed questionnaire directly to CIRCADIAN. The questionnaire evaluates physical condition, sleep patterns, sleepiness (Epworth sleepiness score) and OSA symptoms. Drivers were classified as “at risk”/”not at risk” of suffering sleep apnea.

Results: Seventy seven drivers completed the survey. The average age was 49 years old and only one of the respondents was female. Thirty four percent of drivers were overweight (Body Mass Index, BMI 25-29.9) and 50.6% were obese (BMI ≥30). Average collar size was 17. There was no significant correlation between BMI or collar size and increased sleepiness. On average, drivers reported that they needed 7 hours (± 1h 13’) of sleep per day to feel rested. However, average sleep duration on work days was only 6h 08’ (± 1h 10’). Drivers compensated sleeping longer during days off (7h 35’ ± 30’). The lack of sleep during work days had a clear effect on increased sleepiness: the fewer hours of sleep, the higher the sleepiness score (p<.0001). Moreover, the greater the difference between hours of sleep needed and hours of sleep actually obtained during work days, the higher the sleepiness score (p<.05).

Thirty three drivers were classified as “at risk” of suffering sleep apnea. Among them, eight were already diagnosed and treated, and were not included in the comparisons between the “at risk” and “not at risk” groups. The “at risk” group was younger than the “not at risk” (45 years vs. 50 years). BMI, collar size and sleepiness score were significantly greater in the “at risk” group than in the “not at risk.” The difference between sleep needed and sleep obtained during work days was greater in the “at risk” group than in the “not at risk” group (1 h 20’ vs. 32’, p<.05). The difference between sleep during work days and days off was also greater in the “at risk” group than in the “not at risk” group (2h 02’ vs. 1h 06’, p<.05).

Conclusion: Drivers with disturbed sleep because of sleep apnea need more sleep to feel rested. The chronic sleep deprivation caused by irregular and night work affects drivers with sleep apnea more than drivers without sleep disorders, and likely increases their accident risk.
Objective: The aim of this study is to determine the ability of Maintenance of Wakefulness Test (MWT) to predict simulated driving performance in patients with untreated obstructive sleep apnea syndrome.

Methods: This study involves one hour of simulated driving after controlled habitual sleep (8 hours), one night of polysomnography (PSG), and a 4x40-minute MWT. Thirty male patients with untreated obstructive sleep apnea syndrome (OSAS) (mean age [±SD] = 51 ± 8 years, range 34-62; mean body mass index (BMI) [±SD] = 29 ± 3, range 24-37; mean apnea/hypopnea index (AHI) [±SD] = 43 ± 24, range 14-96) were recruited. Classification of our patients into 3 groups according to their mean MWT scores indicated that 23.3% of the patients were sleepy (0-19 min), 33.3% were alert (20-33 min), and 43.4% were fully alert (34-40 min). Nocturnal PSG, mean sleep latency at 4x40-minute MWT trials, Epworth Sleepiness Scale (ESS), and standard deviation from the center of the road (SDS) on driving simulator were investigated.

Results: Mean MWT scores inversely correlated with SDS during the simulated driving session (Pearson’s r = -0.513, P<0.01). We found a significant effect of MWT groups (sleepy, alert, or fully alert) on SDS (ANOVA, F2, 29 = 5.861, P<0.01). Post hoc tests revealed that the sleepy group had a higher SDS than the fully alert group (P = 0.006). ESS, AHI, microarousal index, and total sleep time did not predict simulated driving performance.

Conclusion: A pathological MWT mean sleep latency (0-19 min) is associated with simulated driving impairment. Before MWT can be used to predict the driving ability of untreated patients with OSAS, further studies are needed to confirm that pathological MWT scores are associated with real driving impairment.
Operation Healthy Sleep: An occupational screening and treatment program for obstructive sleep apnea in a city police department

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For the Harvard Work Hours, Health and Safety Group

Objective: Sleep disorders are common, costly, and treatable, but often remain undiagnosed and untreated. Unrecognized sleep disorders adversely affect personal health and may lead to chronic sleep loss, which in turn increases the risk of accidents and injuries. These problems are exacerbated in shift workers, who may experience additional chronic sleep disturbance and sleep loss due to their work schedules. Police officers work particularly demanding schedules as the need for 24/7 policing often requires frequent overnight shifts and long hours, leading to acute and chronic sleep deprivation in addition to misalignment of circadian rhythms. As police officers are predominantly male and are at increased risk of being overweight compared with age-matched controls, we hypothesized that they were at high risk for having obstructive sleep apnea (OSA). We therefore implemented a fatigue management program - ‘Operation Healthy Sleep’ - the central component of which is occupational screening for and treatment of OSA coupled with sleep health education. The overall goals of this program are to reduce the adverse consequences of fatigue on officers’ health, safety, and performance.

Approach/Methods: The impact of Operation Healthy Sleep was tested using a randomized controlled design; half of the districts in a major city police department were provided with the program and half were not. Districts were paired according to officer number and workload prior to randomization. Officers attended a 30-minute educational presentation on sleep hygiene, caffeine use and the symptoms, consequences and treatment of OSA. Following the presentation, officers were asked to volunteer for the research study and if so, provided informed consent prior to completing a survey which included an assessment of OSA risk. Officers with high OSA risk were then examined by a sleep medicine physician at a temporary occupational clinic and, if warranted, were further assessed using a portable device (ApneaLink™, ResMed Inc.) for two nights at home. Continuous Positive Airway Pressure (auto-titrating) therapy was offered to officers if their Apnea-Hypopnea Index (AHI) was >10/h or >5/h plus additional pre-defined symptoms.

Results: The sleep health presentations were attended by 1126 officers, representing ~70% of on-duty officers. Of these, 682 officers consented to participate in the survey and 662 completed surveys were received. Approximately 34% of officers completing the survey were at high risk of OSA (222/662) and of these, 146 agreed to attend the occupational clinic. After examination or home-based AHI assessment, 20 officers were not referred for CPAP therapy and 18 chose to withdraw from the study. Of the remaining 108 officers, 100 initiated CPAP therapy, 5 refused therapy and 3 were lost to follow-up.

Conclusions: Our screening program indicates that OSA risk is highly prevalent in a city police department, consistent with our previous national survey of police officers. We have demonstrated the potential for conducting large-scale sleep education and OSA screening programs using temporary occupational clinics and home-based assessments, and that the program results in significant numbers of previously undiagnosed patients initiating CPAP therapy. Ongoing analyses are examining the health and safety impact of the program at both departmental and individual levels.

This study was supported by the National Institute of Justice (2004-FS-BX-001), the Centers for Disease Control and Prevention (R01 OH008496) and the ResMed Foundation.
Barriers to the Diagnosis and Treatment of Obstructive Sleep Apnea in Commercial Drivers

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Objectives: Obstructive sleep apnea (OSA) is highly prevalent among commercial drivers and significantly increases the risk of vehicular crashes. We explored barriers to effective OSA screening among drivers in the context of Federal Motor Carrier Safety Administration (FMCSA)-mandated Commercial Driver Medical Examinations (CDME). Specifically, our goals were to identify driver, physician and employer-related obstacles to using recently published consensus guidelines for diagnosing and treating OSA among professional drivers.

Methods: Two distinct methodologies were used. First, the consensus guidelines for diagnosing and treating OSA were “field tested” in a consecutive series of drivers presenting for CDME’s. A retrospective review was then conducted to evaluate driver and physician compliance with polysomnography (PSG) referrals and subsequent OSA treatment. Second, a 5 question, internet survey on the same consensus guidelines was distributed to occupational medicine physicians who perform CDME’s.

Results: Among 456 drivers seen for CDME’s, 78 (17%) met consensus criteria for requiring further OSA evaluation on retrospective review; yet, physicians had referred only 53 (68%) of these drivers for PSG’s. The major reason that physicians failed to refer drivers with suspect OSA for PSG was uncertainty regarding subjective and blood pressure-related criteria in the consensus guidelines. Of the 53 PSG referrals, 33 (62%) were lost to follow-up. The remaining 20 drivers were all diagnosed with significant OSA, however, only one driver demonstrated adequate compliance with subsequent OSA treatment. Thus, the field test resulted in effective OSA treatment for as few as 1.3% of drivers with likely OSA.

Among 552 physicians performing CDME’s, 508 (92%) opined that OSA screening for commercial drivers is important or very important; while 33 (6%) felt it was moderately important; and only 11 (2%) slightly important or not important. Nonetheless, only 42% of the physicians reported that they were using the consensus guidelines or some other formal screening protocol. Physicians cited the following reasons for not applying the consensus guidelines: not aware (36%); too complicated (12%); potential to lose client companies (10%); and driver inconvenience (10%). Most physicians would consider applying the consensus guidelines going forward, but 39% would do so only based on additional data, and another 22% only if they became the “standard of practice”. Both our field test and surveyed physicians attempting to apply the guidelines identified driver/employer resistance to OSA screening; lack of an FMCSA mandate; and ability of drivers to “doctor shop” for other examiners conducting less rigorous exams as major obstacles to effective OSA diagnosis/treatment. Additionally, the cost of and access to PSG’s and OSA treatment were cited by both drivers and physicians as barriers.

Conclusions: FMCSA rules mandating OSA screening and treatment in drivers that meet simple, objective OSA-related criteria and eliminating doctor shopping would increase physician, driver and employer compliance. Innovative solutions that reduce the costs and wait times for OSA diagnosis and treatment are also needed. Physicians, drivers and employers could all benefit from additional education regarding OSA and its effects on health and safety.
Disentangling the Contributions of Synergistic Variables and Loss of Attention
Define and Measure Fatigue Problem (Track A)

This session offers novel approaches to understanding the contribution of fatigue to accidents. Papers will examine the impact of contributory hazards such as monotony, distraction, and impaired effort regulation and aim to disentangle the complex interaction of interdependent variables obscuring fatigue level measurements. A novel and holistic approach to fatigue detection using continuous speech will close the session.

Session Chair: Pik Kwan Rivera
US Coast Guard

Ms. Pik Kwan Rivera currently serves as Engineering Psychologist for the US Coast Guard Headquarters Office of Design and Engineering Standards, Human Element and Ship Design Division. She served in the US Coast Guard since 1999, first in the capacity of psychology technician, and later as project manager for the Crew Endurance Management Program at the US Coast Guard Research and Development Center in Groton, CT. In 2007, Ms. Rivera moved to US Coast Guard HQs where she currently manages the Crew Endurance Management program for commercial maritime operations. Ms. Rivera earned her Bachelor’s degree from the University of Connecticut in Storrs, CT and is a Project Management Institute (PMI) certified Project Management Professional (PMP).
Disentangling the relative effects of time of day and sleep deprivation on fatigue and performance

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Objectives:
There have been a number of benchmarking studies of sleep deprivation and alcohol effects that demonstrated performance equivalence between around 18 hours of wakefulness (commencing from 06:00hrs) and blood concentrations of alcohol at the legal limit for driving in Australia (0.05% blood alcohol concentration, BAC). While there has been considerable consistency between studies on the point of equivalence, the design of all studies has a potential confounding effect between extended time awake and time of day. The performance decrements seen in these studies may be due to a combination of sleep deprivation effects and time of day effects and therefore may overestimate the effects of sleep deprivation and the level of alcohol equivalence. The aim of this study was to obtain a better understanding of the relative effects of time of day and sleep deprivation on fatigue and performance and to examine the alcohol dose equivalence of the performance effects.

Approach:
Two independent groups were exposed, in random order, to 28 hours of sleep deprivation and varying doses of alcohol up to 0.1%BAC. For one group (n=39) the sleep deprivation and alcohol conditions began at 06:00 hours and for the second group (n=22), they began at 00:00 hours. By varying the start time for each of the two groups, but keeping constant the duration of sleep deprivation it was possible to examine the effects on performance of variations in the time of day of testing. For the group commencing at 0600 hours the longest period without sleep occurred close to the low point of the circadian rhythm. For the group commencing at 0000 hours, the circadian low point coincided with only around two to six hours of sleep deprivation. Eight computer-based performance tests were used as well as subjective ratings of fatigue.

Results:
The sleep deprivation results showed a clear interaction effect. Both time of day and sleep deprivation factors affected performance but only in combination; neither had independent effects. If the circadian rhythm was not at its low point or trough, there were no effects of sleep deprivation. Performance at the circadian low point was not adversely affected when the study participant was rested. Analysis of the alcohol equivalence effects is in progress.

Conclusion:
The finding that significant performance deficits only occurred when high levels of sleep deprivation coincided with the low point of the circadian rhythm has clear implications for the design of work-rest schedules. Rested participants did not show the expected circadian effects on performance and sleep deprivation effects on performance were not seen outside the circadian low point. For shift design, these results suggest that night work including driving can be performed safely and without error if the person is properly rested. The circumstance that must be avoided is allowing people to work long hours that culminate in the midnight to dawn period as safe performance cannot be maintained under these circumstances.
**Driving Fatigue as an Impairment in Effort-Regulation**

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**Objectives:** Several psychological mechanisms for loss of attention in states of fatigue have been proposed, including loss of attentional resources and dysfunctional effort-regulation (e.g., Desmond & Hancock, 2001). Prolonged high workload may lead to a depletion of attentional resources that generates performance decrements. However, fatigue is also associated with increasing aversion to effort and loss of performance motivation. Some driving simulator research (Matthews & Desmond, 2002) has supported the effort-regulation mechanism over a loss of resources. The aim of this paper is to review several recent lines of research pursued in the University of Cincinnati driving behavior laboratory that address further the role of effort-regulation in fatigue and its implications for fatigue management.

**Approach:** We briefly review key findings from three studies that used a System Technologies, Inc., STISIM driver simulator to investigate fatigue. Drives were configured to be fatiguing, and measures were taken of performance, subjective state, and self-regulative processes such as coping that mediate effort-regulation. Studies 1 and 2 (N=108, 168) contrasted active and passive fatigue manipulations, as defined by Desmond and Hancock (2001). Study 3 (N=81) investigated a psychophysiological measure of resource utilization, cerebral blood flow velocity (CBFV), measured by Transcranial Doppler sonography. Effects of fatigue manipulations on three types of criterion were assessed: subjective measures of fatigue processes, objective performance, and CBFV during simulated driving.

**Results:** Analyses of subjective data confirmed that fatigue is associated with loss of task motivation and associated self-regulative processes. The key finding for performance was that passive fatigue (monotonous, low workload driving) is more damaging to performance than active fatigue (prolonged high workload). Following a passive fatigue induction (vehicle automation), drivers in Study 2 were slower to respond to an unexpected hazardous event, parked van that suddenly pulled out in front of the participant’s vehicle. They were also more likely to collide with the van than participants in other conditions. Lack of alertness may be a consequence of disruption of effort-regulation due to passive fatigue. Study 3 showed that CBFV declines during low-workload simulated driving, and so may provide a diagnostic index of fatigue. However, by contrast with other sustained attention tasks, there appeared to be no direct link between CBFV and performance. Although resources appeared to be depleted, loss of resources did not directly impact performance, consistent with the effort-regulation hypothesis.

**Conclusion:** Effects of fatigue on driver performance reflect impairment in effort-regulation that is most prevalent in low-workload driving conditions. Insufficiency in effort is expressed both in self-report data, and in loss of alertness following vehicle automation. Psychophysiological techniques such as measurement of CBFV may provide a further source of evidence. Implications for fatigue theories such as that of Desmond and Hancock (2001) will be discussed. At a practical level, the data suggest that fatigue may be most hazardous when workloads are low. Countermeasures for fatigue management may be directed towards self-regulative processes that control effort and motivation.

**References**

Sleepiness Increases Lapses Due to Distraction

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Objective: Sleepiness is a leading cause of motor vehicle crashes often resulting in serious injury or death. Although it is well known that sleepiness causes decrements in performance associated with driving, some aspects of performance are not so well understood due to the controlled sterile environment of the laboratory.

Without stimulation sleepy people are more liable to fall asleep. To avoid tedium, and remain awake, they seek alternative stimulation, especially when the task in hand is boring and monotonous (e.g. driving). Sleepiness at a dull task is indicated by “lapses”, usually attributed to microsleeps. However, in moderately sleepy people some ‘lapses’ may be due to self-generated distractions, and not to microsleeps. In the real-world, our environments are full of potential ‘distracters’ and so an assessment of the impact of sleepiness combined with distraction on performance is imperative. Here, we investigated the incidence of distraction lapses as a consequence of sleepiness.

Approach (or Methods): Twenty-four healthy, young adults (23.2±2y), screened good sleepers (8±1h), without daytime sleepiness (<2naps/month and ESS scores <10) underwent two 30 minute psychomotor vigilance task (PVT) at 22:00h and 04:00h in a repeated measures 2x2 counterbalanced design, with two sleepiness conditions (22:00h vs. 04:00h) and distraction Vs no distraction. Distraction comprised a video in the visual periphery, showing an episode of a popular TV show. Subjects had to ignore this and attend to the PVT. For ‘no-distraction’, the TV was off. Lapses (responses ≥500msecs) were logged and distractions assessed from a video camera on the subjects’ faces (e.g. head turn). Each lapse was categorized as occurring with eyes open (EO), eyes closed (EC), or a head turn (HT).

Results: Repeated measures ANOVA on the number of lapses (irrespective of cause) showed a significant effect of sleepiness (p<0.0005) and a significant sleep*distraction interaction: lapses increased when sleepy in the distraction condition (p<0.04). For number of head turns, there was a significant effect of sleepiness (p<0.0005), distraction (p<0.0005) and interaction (p<0.003). Lapses that were directly due to a head turn increased due to sleepiness (p<0.01) and distraction (p<0.03), but more importantly, these lapses were exacerbated when sleepy and distracted (p<0.04).

Conclusion: Sleepiness increases lapses on the PVT caused by distraction, and we propose that the more typical ‘sterile’ lab-based studies of sleepiness may not reveal the real extent of impairment in the real-world, especially during monotonous driving.

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Differential effects of monotony versus fatigue on driving performance according to multiple psycho-physiological and behavioural measures: Evidence for independent constructs

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Objectives: Situational driving factors, including fatigue, distraction, inattention and monotony, are recognised killers in Australia, contributing to an estimated 40% of fatal crashes and 34% of all crashes. More often than not the main contributing factor is identified as fatigue, yet poor driving performance has been found emerge early in monotonous conditions, independent of fatigue symptoms and time on task. This early emergence suggests an important role for monotony. However, much road safety research suggests that monotony is solely a task characteristic that directly causes fatigue and associated symptoms, and there remains an absence of consistent evidence explaining the relationship. We report an experimental study designed to disentangle the characteristics and effects of monotony from those associated with fatigue. Specifically, we examined whether poor driving performance associated with hypovigilance emerges as a consequence of monotony, independent of fatigue. We also examined whether monotony is a multidimensional construct, determined by environmental characteristics and/or task demands that independently moderate sustained attention and associated driving performance.

Method: Using a driving simulator, participants completed four 40-minute driving scenarios. The scenarios varied in the degree of monotony as determined by the degree of variation in road design (e.g., straight roads vs. curves) and/or road side scenery. Fatigue, as well as a number of other factors known to moderate vigilance and driving performance, was controlled for. To track changes across time, driving performance was assessed in 5-minute time periods using a range of behavioural, subjective and physiological measures, including steering wheel movements, lane positioning, electroencephalograms, skin conductance, and oculomotor activity.

Results: Preliminary results indicate that driving performance, as indexed by lateral lane position, is worse in monotonous driving conditions characterised by low variability in road design. Contrary to expectations, increased variability of roadside scenery was found to worsen rather than improve driving performance. Critically, performance decrements associated with monotony emerged very early, suggesting monotony effects operate independent of fatigue. Also, some psycho-physiological measures of alertness and arousal were found to decline early across all driving tasks, independent of subjective reductions in alertness, providing additional evidence that prolonged time on task is not a prerequisite for driver hypovigilance.

Conclusion: Monotony is a multi-dimensional construct. In a driving context, low task demands associated with vehicle operation and low variability in road design combine to form a monotonous context. In such contexts not only can hypovigilance emerge very early into a driving session but also, perhaps counterintuitively, it is unlikely to be reduced by increased variability in roadside scenery (such as can be introduced using billboards). We suggest that, when travelling on monotonous roads, the introduction of roadside (scenic) distractions have a negative effect on driving performance. Current fatigue-related safety countermeasures in Australia focus on encouraging drivers to take rest stops during prolonged driving and on educating drivers to recognise the early signs of fatigue. It remains to be determined how best to prevent and recognise the effects of monotony on driving performance. Implications of our results for the relationship between monotony and fatigue, and the possible construct-specific detection methods in a road safety context, will be discussed.

A holistic approach to estimating crew alertness from continuous speech

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Objective: A novel algorithm has been developed for generating a numerical metric that is correlated to crew alertness through processed speech in real-time without the need for interpretation of individual words. The algorithm is the foundational building block of a holistic approach, which incorporates aspects such as cost feasibility and the ability to implement this technology as a solution to the fatigue detection problem.

Methods: Principally the method estimates a variety of key lower-level metrics such as word production rate, phrase production rate, words per phrase, etc., that are known to be indicative of human mental states. These metrics are then used to compute statistical measures, which are in turn correlated with thresholds to determine how far the current value is deviating from acceptable limits. The result is then used to produce an alertness quotient. The overall goal is to develop a solution for monitoring locomotive crew alertness considering key constraints that commonly limit the realizability of a new design. The real-time algorithm presented here is unique in that it employs a simple and efficient pattern matching method to identify temporal word boundaries by monitoring threshold crossings in the speech power signal. This algorithm eliminates the need to interpret the speech, and still produces reasonable estimates of word and phrase boundaries; The proposed algorithm has been tested with a batch of experimentally recorded speech data as well as with real time speech data. As part of a validation study, the algorithm has also been evaluated under a range of typical SNR conditions to determine the algorithm’s robustness against noise.

Results: The code was successfully run and evaluated in batch mode as well as in real-time mode. The proposed metrics were extracted and could be directly related to the speech signal. Testing with a sample file with a duration of 60 seconds and 149 words led to an accuracy of approximately 96%. 143 out of the 149 words were correctly identified. The SNR study led to the result that the code will function under noise levels of up to 1 dB with an accuracy of approximately 83%. Figure 1 illustrates the manner in which the metrics were derived from the detected speech signal.

Conclusion: Since the functionality of the system is directly depending on the correct detection of the word boundaries the accuracy is quantified in percentage of detected words. It has been shown that estimating word boundaries without any kind of linguistic knowledge can be performed with high accuracy. The robustness against noise is another highly important factor in a railroad environment which is addressed in this study.

Figure 1. Extracted Metrics From Processed Speech
Recent Advances in Fatigue and Performance Modeling
Fatigue and Performance Modeling (Track E)

This paper session will highlight cutting-edge research in the area of fatigue and performance modeling. Topics will include the development of individualized fatigue and performance models, the use of novel methods for classifying individuals as sleep deprived, and the development of new models for shiftwork stress resistance.

Session Chair: Jana Price, Ph.D.
National Transportation Safety Board

Jana Price has worked at the National Transportation Safety Board (NTSB) since 2001 in the Office of Research and Engineering. Dr. Price leads the safety team addressing the NTSB Most-Wanted recommendations concerning operator fatigue, and has conducted numerous presentations on investigating human fatigue factors in transportation accidents. She also represents NTSB as part of the DOT Human Factors Coordinating Committee.
Improving individual performance predictions with Bayesian estimation using traits learned from reference data

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Objective: The magnitude of performance impairment experienced by individuals in response to sleep deprivation exhibits considerable trait variability. Mathematical models with individualizable trait parameters may be used and adapted to provide tailored predictions of performance impairment of individuals under conditions of sleep loss. Following up on our pioneering work in this area, we describe a technique for assessing individualized trait parameters from population and individual reference data sets, then applying this information to improve future performance predictions for specific individuals, even if their present state is unknown. We illustrate this with an example in which individuals’ sleep/wake history is unknown.

Methods: Performance data were taken from psychomotor vigilance task (PVT) lapse scores of a sample of \( n = 19 \) healthy young adults who repeated three trials of 36-hour total sleep deprivation in a laboratory. Two of the trials involved 12 hours time-in-bed on the previous night (full pre-sleep conditions), and one of the trials for each subject involved a restricted prior sleep of 6 hours time-in-bed (restricted pre-sleep condition). These conditions were encountered in randomized order. A reference group of subjects \( (n = 10) \) was randomly selected from the larger sample. A standard two–process model of performance, reparameterized to incorporate individualized parameters for homeostatic and circadian characteristics, was fit to each reference subject using a maximum likelihood method. Parameter values from the reference fits were used to generate parameter probability distributions representative of the population and usable as Bayesian priors.

New subjects were then selected from the remainder of the data set, and predictions were generated for each subject’s performance in the restricted pre-sleep condition, and in the second full pre-sleep condition, with the sleep condition blinded. We compared three different predictions. First, population average predictions were calculated using mean parameter values determined from the reference group. Second, individualized predictions were made using a recursive Bayesian particle filter initialized with the population priors for the trait parameters. To account for the a priori unknown initial conditions (i.e., varied sleep/wake history), the homeostatic state parameter was reinitialized to a uniform distribution for each condition. Third, individualized predictions were made using individual-specific instead of population-based trait priors. These individual trait priors were generated for each subject by passing the first full pre-sleep condition data through the recursive Bayesian particle filter.

Results: Each time a new data point was encountered in the restricted pre-sleep condition or the second full pre-sleep condition new predictions were made for subsequent performance across a 12-hour prediction horizon. The accuracy of the predictions was evaluated by calculating the root mean square error (RMSE) relative to the actually observed data. For each of the three prediction methods evaluated, we calculated an overall prediction accuracy metric by averaging the RMSE across all data points and over all subjects. The overall RMSE from individualized predictions using population priors showed a 6% improvement over the population average model predictions, and predictions using individualized trait priors showed a 20% improvement over the population average model predictions.

Conclusion: We demonstrated that implementation of a recursive Bayesian particle filter algorithm, making use of either population-based or individual-specific Bayesian priors for trait individual variability, can achieve a systematic improvement in the accuracy of performance predictions under conditions of sleep deprivation. Prior statistical knowledge of an individual’s trait parameters improved model predictions even when information about the individual’s state in terms of prior sleep/wake history was not a priori known. Thus, application of individualized modeling on the basis of new performance measurements combined with previously collected reference data provides a promising new strategy to manage and predict person-specific performance impairment in operational settings.

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Objective: Were we really designed to rock around the clock? How many women and men are fatigued at work right now? To what extent does this fatigue affect performance and well-being? Most importantly, can we predict and mitigate these costs to man and machine?

Amidst 21st century challenges to 24/7 performance – where human biology, psychosocial interactions, and the economics of allocating scarce resources all compete in a biopsychonomic soup – the need presents itself to effectively manage irregularly scheduled operations. Indeed, a well established body of research illuminates the challenges of shiftwork-related fatigue. To help address these concerns, several groups have independently developed fatigue algorithms to estimate fatigue risk based on historical or simulated data that may include, for example, aspects of sleep history and/or work-rest schedules.

The current study proposes to complement and further strengthen such efforts by offering models of wellness and performance that consider how individual differences affect stress resistance and outcomes. Integrating stress and coping research with shiftwork theory and practice, the study aims to enhance understanding of shiftwork stress by modeling contributions to wellness (e.g., physical and psychological health) and performance (e.g., safety and productivity). More specifically, the model examines mechanisms through which control and support influence shiftwork adjustment. By integrating demand, control, and support, the study further proposes to broaden Karasek’s insightful demand-control model.

Approach: 603 industrial shiftworkers met criteria at baseline and at one-year follow-up. The longitudinal design utilized established and contemporaneous survey instruments. Monthly OSHA data was captured at two-year follow-up. A multitrait-multimethod approach was utilized, with scales tapping four categories: outcomes, modifiers, mediators and organizational systems. Statistical techniques used to test hypotheses relating to predictive models included descriptive statistics and zero-order correlations, analyses of variance and covariance, multiple regression, principal components analysis, and structural equation modeling using LISREL.

Results: A theoretical model of shiftwork stress resistance is supported, accounting for a significant proportion of the variance in adjustment (e.g., wellness and performance) in a direct model as well as in a mediational model operating directly and indirectly through coping and in which demand, control, and support constructs work in unique ways. Furthermore, control and support operate interactively in predicting adjustment, with higher levels of internal control buffering the relationship between support and adjustment, strengthening the demand-control-support conceptualization. Work schedule preference also significantly relates to adjustment.

Conclusion: Results broaden our understanding of the significant relationships among shiftwork stress resistance, wellness, and performance. As a predictive, integrative model, the findings underscore the roles of individual variability, adaptive coping strategies, schedule preference, and their relationships in predicting biopsychosocial adaptation under stress. The clinical implications of refining our understanding of coping with shiftwork stress are exciting. Maladaptive response patterns may be moderated through a better understanding of the nature of coping and its malleability in response to moderating effects of support and control. Moreover, findings may encourage interventions aimed at facilitating both adaptive lifestyle changes and improvements in operational performance through workforce strategies that align with the new biopsychonomy.
Individualized Biomathematical Models for Performance Prediction of Sleep-Deprived Individuals

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OBJECTIVE: Traditionally, biomathematical models of performance have focused on predicting group-average performance impairment. Such a modeling strategy necessarily de-emphasizes individual differences in resilience and vulnerability to sleep loss and is not in agreement with recent findings that suggest systematic and significant differences among individuals. In this paper, we propose a method of performance prediction for individuals subjected to total sleep loss with unknown initial states (i.e., unknown initial homeostat and circadian phase) and unknown traits (vulnerable and resilient to sleep loss).

METHODS: Recently, we developed a method for performance prediction for individuals subjected to total sleep deprivation that employs the two-process model of sleep regulation as the underlying model template, and uses previously collected psychomotor vigilance test (PVT) lapse data to customize the model parameters (and thus the model predictions) for an individual. In this method, we utilize a linear representation of the two-process model that affords unique estimation of the two-process model parameters for an individual. A major limitation, nonetheless, is the requirement that a minimum number of past performance measurements be available from an individual before model-parameter estimation and predictions could commence.

Here, we improved on our previous method for individualized performance prediction to enable estimation of an individual’s performance impairment as soon as the first observation (data point) for that individual is available. This was achieved through Bayesian inference by combining a priori information about the model parameters with information obtained from the individual’s performance measurements. However, by retaining the previously proposed linear representation of the two-process model, we ensured unique model-parameter estimates for the individual. Moreover, the linear representation of the two-process model allowed analytical estimation of statistically based error bounds around the model predictions in the form of prediction intervals (PIs).

RESULTS: Using simulated performance data, for which the model parameter values are known, we found that the newer method yielded parameter estimates that asymptotically converged to their true values as the number of performance observations for an individual increased and as the amount of uncertainty (noise) in the data decreased. Moreover, the newer method yielded improvements in parameter-estimate accuracy ranging from 50 - 90% over the previous method. Using a PVT lapse data set obtained from a laboratory study of healthy individuals exposed to 82 h of total sleep loss, the proposed method yielded individualized predictions that were up to 43% more accurate than group-average prediction models and, on average, 10% more accurate than individualized predictions with our previous method. Finally, the analytically computed PIs were validated by showing that they reproduced results obtained through Monte Carlo simulations.

CONCLUSIONS: The current work expands the capability of existing biomathematical models of performance prediction, shifting the focus away from traditional, group-average performance predictions to more accurate, operationally useful individualized-performance predictions.

DISCLAIMER: The opinions and assertions contained herein are the private views of the authors and are not to be construed as official or as reflecting the views of the U.S. Army or of the U.S. Department of Defense. This paper has been approved for public release with unlimited distribution.
Pattern recognition algorithms to classify performance on the psychomotor vigilance task

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Objective: The psychomotor vigilance task (PVT) is a simple reaction time (RT) test used to measure sustained attention. Significant individual variability in performance on the PVT under both well-rested and sleep-deprived conditions makes it difficult to determine a priori whether an individual will suffer severe performance decrements with increasing time awake relative to their baseline performance. Existing methods to accurately predict performance decrements require data from multiple PVT sessions administered over several hours. Here we introduce a method to classify an individual as well-rested or sleep-deprived relative to their baseline performance from the distribution of RTs in a single PVT session.

Methods: We used PVT data collected under three in-laboratory studies in which 40 subjects were scheduled to 28–52 hours sleep deprivation (SD) and in which the PVT was administered every 2 (N = 31) or 4 (N = 9) hours. For each subject and for each PVT session, the following feature space was computed: percent RTs falling within a 50-ms bin for 100ms<RT<500ms, percent RTs greater than 500ms (lapses), percent RTs < 100ms (anticipations), and the subject’s mean RT as a function of baseline (day before SD). These data were divided into training, validation and testing sets by subject and categorized as ‘well-rested’ if length of time awake < 16 hours or ‘sleep-deprived’ if length of time awake > 16 hours. We implemented two pattern recognition algorithms: K-Nearest-Neighbor (KNN), which classifies objects based on the closest training example, and ARTMAP, a supervised learning neural network. The training and validation sets were used to optimize parameter estimates for each algorithm based on total percent correct. For KNN, we fit the parameter k, which is the number of nearest neighbors. For ARTMAP, we fit p and r, which correspond to the vigilance and learning rate, respectively. We report the following classification results of the testing set: true positive rate (TP) is the percentage of subjects predicted as sleep-deprived that were sleep-deprived, false positive rate (FP) is the percentage of subjects predicted as sleep-deprived that were not sleep-deprived, false negative rate (FN) is the percentage of subjects predicted as well-rested that were sleep-deprived and true negative rate (TN) is the subjects predicted as well-rested that were well-rested.

Results: Using the validation set, we found k=9 as the optimal number of nearest neighbors and p=0.5 and r=0.5 as the optimal values for vigilance and learning rate. From the test set, we obtained TP=83%, FP=36%, FN=17% and TN=64% for KNN, and TP=78%, FP=40%, FN=22% and TN=61% for ARTMAP.

Conclusion: Two pattern recognition algorithms were used to classify individuals as well-rested or sleep-deprived using baseline performance levels and the distribution from a single PVT session. This information provides an objective measure that can be obtained in real-time, compared to tracking changes across multiple PVT sessions, to determine the objective performance level of an individual. Future implementations of these classification methods will include more training data and will label an individual’s performance level on a continuous scale (e.g. percentage of baseline performance).
Fatigue Risk Management Systems (FRMS)
Enacting/Implementing Change (Track C)

Historically, prescriptive regulation has been used to manage fatigue in the transportation industry. It no longer fits the challenge, or the science. “Prescriptions” may be the problem and given the complexity of the fatigue issue as related to industry operations and the economic interests affected, many attempts in resolving problems with prescriptive regulations to the satisfaction of all parties, have failed. Generally cast within the context of an overall Safety Management System (SMS), a Fatigue Risk Management System (FRMS) is an approach that can be shown to improve operational flexibility and safety. This session includes presentations that review SMS, FRMS, and what was learned from an aviation industry fatigue symposium.

Session Chair: Thomas E. Nesthus, Ph.D.
FAA Civil Aerospace Medical Institute

Tom Nesthus is an Engineering Research Psychologist at the Civil Aerospace Medical Institute (CAMI) in Oklahoma City, OK. His focal research activities include studies of fatigue and performance associated with flight crew and flight attendant duty/rest regulations and Air Traffic Control Specialist shiftwork scheduling.
Safety Management Systems (SMS) and Fatigue Risk Management Systems (FRMS) – Lessons Learned and Actions to Pursue

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Objective: Safety Management Systems (SMS) are a “system safety-based” and relatively recent development in safety “technology.” The idea of SMS is based upon the growing understanding that the origins of mishaps are related to the policies, procedures and practices of an organization. This presentation will explain what Safety Management Systems (SMS) are, point to lessons that Fatigue Risk Management System (FRMS) proponents can derive from SMS development, and suggest FAA and industry actions for FRMS advocacy.

Approach: The U.S. Federal Aviation Administration (FAA), in concert with the International Civil Aviation Organization (ICAO) and other civil aviation authorities, is moving toward the SMS approach to mishap prevention. Fatigue Risk Management Systems (FRMS) can be a vital component of an organization’s SMS, but FRMS, as a tool for fatigue management, lacks the definition that the aviation industry needs for effective application. The “lessons learned” from SMS development and application can be instructive. These lessons can help us to consolidate FRMS theory and bring FRMS to a state of maturity that will permit industry wide application.

Conclusions: This presentation summarized what SMS is, and is not, and described problems and successes in SMS application. FRMS’s relationship to an organization’s SMS was discussed along with the problems in FRMS development. A description of FAA and industry actions on FRMS was also provided.
Review of a Fatigue Risk Management System and the Monitoring of Related Health Concerns

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Objective: The presentation will first describe the development and implementation of Union Pacific Railroad’s (UPRR) Fatigue Risk Management System (FRMS). This is a multi-level risk based system based on the work of Dawson & Roach (2007) that provides for different interventions based on assessment of fatigue related risk. In addition, UPRR has conducted several field studies designed to determine employees' perception of the extent to which they report various psychosocial and affective correlates of job related fatigue including general health and depression.

Approach/Methods: Initial review of UPRR FRMS and presentation scientific panel review. Remaining presentation will focus on related employee health concerns. Survey data was collected from over 500 employees using standard epidemiological measures of depression (e.g., Beck Depression Inventory). Additionally, survey data was gathered on 434 employees describing levels of sleepiness, fatigue and other fatigue related affective reactions (e.g., Epworth Sleepiness Scale).

Results: Significant correlations were obtained between sleepiness, in an operational setting, and psychological symptoms such as depression, anxiety and stress. For example, the odds ratio for reporting moderate depression on the BDI when excessively sleepy as measured by the Epworth was 2.75 and the relative risk of excessive sleepiness following a near miss was 1.70. Interestingly, the odds ratio for reporting excessive sleepiness under stressful conditions at work was 2.4. Significant correlations were also found between fatigue, psychological symptoms and working safely.

Conclusions: The FRMS is a significant component of the overall UPRR Occupational Health Psychology program designed to positively impact culture, health and safety. This study demonstrates the increase risk in employees reports of safe work behavior, stress and psychological health associated with fatigue. The study also addresses the need to manage the risk of fatigue, safety and psychological health in the broader context of behavioral health. Important questions are raised about the need for a broad array of behavioral health measurements and interventions. Implications for the effects of this study regarding job performance, health and safety and increased performance are discussed.
Alternative Approaches for Implementation of Safety Culture Change Programs

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Objective: The objective of this paper is to present and compare alternative approaches for design of safety culture change programs.

Approach: Although fatigue measurement, diagnostics and best practice implementation are desirable for the short run as remedial measures, long term and sustainable changes to transportation organizations require a grassroots based culture change to support these best practices. In one case, a major US airline implemented a series of focus groups with key personnel at several locations to identify the safety related issues that needed attitude change and policy revisions. Another case involved the implementation of a comprehensive system of best practices that is now being utilized by an African airline. The new system offers the possibility of conducting computer supported diagnostic assessments in areas such as environment, health, safety as well as teamwork, leading and managing change and focused improvement. Cost savings and safety related improvements are consistently identified and managed using a system of software called digiTRACC. Management can monitor the cost savings and program costs for each team and each location as well as corporate wide summaries. A loss and waste analysis is facilitated by the use of benchmark indicators to compare with company specific indicators. Graphics that track the improvement of key performance indicators in operating efficiency and safety are cross referenced to each of the implemented best practices. Management is more likely to be involved in this program because they are able to monitor cost and profitability. Workers in teams are motivated because they are empowered to make suggestions that will be implemented. Compensation systems can be modified to motivate the implementation of changes and workers can share in the savings. Payback dates and ROI for over 500 applications in 50 countries indicate that there is a payback in 6-9 months and an expected ROI of over 450%.

Weaknesses in any area are supported by training, train the trainer and relevant implementation action items in a unique set of computer generated action plans for each of the teams and each organizational unit (team, shift, area, plant and company) over five stages of maturity. The entire program is automated and easily transferable between and within organizations. Knowledge sharing is facilitated by a database that links information for each implementation action.

Results: The author compares the two methods and suggests that a comprehensive culture change program with grassroots empowerment can satisfy the need to help management and workers develop a better working relationship and deliver sustainable culture change.

Conclusion: The author suggests that preliminary R&D funding could be used to provide manuals to circulate to US transport organizations. A customized version for US transportation organizations could be made available using the TSC as a clearing house. In addition, the interface with the ICAO adopted Safety Management System could be explored for future applications in the aviation industry in a pilot study of the relevance and efficacy of digiTRACC.
Objectives: Since Lindbergh’s historic trans-Atlantic flight, the challenges of aviation fatigue have been a matter of concern. Regulations in the United States limiting flight time and mandating pilot rest have been in place since the 1940s. While pragmatic, these regulations were developed when the scientific understanding of fatigue and its physiological drivers were poorly understood. Additionally, industry developments combined with continuing pressure for increased productivity and reduced cost have created conditions than can lead to increased fatigue in both flight operations and shift work operations on the ground. The Federal Aviation Administration (FAA) has recognized the need for leadership to begin dialogs to understand and address fatigue in the aviation industry and sponsored the “Aviation Fatigue Symposium: Partnerships for Solutions.” The meeting had four main objectives: 1) Energize the aviation community to solve aviation fatigue problems; 2) Provide attendees with the most current information on fatigue physiology, risk assessment and mitigation alternatives; 3) Develop a common understanding of fatigue issues, identify challenges that create the potential for fatigue, and discuss barriers that have historically prevented solutions to reduce fatigue; 4) Discuss the potential for collaborative alliances to develop and implement fatigue mitigation strategies.

Approach: The symposium was conducted in June 2008 in Tyson’s Corners, Virginia over a 2.5 day period. The meeting included keynote addresses and panel presentations by leaders in the aviation industry, government regulators, and scientific experts and was designed to disseminate essential information about aviation fatigue, from the underlying biology to the operational impacts, and to stimulate discussion leading to seeds for future collaborative solutions. Challenges in both flight operations and ground support shift work operations were addressed. Breakout discussion groups, each with specific assignment areas, occurred at various times throughout the symposium. Each discussion group reported a summary of their discussions on the last day of the meeting.

Results: Over 300 safety professionals representing over eight different countries attended the symposium. The audience of the meeting was broadly defined to include government agencies concerned with transportation fatigue (FAA, National Transportation Safety Board (NTSB), National Aeronautics and Space Administration (NASA), Federal Railroad Administration (FRA), Department of Defense (DOD), and others), commercial air carriers, major employee groups representing flight and ground support personnel, aircraft manufacturers, aviation associations, and the Flight Safety Foundation. Panel discussions provided presentations on drivers of fatigue, operational evidence of fatigue, fatigue risk management approaches, mitigation strategies, and measures of effectiveness for both flight operations and aviation shift work operations.

Conclusions: Fatigue challenges are cross-cutting in aviation operations and affect flight crews, ground support personnel, maintenance personnel, and air traffic controllers. The solutions require the cooperative action of industry, employee groups, and the FAA. Importantly, there is also a need for a shared commitment that rests on a common understanding of the problem, a frank understanding of the barriers, and a collaborative approach to developing practical solutions. This presentation will review the motivation for this historic meeting, the information covered during the meeting, the results of industry discussions, and a summary of implications from the discussions.
Poster Session II
Towards a Fatigue Risk Management System for the French regional airlines: applications to the reduced rests and split duties

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Objectives. By July 2008 the new regulation on Flight Time Limitations (FTL) (EU-OPS-sub-part Q) for pilots and flight attendants has came into force in Europe. Besides the changes in the FTL introduced by this regulation compared with the current national regulations it specifies that an operator may grant reduced rest arrangements if it demonstrates to the Authority that its request produces an equivalent level of safety. In order to comply with this requirement, France issued a regulation defining the concept of a Fatigue Risk Management System (FRMS). A FRMS is a process that enables the organization to manage the specific risks associated with fatigue. In this context, the DGAC has launched a study on the implementation of FRMS for the French regional airlines. This FRMS will have to address the specific case of the “reduced rests” (i.e. a late evening arrival followed by an early morning departure by the same crew) and split duties that are used by French airlines due to their specific network. This study that is addressing numerous research issues such as the link between fatigue, human performance and risk will provide the overall strategy to implement a scientific based FRMS to enable an efficient prevention of fatigue.

Method. The method is based on the use of validated biomathematical predictive models of fatigue (Fatigue Risk Index and Sleep Wake Predictor) and on the analysis of existing safety indicators within the airlines, i.e. Air Safety Reports (ASR) and Flight Data Monitoring (FDM). As fatigue may have a potential impact on health, statistics such as sickness leaves are also recorded. These data are systematically analyzed with regards to the fatigue risk predicted by the model. In parallel, a website survey and specific in-flight observations and data collection (sleep log and actometry) are performed on a selected set of rosters in order to tackle other contributing factors to fatigue than flight duty time (e.g. operational environment) and to evaluate the fatigue impact on aircrews work.

Results. First results on the planning analysis show that the fatigue risk associated with rosters including a reduced rest varies considerably depending on the position of the roster within a sequence of duties. This shows that cumulative effects should be considered in the scheduling of aircrew. First analysis of ASR and FDM highlights a significant impact of the time of the day suggesting that these parameters, provided that an appropriate methodology is applied, could be used to evaluate the impact of scheduling on aircrew fatigue.

Conclusions. From these results, first outlines of the future FRMS are currently being developed to prevent fatigue risk at different levels of the organization, the strategic, tactical and operational levels. At the strategic level it could include the opening of a new line or the remuneration policies. At a tactical level, the fatigue risk has to be considered in the scheduling process. Finally, at the operational level, appropriate education program should help aircrews to increase their awareness and help them to manage the risks associated with fatigue.
Managing Fatigue in the Remote Australia Livestock Transport Industry

Objective: In Australia, the National Transport Commission has recently enacted a regulatory scheme, Advanced Fatigue Management (AFM), to manage fatigue-risk in truck drivers. The approach differs from past prescriptive regulatory practice by accrediting haulers to operate under compliance rules which they propose themselves, within outer legislated boundaries. The Remote Australia Livestock Transport (RALT) industry faces unique operating conditions based on animal welfare needs, extreme geographical isolation and long distances between facilities. As such, the industry has proposed to adopt a compliance regime that would see fatigue-related risks for individual drivers assessed on the basis of sleep obtained rather than hours worked. As part of this regime, drivers would be required to report a ‘fatigue index score’ based on their recent sleep/wake history. Fatigue index scores would then be used to assign a level of fatigue-risk to work hours according to specific threshold values. The objectives of this study were to: (1) survey the sleep/wake behaviour of livestock transport drivers working in remote Australia; and (2) evaluate current operating practices against the compliance regime proposed by the industry.

Approach (or Methods): A sample of 32 male livestock transport drivers volunteered to participate in the study during the peak demand season. They had a mean (± st. dev.) age of 35.41 (±9.78) years and had worked as truck drivers for 13.83 (±9.11) years. Participants recorded information about their sleep and driving times in a study diary for 3 weeks, and wore a wrist activity monitor to cross-validate sleep and wake times. Analyses were based on a total of 669 days of sleep and driving time information, which included 767 sleep periods and 1,319 driving shifts.

Results: In general, drivers exhibited appropriately timed sleep/wake cycles – main sleeps were initiated at night while naps occurred during the days. However, they obtained an average of only 6.07 (±1.18) hours of sleep per day. The great majority of sleeps were initiated in a workplace setting, either in barracks at company depots (11%) or in truck cabins (77%) during trips. In respect to the proposed compliance regime, 34% of total driving hours fell into a low fatigue-risk category, 34% were classified as having moderate fatigue-risk – and could only have been worked if additional fatigue-risk controls were implemented, while the remaining 32% were in a high fatigue-risk category and would not have been permitted at all.

Conclusion: Livestock transport drivers working in the RALT industry obtain approximately 6 hours of sleep per day; between 1 and 2 hours less than ideal. Thus, policies encouraging drivers to get more sleep have the potential to convey safety benefits to the RALT industry. If appropriately implemented, the compliance rules proposed by the industry would greatly improve its fatigue-risk profile, but at the expense of a substantial re-organization of current operating practices. From the regulatory perspective, the adoption of the AFM system allows unique industries such as RALT to propose a robust compliance regime that gives comfort to regulators that fatigue-related safety is being suitably managed, while allowing that industry to continue to meet the transport task.
A Fatigue Management Safety Tool Designed Specifically to Address Best Practices of Actual Rosters both On and Off Site

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Objective: Educate, inform, and motivate rotating shift workers with regard to their roles and responsibilities regarding fatigue management. Shift worker fatigue, recognized as a major performance and safety problem in the 24/7 sector, is strongly influenced by work/rest patterns and shift worker lifestyle. In the U.S. alone, fatigue costs are estimated to be in excess of fifty billion dollars per annum. While work and rest hour regulations are commonly applied to manage fatigue, they predate advances in alertness science and do not recognize that human physiology determines alertness and performance limits. These approaches, which are inconsistent with sleep science, provide little fatigue management protection, restrict operational capacity, competitiveness and hinder work schedules promoting staff wellbeing and quality of life. Managing fatigue by prescriptive rules has proven to be an elusive goal. However, application of advances in scientific research in sleep and circadian physiology offers an opportunity to proactively manage fatigue, help ensure alert decision-making, and decrease the relative risk of human error and failure. While the science continues to advance, the shift worker continues to have no practical or cost effective avenue with which to adapt his or her lifestyle to mitigate fatigue.

Methods: Provide user friendly and cost effective tools to every shift worker. 24/7 Lifestyle Planner tools (Family Planner and Personal Pocket Planner) are designed to guide innovative science based, practical fatigue management and shift work lifestyle strategies into singular management tools. These Planners flag fatigue risk of shift work and rest patterns and offers proven strategies to assist workers and families manage these risks, while additionally providing guidance to shift workers and managers on fatigue associated with current work schedules. Through the application of these tools, both workers and managers can proactively take steps to improve fatigue scores and lifestyle adaptation. These tools are designed on the platforms of the ARC (Activity Rest Cycles) and FIRM (Fatigue Index Risk Measurements) software systems. ARC generates colour coded, easy to read graphs, reflecting fatigue issues and challenges of actual work/rest patterns. FIRM projects and quantifies fatigue risk arising from the interaction of work/rest patterns and cycles. The intricacies and advances in the sciences of human physiology, sleep, and fatigue management are all captured on inexpensive and easy to follow planners that tape to the refrigerator or fit in a pocket.

Results: A safer and more productive environment. Application of the 24/7 Lifestyle Planners safety management system tools can help reduction of fatigue and the rate and costs of accidents, while improving other operational parameters and employee quality of life.

Conclusions: Applying 30 years of international scientific scheduling design and fatigue risk consulting expertise, helping 24/7 companies and staff improve performance, safety and quality of life, the unique and innovative 24/7 Lifestyle Planners. integrate and incorporate the best known science based practices for combating residual impacts of fatigue of actual applied schedule rosters into a very economical and easy to use science based tools that are developed to not only flag problems, but to fix them. Reflecting fatigue issues and challenges of actual work/rest patterns 24/7 Lifestyle Planners will help staff:

1. Self-assess and confirm their individual 24/7 life style and work/rest issues and challenges
2. Manage fatigue by applying any of 10 practical and proven strategies corresponding to fatigue identified for applicable days and zones within days
3. Manage 24/7 lifestyle instead of simply tolerating it
4. Assume responsibility in managing their lifestyle
Complex interaction of aging on reaction time performance across three weeks of forced desynchrony.

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Objective: The purpose of our analysis was to quantify homeostatic (duration of prior wakefulness) and circadian (biological time) influences on reaction time (RT) performance in older adults in a study where we could manipulate the circadian time; to assess these measures across a three-week laboratory study; and to compare these findings with results from younger adults.

Methods: Ten healthy older volunteers (mean age 64.00 ± 5.98, 5f) participated in a study consisting of three baseline days followed by 18, 20h “days” (consisting of 13.3h wake and 6.7h bedrest; this allowed wake episodes to occur at all circadian phases, or times of day). A 10-min psychomotor vigilance test (PVT) was administered every 2 waking hours. Core body temperature (CBT) data were collected throughout to assess circadian phase. PVT data from each subject were binned into 2h “time awake” bins, 60 degree (4 circadian h) “circadian phase” bins, and assigned a CYCLE based on elapsed time into the experiment. CYCLES consisted of six 20h “days,” with each CYCLE beginning at the same clock hour. Data were compared to those collected from 10 healthy younger volunteers (mean age 24.50 ± 3.54, 5f) who took part in a similar study. We analyzed the data using mixed model analysis for factors AGE, TIME AWAKE, CIRCADIAN PHASE and CYCLE. Two-way interactions between AGE and all other factors were also tested.

Results: During baseline, there was no significant difference in mean RT between age groups (p = 0.70). During the 20h day portion of the study, there was a significant main effect of TIME AWAKE (p < 0.0001), with mean RTs slowing with longer time awake. A significant AGE - TIME AWAKE interaction (p < 0.05) revealed younger subjects to have longer RTs throughout the wake episode. A significant main effect of CIRCADIAN PHASE (p < 0.0001), revealed poorest performance at the phase near the CBT minimum (equivalent to the early morning hours under normal conditions), with no AGE – CIRCADIAN PHASE interaction indicating that the circadian influence on RT was similar for both age groups. There was a significant main effect of CYCLE (p < 0.0001), with mean RTs slowing with each successive cycle. A significant AGE - CYCLE interaction (p < 0.0001), revealed that the magnitude of the slowing of RT from one cycle to the next was significantly greater for younger subjects than for older subjects.

Conclusion: There was not a significant main effect of age on RT, but we did observe a significant interaction between age and the duration of time awake, with young subjects showing slower RTs than older subjects throughout the waking day. We also observed a significant interaction between age and cycle (duration within the study), with the young subjects slowing down with each successive study cycle while the RT performance of the older subjects was maintained across the 3 study cycles. In summary, our findings indicate that young adults may be more vulnerable to adverse homeostatic influences on RT performance than are healthy older adults.
Subject-Specific Evaluation of Performance Based on Forced Desynchrony Data

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Objective: We used modern statistical methods to build subject-specific models for the effects of circadian phase and homeostatic sleep drive on individual neurobehavioral performance. The model allows (1) conducting hypothesis tests on the significance of effect of circadian phase and homeostatic sleep drive on an individual's neurobehavioral performance, (2) assessment of the functional form of these effects and (3) testing for the presence of inter-individual differences. Our objective was to develop a method that could be used to statistically assess an individual's response (rather than a group average response) to a work schedule that includes different combinations of circadian phase and length of time awake, such as occurs for workers in transportation.

Approach and Methods: When an individual lives on a 24h day, two covariate processes, circadian phase and homeostatic sleep drive (related to length of time awake), covary. This does not allow reliable estimation of the effects of the two covariates under different sleep/wake schedules on different physiologic measures, including performance and alertness. Therefore, a forced desynchrony protocol is used, whereby subjects are scheduled to live on non-24h days, for example, a 42.85h day with 28.56h awake and 14.28h asleep. This protocol allows neurobehavioral testing at different combinations of circadian phase and homeostatic sleep drive. We estimated subject-specific effects of circadian phase and homeostatic sleep drive on neurobehavioral performance using smoothing spline ANOVA models with restricted number of knots. We developed a unified framework for conducting hypothesis tests to assess goodness-of-fit and test for inter-individual variability via a permutation approach.

Results: The functional estimates for the effects of circadian phase and homeostatic sleep drive revealed that, for most subjects, the two variables have statistically significant effects on performance. In addition, there are statistically significant inter-individual differences in the effects of circadian phase and homeostatic sleep drive on performance.

Conclusions: The new method of functional estimation and hypotheses testing is reliable, allows estimation of subject-specific effects as well as assessment of inter-individual variability. It has better estimation properties than previously used methods, such as parametric ANOVA models, and can be applied by the transportation industry to assess effects of multiple factors on human performance, alertness and fatigue for individuals.
The Effect of Diurnal Preference on Subjective Alertness During Extended Wakefulness

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Objective: Humans are a diurnal species and, for the most part, schedule their activities during the daytime and sleep during the night. The preferred timing of this activity/rest schedule, also known as morningness-eveningness or diurnal preference, varies greatly in the general population. The Horne and Östberg Morningness-Eveningness Questionnaire (MEQ) is used to measure diurnal preference and has been validated in several different populations. Previous reports in morning (M) and evening (E) types have found differences in the timing of circadian rhythms and differences in sleep homeostasis between the groups. In the present study, we aim to compare alertness and cognitive performance between morning and evening types during extended wakefulness.

Methods: The current analysis includes data from 25 healthy young adults (18-30 years of age) who were selected based on their MEQ score. Seventeen M types (6 females; 23.76 ± 3.35 years (mean ± SD)) and 8 E types (2 females; 22.75 ± 3.24 years) completed inpatient studies including 3 baseline days in the lab followed by a 40-h extended wake episode in constant conditions. A series of neurobehavioral tests were administered throughout the study. We report here on results from the Karolinska Sleepiness Scale (KSS), a 9-point subjective sleepiness-alertness scale, and a Psychomotor Vigilance Task (PVT). The Karolinska Sleepiness Scale (KSS) was given every 30 minutes and the Psychomotor Vigilance Task (PVT) was given every 2 h throughout the study. Data were binned in 1-h (KSS) or 2-h (PVT) bins, and a mixed model analysis with repeated measures (SAS 9.1) was used to compare the self-rated sleepiness and performance between the groups.

Results: Results from the KSS showed that both M and E types reported growing progressively sleepier across the 40-hour wake episode. Results also showed that E types, on average, rated themselves as sleepier than M types throughout the entire 40 hours, although this difference was not significant (p = 0.10). In contrast PVT results showed a slower reaction time (RT) and more lapses in M types compared to E types. We next divided the 40 hours into 2 parts, the first 16 hours equivalent to a normal waking day and hours 17-40, representing the extended wake/sleep deprivation part of the study. Both groups reported that they were sleepier during the second segment, representing the extended wake portion, than during the first 16-hour segment, but there was a greater difference between the groups in subjective alertness during the first 16 hours, with E types reporting greater sleepiness. In contrast, the greatest performance difference between the two groups was during the extended wake segment, with the E types showing faster RTs and fewer lapses.

Conclusion: We found that E types appeared to be subjectively sleepier, as a group, than M types, however, E types showed faster RTs and fewer lapses during the PVT, particular during extended wakefulness. We plan to study additional E types to determine whether there are differences between these types under standard daytime conditions or under conditions of sleep deprivation, and to extend our analysis to data collected across different circadian phases.
Predicting risk of cognitive performance decrements during residents’ commute home

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Objective: Despite work hours regulation in other safety-sensitive professions, US physicians and surgeons continue to work extended duration shifts of 24 hours or more. Recent studies highlight the risks posed to physician health and patient safety by the acute sleep deprivation inherent in such marathon extended shifts (>24-30hr). In a nationwide survey, the odds ratio for 2737 PGY-1 residents reporting a motor vehicle crash after an extended duration shift was 2.3 (95%CI,1.6-3.3) as compared with non-extended shifts. Circadian Performance Simulation Software (CPSS) permits the prediction of cognitive performance levels according to sleep-wake behavior and circadian phase. Under normal sleep-wake conditions, CPSS predicts that performance will drop below 80% of maximum after 16 hours of continuous wakefulness. The risk ratio (RR) of the predicted duration spent below the 80% threshold during the commute after scheduled work was compared in medical interns’ schedules with and without extended shifts using CPSS.

Approach: The scheduled work times for two operational ICU rotas were compared: a traditional rotation that required a three-person team to each work 24-30 hours every other shift (Q3) and a four-person team intervention schedule that limited continuous duty to 16 hours maximum. Sleep times for the model were created by averaging the self-reported sleep-wake times of 20 interns (8F, age 26-32) while working these schedules (~840 days) and grouped by the scheduled shift types. Naps were averaged separately and were added to the schedules on random days at the same daily frequency as observed in the real data. CPSSv1.2 was used to simulate cognitive performance levels. Sub-optimal performance was defined as below 80% of the maximum predicted level, equivalent to performance after 16 hours of continuous wakefulness following 8 hours of sleep. CPSS predictions were binned by minute and RR values (95% confidence intervals) were calculated for each team for the number of minutes of exposure below 80% performance for the hour after the end of each shift to represent the after-work commute.

Results: The RR of sub-optimal performance on the traditional schedule as compared to the intervention schedule was 1.64(1.55,1.74) during the commute home. The CPSS-predicted risk of sub-optimal performance paralleled the increased risk of motor vehicle crashes on the commute home reported by interns after working extended shifts. Similar differences in predicted cognitive performance were also observed during work hours in a separate analysis.

Conclusion: Oversimplified approaches to schedule design, which do not take into account the main physiological factors that affect sleepiness (circadian phase, acute sleep deprivation, chronic sleep deprivation, sleep inertia), may inadvertently elevate the risk of drowsy driving crashes and other sleepiness-related accidents and injuries. CPSS software may be a useful tool to evaluate schedules prior to implementation in order to predict the amount of time spent in sub-optimal performance, the risk of motor vehicle crashes to and from work, and the risk of performance degradation during work shifts.
Guiding the Design of an FRMS
Part 1) A Fatigue Survey of Crew Working for a Charter Airline

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Objectives: The aim of the study was to provide Jetairfly, a European charter airline, with an overview of the fatigue associated with its operations in order to guide the design of an effective fatigue risk management system (FRMS). The study consisted of two parts: 1) a crew survey and 2) the statistical analysis of crew rosters (reported in a second poster). The key aims of the survey were to identify: the extent to which crew felt fatigue was adversely impacting on safety; the aspects of crew performance being impaired by fatigue; and the features of the roster that were promoting fatigue.

Methods: In April 2008, all crew (125 pilots; 223 cabin crew) were emailed a personalised web-link to the survey. The survey was designed to take approximately 5-10 minutes to complete and consisted mostly of multiple-choice questions. From a list of airline safety risks, crew were asked to identify what they felt posed the greatest risk to Jetairfly. From a second list of the different ways fatigue can affect performance they selected the type of impairment they most commonly experienced. To quantify the fatigue hazards associated with the roster, crew were provided with a list of roster features and asked to rate each one according to both the frequency with which it was encountered and severity of any associated fatigue. By combining the data using a risk matrix method, the prime perceived fatigue-related roster hazards were identified.

Results: The majority of pilots (82%) and cabin crew (83%) completed the survey. Pilot tiredness (53% of pilots) and cabin crew tiredness (35% of cabin crew) were risks that the most crew identified as posing the greatest safety risk. 16% of pilots and 27% of cabin crew reported that fatigue adversely affected their work performance on ‘every’ or ‘most’ duties. The most common effects of fatigue on performance reported by pilots were increased reliance on aircraft automation, slips and lapses and forgetting information or actions. In contrast, cabin crew cited increased irritability, distraction and loss of interest or motivation as the most frequently encountered affects of fatigue.

Both crew groups identified transitions from late to early duties, long duty days (>9 hours), >4 consecutive early duties and roster changes as the prime roster-related fatigue hazards. The most frequently recommended method for reducing fatigue risk was to increase roster stability (28% pilots and 31% cabin crew).

Conclusion: Crew reported that fatigue was having a significant impact on safety and performance, thereby supporting management’s decision to develop an FRMS. The survey data, combined with the results of the statistical roster analysis, informed the design of a number of controls including training schedulers to more effectively manage aspects of the roster now known to promote fatigue and company rostering guidelines that prevent rostering of early to late transitions. The results also guided the design of a crew fatigue report form and a bespoke fatigue awareness and countermeasures training (FACT) programme that specifically addressed the fatigue risk associated with the Jetairfly operation. Finally, as the survey collected ‘baseline’ data, repeating the survey at regular intervals will enable subjective indicators of fatigue to be tracked on an ongoing basis.

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Objective: Human factors can have substantial impact on work quality and safety in aircraft maintenance. Marx and Graeber (1994) estimate approximately 12% of major aircraft accidents and 50% of engine-related flight delays and cancellations are due to maintenance deficiencies worldwide. Aircraft maintenance personnel report that fatigue is one of the most prevalent causes of accidents and deficiencies (Hobbs & Williamson, 1999). Accordingly, the objective of this presentation is to: 1) determine what is being done internationally by regulators and operators to prevent or reduce fatigue and 2) identify best practices for managing fatigue in aviation maintenance operations.

Approach: To obtain information regarding international maintenance operations, researchers contacted international experts and aviation regulatory authorities on several continents. Information was collected regarding current international policies and regulations for aviation maintenance personnel. Policies and regulations were content analyzed in terms of five key questions: 1) presence of regulations on maintenance fatigue, 2) presence of duty-time limitations, 3) plans for future maintenance regulations, 4) presence of handbook or guidance material on fatigue, and 5) guidance on fatigue risk management system (FRMS). To identify best practices for managing fatigue, queries were sent to 25 experts regarding the issue of maintenance fatigue and potential suggestions for safety management practices. Expert responses were content analyzed and classified into emergent themes.

Results: Preliminary analysis of international policies and regulations indicates few regulatory agencies have duty-time limitations for aviation maintenance personnel. There is a growing trend toward regulatory agencies providing either guidance material or handbooks that address fatigue. Increasing attention is being directed toward the development or implementation of fatigue risk management systems. In fact, a content analysis of expert responses regarding maintenance fatigue management reveals a similar trend toward fatigue risk management systems.

Conclusions: Aviation maintenance fatigue continues to be an area of substantial concern. International regulators and operators have taken different approaches to safety management (e.g., duty time limitations, guidance material, FRMS). Experts from across disciplines (airlines, unions, academia, and government) advocate an integrated multi-method safety management approach that addresses key issues associated with maintenance fatigue.
Guiding the Design of an FRMS
Part 2) Statistical Analysis of the Rosters Worked by a Charter Airline

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Objectives: To guide the design of a fatigue risk management system (FRMS) at Jetairfly (a Belgian charter airline), the fatigue associated with the operation was explored via 1) a crew survey (reported in another poster) and 2) the statistical analysis of crew rosters. The aim of the roster analysis was to objectively identify the roster features which limited and which promoted alertness and quality of life.

Methods: The actual rosters worked by all pilots (n=162) and cabin crew (n=346) during 2007 were analysed. Descriptive statistics were calculated for variables including: duty type, duty duration, duty timing, duty sequences, rest durations between duties, destinations, time-zones and layover durations. Excluding the 46 pilots who worked long-haul, the rosters were also analysed using FAID fatigue modelling software. The duty sequences associated with ‘high’ FAID scores were scrutinised to identify the aspects of the roster that were responsible.

Results: Pilots and cabin crew worked the same fully-flexible roster. The majority of duties involved 1 to 3 flights. When crew were not working long-haul duties, they almost always finished their duties back at base (Brussels). Statistical analyses showed that a large proportion of duties (43%) started early (0400-0559) and had the longest mean duration (10h20min). The longest blocks of duties were 11 duties long.

The majority of high FAID scores were observed during the European summer period, when workload is highest. The FAID results indicated that the key sources of roster-related fatigue were: >4 consecutive early duties, >5 consecutive duties of any type, transitions between early and late/night duties and >3 consecutive late/night duties.

All long-haul outbound flights were to sunny Westward (range: -6h to -8h from Brussels time) destinations, for example, Jamaica. Average layover duration was 3 days (range: 2 to 5 days) before crew returned to Brussels. Most outbound long haul flights departed during the day, Brussels time, and returned during the day, layover time.

49% of the rest periods between duties were greater than 24 hours and 30% greater than 48 hours. 85% of duties provided crew with a free evening and 40% of weekends were completely free from work.

Conclusion: The roster-related sources of fatigue identified in the analysis essentially matched those identified by the crew in the survey (see other poster). The analysis highlighted the high prevalence of relatively long early duties as a key fatigue hazard to be managed within Jetairfly’s FRMS. Overall, the analysis results indicated that the roster affords crew a very good quality of life. However, it is important to note that at the time the airline did not collect the data required to quantify roster stability. “Improved roster stability” was the most prevalent suggestion for reducing fatigue made by crew in the survey.

Long-haul duties were well rostered in that most outbound flights departed during the day. During a 3-day layover in a sunny location crew sleeping habits are likely adapt (delay) considerably to suit the local time. Adaptation is positive because most flights returned during the day (layover time). However, once crew return home they are likely to encounter jet lag as they re-adapt (advance) to Brussels time.

The analysis results informed the design of a number of the elements of the Jetairfly FRMS, including fatigue management training for schedulers. The company is now utilising FAID on a day-to-day basis and investigating ways to automatically track roster stability and other roster-related contributors to fatigue, such as the number of early duties worked, on an ongoing basis.
An Analysis of Self-Reported Locomotive Engineer Alertness and Activity

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Objective: The Locomotive Engineer Activity Project (LEAP) was a voluntary self-rated fatigue study conducted from 1992 to 1994 by the Volpe National Transportation Systems Center. The subject sample consisted of 163 engineers assigned to regular road, road pool, extra board, and local/yard jobs. A total of 1,366 engineer work days and 820 engineer non-workdays were analyzed. The self-reported log was utilized to record information related to sleep, activity, and on-duty alertness for work and non-work days over 14-day and 28-day periods.

Methods: The main objective of the current study was to evaluate the relationship of activity, sleep, and job assignment variables to self reported on-the-job alertness using descriptive and non-descriptive analytical methods. Study variables included ease of sleep onset rating, sleep maintenance rating, sleep quality rating, sleep location, sleep length, age, body mass index (BMI), commute distance, alertness all subjectively reported by engineer subjects. The descriptive matrix included arithmetic mean, median, standard deviation, variance, and kurtosis. A single factor analysis of variance (ANOVA) and a Duncan multiple range test were conducted for each variable to test job assignments against all other variables at alpha = 0.05.

Results: Road pool engineers slept the longest and local/yard engineers slept the shortest. The ability to stay asleep was “easy to slightly difficult” for approximately one-half the engineers on work days as well as non-work days. On non-work days, approximately 55% of the engineers reported feeling “well rested”, this number decreased to 40% on work days. The activity logs indicated that 44% engineers felt “fully alert” while on-duty, 29.4% “moderately alert”, 18.3% “drowsy”, and 8.2% “fighting sleep” at some time while operating the train. ANOVA indicated age, BMI, sleep length, and sleep quality were significant predictors of on-the-job alertness, and the Duncan test showed significant differences between job assignments for age, BMI, and sleep length and sleep quality.

Conclusion: Analyses showed that a typical engineer in the study sample was at least Grade I Obese (based on BMI), between the ages of 40 and 50 years old, assigned to the road pool, slept mostly at home on non-work days, slept both at home and away from home on work days, felt “moderately to well rested” upon awakening on work and non-work days, and subjectively reported being “not fully alert” at least once while on duty. These findings suggest the possibility of higher risk for sleep apnea, reduced sleep quality, decreased on-the-job alertness, and elevated risk for fatigue-related problems in train crew operations.
Risk Factors for Motor Vehicle Crashes in Medical Residents.

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Objectives: Extended duration work shifts (≥24 hours) have been a hallmark of medical education. The substantial sleep loss and circadian misalignment associated with shifts of such extended duration bring about decreased alertness and decrements in performance, including an increase in medical errors and motor vehicle crashes. In this study, we are completing an analysis of all risk factors associated with motor vehicle crashes in medical residents.

Methods: 2,737 residents in their first post-graduate year (PGY1) participated in a prospective nationwide, web-based survey. They completed 17,003 monthly surveys providing detailed information on work hours, extended duration work shifts, MVCs, near-miss accidents, the usage of wake-promoting and sleep-promoting sleep medications, caffeine and alcohol and amount of exercise. In addition, driving history data, specialty, and demographic data were collected.

Results: 320 MVCs were reported and we requested documentation of each. PGY1 residents had an 8.8 % (3.2%-14.4%) increased monthly risk of any MVC and a 16% (7.6%, 24.4%) increased monthly risk of an MVC on the commute home from work for each extended duration work shift scheduled. MVC risk was doubled [O.R.: 2.2 (1.5, 3.2)] and reported near-miss accidents risk increased nearly six-fold [O.R.: 5.9 (5.4, 6.3)] following an extended duration shift versus a non-extended duration shift (Barger, et al., 2005). Analysis of the independent effects of specialty, history of prior MVCs and citations, caffeine, alcohol, and medication use, and demographic variables is ongoing.

Conclusions: Motor vehicle crashes are common in medical interns. Extended duration work shifts are a major risk factor for motor vehicle crashes and pose a serious safety hazard for interns and other motorists. Other potential risk factors may also bear significantly on safety but have not been adequately explored – final analyses of these factors is currently being completed. Understanding the risk factors for motor vehicle crashes in this high-risk occupation has important implications for hospitals and medical residency programs.

References:
Time of day and skill-based errors in airline maintenance

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Objective:

In workplaces where activity continues around the clock, the frequency of accidents and human errors have been observed to peak in the early hours of the morning. Most previous operational studies of human error variability throughout the 24 hour day have not controlled for unequal levels of work activity at each hour of the day and night. Without information on work activity, it is unclear whether variations in occurrence frequency reflect changes in human performance or simply reflect the pace of work activity. The objectives of the current study were (1) to determine, with the aid of normative data, whether there is evidence for an early morning peak in airline maintenance errors, and (2) if such a peak exists, to determine whether it is related to a uniform increase in the frequency of all forms of error, or an increase in the frequency of specific errors forms.

Approach:

A survey was distributed to approximately 5000 aircraft maintenance personnel in Australia. Respondents were asked to report their hours of work attendance during their most recent work shift. In addition, respondents were given the opportunity to report a maintenance occurrence in which they had been involved. Of the returned surveys, 402 contained reports of an occurrence involving an airline aircraft. The errors that were described in occurrence reports were classified into the categories of skill, rule or knowledge-based errors and procedure violations. The frequencies of occurrences and errors throughout the 24 hour day were normalized using the work attendance data.

Results:

When normalized for work attendance, airline maintenance occurrences showed a peak in the early morning hours. This peak was largely attributable to an increase in skill-based errors such as memory lapses and absent minded slips. In contrast, the frequency of rule-based errors, knowledge-based errors and procedure violations exhibited less variation throughout the 24 hour day.

Conclusion:

Consistent with anecdotal evidence and the body of human performance research, the current study provides evidence that the early hours of the morning are a risk period for maintenance error. While this general finding may be expected, of critical importance is that the increased risk appears to reflect specific cognitive challenges, rather than an overall degradation of human performance. This study has suggested that, compared to other times of the 24 hour day, maintenance personnel on duty in the early hours of the morning are at increased risk of errors involving failures to carry out intentions, but are not necessarily at an increased risk of making errors involving the formulation of intentions, or the performance of willful procedure violations. Interventions designed to prevent or capture maintenance errors should be designed with this in mind.
Objective: In 2006, according to AASHTO, (American Association of State Highway and Transportation Officials) approximately 59% of highway fatalities were the result of leaving the lane or departing the highway unintentionally in the U.S. This presentation will show real world statistics gathered over 6 years of commercial vehicle deployment of vision-based Lane Departure Warning Systems.

Approach: Some medium and large fleet have had these systems deployed for more than 5 years. Many of these fleets have tracked the progress of trucks equipped and not equipped with these systems over various amounts of time and miles accumulated. LDW-Preventable accidents have been closely tracked over the time period by these fleets, using data sets consisting of trucks with and without Lane Departure Systems.

Results: The fleets involved have collected nearly 1.3 billion miles in trucks not equipped and about 860 million miles in trucks equipped with Lane Departure Systems. These fleets have seen a 74% decrease in the rate of these LDW preventable accidents when measured by accidents per million miles.

Conclusion: Vision-based LDW systems are quite similar to Highway rumble strips and are a proven method of significantly reducing Lane Departure Related accidents and fatalities. Like highway rumble strips, Lane Departure Warning helps get drowsy and distracted drivers off the road.
Individual Differences in Response to Sleep Loss: Implications for Occupational Safety
Health-Related/Pharmacological Issues (Track B)

Effects of extended duration shifts on performance and safety in the context of transportation operations will be covered. Recent findings on individual differences in vulnerability to the effects of sleep loss, including the contribution of genetics, will be reviewed. Finally, legal and policy implications of these findings for workforce hiring and scheduling will be considered.

Session Chair: Shantha M.W. Rajaratnam, Ph.D. LLB.
Harvard Medical School and Monash University

Shantha Rajaratnam is Associate Professor in the School of Psychology, Psychiatry and Psychological Medicine at Monash University (Australia) and Lecturer in Medicine in the Division of Sleep Medicine at Harvard Medical School (USA). He is a Psychologist with expertise in the physiological mechanisms underlying circadian rhythm sleep disorders, treatment options for such disorders, and fatigue management programs for shift workers. He also has a strong interest in legal issues relating to shiftwork and sleep deprivation.
Inter-Individual Differences in the Impact of Sleep Loss on Neurobehavioral Performance: Regulatory Implications for the Transportation Industry

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Summary: It is well known that – on average – healthy individuals exhibit more attentional failures and make more errors when they are sleep deprived. This was recognized more than a century ago. For this reason, prescriptive work-hour regulations exist in many sectors of the transportation industry—the first having been established in the U.S. for the rail industry in 1907. Extensive scientific evidence has since demonstrated that performance drops and risk of error increases as duration of wakefulness and/or chronic sleep deficit increases. In fact, a recent meta-analysis concluded that—on average—after 24-30 hours of sleep deprivation, individual performance drops to the 15th percentile compared with a rested group. Biomathematical models have been developed to estimate the average increase in risk associated with differences in the timing and duration of work shifts. Some have suggested that work-hour regulations should be reevaluated in light of this increasing body of scientific evidence; others have even suggested that such regulations be replaced by fatigue management programs.

Emerging evidence indicates that some healthy individuals are more resistant than the average person to the detrimental effects of sleep deprivation on performance. Several genetic polymorphisms have been identified that relate to such differences in the tolerability to acute sleep loss. The 2008 Genetic Information Nondiscrimination Act prohibits employers from using genetic information to make decisions about hiring, firing or compensation, or from using such information to classify or segregate employees in such a way as to deprive them of employment opportunities. Yet, a substantial fraction of the population appears to be particularly vulnerable to the performance-impairing effects of 24 hours of wakefulness, which often occurs by the end of the first night shift of a sequence. Data indicate that affected individuals have 2-3 times the risk of error under such conditions. Experimental data indicate that these inter-individual differences are stable traits that are not dependent on inter-individual differences in prior sleep-wake history. Given that night shift work, resulting in acute and chronic sleep loss, is essential to the transportation industry, this evidence presents the transportation industry with a dilemma. Should vulnerable individuals be identified with testing of vigilance and operator performance under conditions of sleep deprivation while operating a transportation vehicle or simulator? Alternatively, should regulations and work schedules be modified to ensure that work schedules are safe for all employees, regardless of their genetic background? This would require that, in the interest of public safety, work hour regulations in the transportation industry be based on the effects of sleep loss on the most vulnerable quartile of the population, rather than on the average response to acute and/or chronic sleep loss.
Individual Differences in Responses to Sleep Loss

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Individual differences in the neurobiological processes regulating sleep, circadian rhythms, alertness and performance shape individuals’ responses to extended work hours and shift work, and affect their performance, safety and well-being. Recent studies have demonstrated that individual differences in performance impairment due to sleep loss are substantial and constitute a trait. Self-assessments of sleepiness do not correspond well with individual differences in objective performance impairment during sleep deprivation. Perhaps because of this discrepancy, individual differences in vulnerability to sleep loss in operational settings do not appear to be limited by self-selection mechanisms.
Genetic predictors of physiological and behavioural responses to sleep loss

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Background: People differ with respect to their preferred timing of sleep and wakefulness and can either be morning, intermediate or evening types. These inter-individual differences can be associated with variations (polymorphisms) in one gene (PER3) that plays a role in the generation of biological rhythms. Following sleep deprivation, which is known to induce physiological and behavioural deterioration, morning types report higher levels of sleepiness. These differences can be more pronounced in some individuals and it is very likely that these inter-individual differences in response to sleep loss have trait-like characteristics consistent with a genetic basis. Objectives: This project focuses on the physiological consequences of this polymorphism on hormonal, sleep and performance rhythms.

Methods: Healthy volunteers were selected only on the basis of their genotype, irrespective of diurnal preference or any other sleep related characteristics. Approximately, 400 volunteers (age 20-35) were genotyped for the PER3 polymorphism. Individuals homozygous for the rarer 5-repeat VNTR (PER3-5/5) were identified and matched for age, gender, ethnicity and body mass index with individuals homozygous for the 4-repeat VNTR (PER3-4/4). Subjects (n=28) wore actigraphs and completed daily sleep diaries for three weeks prior to a five-day laboratory study. The “in-lab” part of this study was completed by 24 subjects and consisted of two baseline sleep episodes followed by 40-h constant routine and a recovery sleep episode.

Results: Questionnaires, sleep diaries and actigraph analyses indicated that the two groups did not differ with respect to habitual sleep-wake timing and sleep duration. The two groups also did not differ with respect to the timing of hormonal markers (melatonin and cortisol) and PER3 mRNA rhythms. However, the sleep structure of PER3-5/5 and PER3-4/4 subjects exhibited substantial differences. PER3-5/5 subjects slept more quickly, showed more deep slow wave sleep during NREM sleep, and more alpha activity in REM sleep. Furthermore, they responded differently to sleep deprivation:.PER3-5/5 experienced a very high sleep pressure. In addition, their performance on a cognitive test battery deteriorated much in comparison to PER3-4/4 participants, particularly during the biological night. The analyses of wake and sleep ECG data revealed a loss of parasympathetic control on autonomic balance in PER3-5/5 compared to PER3-4/4 subjects.

Conclusions: The clock gene PER3 can affect several aspects of sleep homeostasis and does not appear to have an effect on the circadian phase. Taken together, it might be that in humans sleep homeostasis is affected by clock genes and that these effects may explain inter-individual differences in the susceptibility to sleep loss and circadian phase misalignment, as occurs during shift work and jet lag.
The Genetic Information Non-Discrimination Act of 2008: The Intersection of Science, Individual Privacy Rights and the Law

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Summary: Congress recently enacted the Genetic Information Non-Discrimination Act of 2008, or GINA as it is also known. GINA prohibits discrimination against individuals on the basis of genetic information and further strictly limits the collection and use of such information by group health plans and employers. GINA broadly defines “genetic information” not only as the results of genetic testing, but also includes information about manifestation of a disease or disorder in an individual’s family member.

In enacting GINA, Congress acknowledged that deciphering the human genome, along with other advances in genetic technology, has resulted in significant medical developments and progress. For example, new knowledge pertaining to the genetic basis of a disease or disorder may allow for earlier detection and intervention, often before symptoms manifest in an individual. However, with this proliferation of recent advances in medicine and science comes concern in the legal community that knowledge of an individual’s genetic information could be misused to discriminate against individuals in health insurance and employment.

GINA attempts to address the social consequences of scientific advancements in genetic technology while protecting potential individual beneficiaries from discrimination in health insurance coverage and employment. Although more than 30 states have laws that prohibit genetic discrimination, until GINA, federal law addressing genetic discrimination was incomplete in both the depth and scope of its protections. To that end, GINA establishes a baseline for protection from discrimination on the basis of genetic information, which, in turn, allows individuals to receive the benefits of genetic testing, technologies and research without jeopardizing health insurance coverage, employment or privacy.

Because employers and group health plans may receive an individual’s genetic information in a multitude of different contexts, there is increased liability exposure under GINA. As a result, GINA will impact all employers and group health plans, regardless of whether they conduct genetic testing.
Measuring the Fatigue Problem: The Contributions of Individual Health, Lifestyle, and Behavior
Define and Measure Fatigue Problem (Track A)

Papers in this session will examine the contributions of behavioral and health variables affecting operator performance. More specifically, presentations will concentrate on the examination of sleep restriction, health status, lifestyle, and behavior as contributory causes to accidents, fatigue, and performance degradation.

Session Chair: Lynn Caldwell, Ph.D.
United States Air Force

J. Lynn Caldwell obtained her Ph.D. in Experimental Psychology from the University of Southern Mississippi in 1988. In 1998, she was certified by the American Academy of Sleep Medicine as a Board-Certified Sleep Specialist. During her 11 years with the U.S. Army’s Aeromedical Research Laboratory, she performed human-factors, conducting numerous simulator and in-flight investigations on fatigue countermeasures and circadian rhythms in rated military pilots. In 2002, she became a Senior Research Psychologist for the U.S. Air Force’s Warfighter Fatigue Countermeasures Program and is currently stationed at Wright-Patterson Air Force Base, OH. From 2005-2007, she was a Distinguished Visiting Scholar at the U.S. Air Force Academy. She is a Fellow of the American Academy of Sleep Medicine, and she has served as a fatigue consultant for the U.S. Air Force’s Air Combat Command, the nuclear power industry, and other military and civilian groups. She frequently provides fatigue-management workshops, safety briefings, and training courses to aviation personnel, flight surgeons, commanders, and safety officers.
Objective: Sleep restriction is associated with reduced daytime alertness and decrements in neurobehavioural performance. This study aimed to examine the effects of short-term, partial sleep restriction on subjective and objective measures of daytime sleepiness, and to assess the temporal pattern of sleepiness across the waking day.

Approach (or Methods): 33 healthy adults (15 M, 18 F) aged 22.8 ± 3.2 (mean ± SD) years participated in a between-subject design; 16 habitual sleep (control) and 17 sleep restricted subjects. Participants maintained a regular sleep-wake schedule (2230-0630 or 0030-0830), confirmed with sleep diaries, actigraphy and calling a time-stamped answering machine, for at least three weeks prior to a laboratory visit. Sleep restricted subjects were scheduled to 5 hours time in bed on the night before the laboratory visit and to 3 hours on the night in the laboratory. Sleep restriction was achieved by delaying the onset of time in bed. Control subjects maintained the 8 hour sleep schedule throughout the study. During the laboratory visit (~26 hours), participants were woken at their habitual wake time and remained in low light conditions (< 2 lux) and constant posture during 9 hours of testing. Each hour, sleepiness was assessed objectively as electrooculographic (EOG) slow eye movements and electroencephalographic (EEG) delta and theta activity during the Karolinska Drowsiness Test (KDT, 3 min). In a subset of participants, eye and eyelid movements were also monitored using the Optalert Drowsiness Measuring System (ODMS) with a drowsiness score calculated for each minute of the KDT. Subjective sleepiness was assessed before and after each KDT using the Karolinska Sleepiness Scale (KSS). Neurobehavioural, cognitive and mood assessments were obtained.

Results: Preliminary analysis of data from 2-4 hours after waking confirms that subjective sleepiness (KSS) was higher following sleep restriction than in the control condition (p < 0.01, n = 33). Correlational analyses between the different measures of sleepiness demonstrated associations between ODMS score and slow eye movements ($r^2 = 0.28$, $p = 0.05$, $n = 14$), and between ODMS score and KSS ($r^2 = 0.24$, $p = 0.05$, $n = 16$).

Conclusion: The adverse effects of short-term partial sleep restriction were demonstrated using both objective and subjective measures of sleepiness. The analysis will be extended to examine the temporal changes in these measures and the association between self-awareness of sleepiness and objective measures of sleepiness.

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Using Naturalistic Driving Data to Explore the Relation of Body Mass Index and Fatigued Driving Among Professional Truck Drivers

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Objective: This study investigated 16 months of naturalistic, commercial motor vehicle driving data to explore whether driver body mass index (BMI) was associated with a propensity to drive while fatigued.

Methods: Using naturalistic driving video data, two independent measures of driver fatigue were implemented. One was a subjective Observer Rating of Drowsiness measure (ORD; rating of drivers’ physical appearance and mannerisms), and the other was percentage of eye closure (PERCLOS) over a three minute window leading to an event. A total of 1,217 safety-critical events and 2,053 baseline driving episodes (driving when no safety-critical event occurs) were identified and scored for driver fatigue. Prior to the study, participants completed a demographic survey which included self-reported height and weight. These variables were used to calculate the drivers’ BMI and classify them as either normal weight, overweight, or obese based on the definitions set forth by the U.S. Surgeon General’s office.

Results: Results indicated that of the 103 participating truck drivers, 28.2% were overweight and 53.4% were obese based on BMI. Odds ratio calculations revealed these overweight/obese individuals were 8.95 times (CI = 5.82 - 13.77) more likely than normal BMI individuals to be rated as fatigued based on the ORD measure. Using the PERCLOS measure, overweight/obese drivers were found to be 1.69 times (CI = 1.19 - 2.40) more likely to be rated as fatigued than normal BMI drivers. The two measures of driver fatigue in this study suggested the same results, however, the ORD measure indicated a greater relative risk of overweight/obese individuals driving while fatigued when compared to the PERCLOS measure. This is likely due to the nature of the two measures; ORD focuses on the driver’s face and mannerisms, while PERCLOS is solely based on eye closures.

Other analyses showed that there was no greater relative risk of involvement in a safety-critical event when comparing normal weight versus overweight/obese individuals (OR = 1.03; CI = .086 – 1.24). However, it was found that obese individuals were at 1.37 times greater risk for involvement in a safety-critical event than non-obese individuals (normal weight and overweight individuals). Finally, an odds ratio calculation revealed that overweight/obese individuals were at 3.23 times (CI = 2.59 – 4.03) greater relative risk for not wearing their safety-belt while driving.

Conclusion: The finding that 82% of the truck drivers in this sample were either overweight or obese is alarming, indicating that driver health is a serious issue in this occupation. The results of this study support other research in the field of health and well-being which suggests a strong link between being overweight/obese and fatigue, particularly daytime sleepiness. This issue is especially relevant to commercial vehicle drivers whose work schedules present few opportunities for exercise and proper nutrition, in addition to working long days while on the road. Not only is being overweight/obese associated with multiple health risks, but it is also linked to driving while fatigued, involvement in safety-critical events, and lack of safety-belt use. It is suggested that future initiatives focus on driver behavior and organizational policies to encourage a healthier lifestyle among commercial motor vehicle drivers.
Screening for and Confirmation of Excessive Daytime Sleepiness (EDS) and Obstructive Sleep Apnea (OSA) in Railroad Workers

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Objective: To establish that a study could be performed successfully, assess the risk for and prevalence of Excessive Daytime Sleepiness (EDS) and Obstructive Sleep Apnea (OSA) in railroad workers, demonstrate that a two step process of screening by questionnaire and confirmation by a self applied ambulatory device is a reliable alternative in this population.

Methods: The study had screening and confirmation components. Participants were screened by completing the Epworth Sleepiness Scale (ESS) received along with their recertification packet. These employees in safety sensitive positions are required to recertify every 3 years. Each were given the opportunity to answer the questions and then submit their answers via fax, mail, or on a secure website. An ESS score of 10 or greater was considered to indicate risk for EDS. A confirmation protocol was deployed by inviting “at-risk” employees to wear a device that has been clinically validated to accurately differentiate between sleep and waking states, measure the Apnea Hypopnea Index (AHI), measure oxygen saturation of the blood, and report the subjects’ body position. The device was shipped to the participant with illustrated instructions for its proper use. A DVD which showed how to properly use the device was also included. Live support was also available at all times via a toll free telephone number. The device was worn for one night while sleeping then shipped back for data analysis. Participants who confirmed positive for OSA received a copy of their results and were advised to follow-up with their personal physicians. Participants who did not confirm positive for OSA received a letter informing them that their test was negative.

Results: The EDS risk percentage of the respondents as indicated by an Epworth Score of 10 or higher was 40%. Of those in the confirmation step, OSA was identified in 80%. There was a 100% success rate in shipping, self application and receiving complete data for interpretation by a Board Certified Sleep Physician. No devices were lost or misapplied.

Conclusion: Screening by questionnaire and confirmation by an ambulatory device capable of producing multiple channels of data for interpretation by an appropriately credentialed professional that can be shipped and self applied is a reliable and successful approach in transportation workers. The prevalence of EDS and OSA (40% in our study) in this population is higher in this population than it is in the general population (variously reported as 2-8%). A more extensive, ideally multi-company, study would further define the universe of those at risk as well as further document the reliability of the ambulatory approach as a complement or alternative to a fixed site overnight polysomnography in a sleep center.
Assessing associations between video drowsiness ratings and subjective measures of fatigue with lifestyle and behaviour: a driver study

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Objectives: Fatigue is a major public health issue and causes emotional and financial burden on society. It is important to develop technology and countermeasures to assess fatigue states in drivers (Lal et al., 2003). Video facial recognition and mannerisms have been known to be used to identify fatigued states (Wierwille & Ellsworth, 1994). Behaviour may also influence the fatigue state of an individual. The aim of this study was to investigate the associations between video data ratings of drowsiness and subjective measures of fatigue with lifestyle and behaviour.

Methods: Fifty drivers conducted a laboratory based driver simulated study. Facial features and driver mannerisms were recorded using video and an observer drowsiness scale used to rate levels of drowsiness (rated from 0-alert to 4-extremely drowsy). Questionnaires to measure lifestyle, anxiety, mood, control efficacy and self-reported fatigue states were administered.

Results: Tension-Anxiety (p=0.04), Anger-Hostility (p=0.048) and not eating a healthy diet (p=0.03) were associated with drowsiness counts of 3 or greater. Perception (p=0.002), State anxiety (p=0.001), Depression-Dejection (p=0.03), Anger-Hostility (p=0.03), Fatigue-Inertia (p=0.04), Confusion-Bewilderment (p=0.0001) and surprisingly younger age (p=0.04) were associated to the subjective measure of fatigue. Trait anxiety and lack of support from family and friends also showed trends towards this association. Pre study self-reported fatigue prior to the driving session commencing was related to increased State and Trait anxiety (p=0.002, p=0.008), Fatigue-Inertia (p=0.001), Confusion-Bewilderment (p=0.001), total mood score (p=0.03), and increased stressful events in the last 6 months (p=0.01). Regression analysis identified these six variables as collectively explaining 38% of the variance in pre-fatigue state (p<0.001).

Conclusion: Increased anxiety and anger and an unhealthy diet is associated with observer ratings of drowsiness. Increased anxiety, perception, mood states of depression, anger, confusion, fatigue and confusion and younger driver age were associated with subjective measures of fatigue. Lack of family support and increased rate of stressful events also contribute to fatigue effects. This study shows that behavioural and lifestyle factors may influence driver fatigue significantly. The results have implications for future fatigue management programs and driver education.

References
Obstructive Sleep Apnea and Motor Vehicle Crashes – A Systematic Review and Meta-Analysis

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Objective: Obstructive sleep apnea (OSA) is a common disorder that is characterized by a reduction or cessation of breathing during sleep coupled with symptoms such as excessive daytime sleepiness. Consequently, individuals with OSA may pose a threat to road safety. We synthesized the available data from published studies that have addressed the association between obstructive sleep apnea and motor vehicle crash.

Approach (or Methods): Sensitive search strategies, developed and refined by an information specialist, were applied to 13 electronic databases. Additional hand searches of the published literature (i.e., bibliographies of identified relevant articles) and “gray literature” resources (e.g., Web searches) were also performed. Formal a priori criteria for article retrieval and inclusion consisted of: (1) English language publications, (2) full-length articles, (3) controlled (case-control or cohort) study design, and (4) enrolled ≥10 patients. The quality of all included studies was determined using a revised version of the Newcastle/Ottawa Scale. Random-effects meta-analysis was used to pool data from different studies. Sensitivity analyses, aimed at testing the robustness of our findings, included the use of cumulative random-effects meta-analysis. Publication bias was tested for using the “trim and fill” method.

Results: Our searches identified 17 relevant articles. An assessment of study quality of the included studies found them to be in the low-to-moderate range. While attempts were made to control for differences in the characteristics of individuals that may confound the relationship between OSA and crash risk in all included studies, many failed to control for driving exposure. Meta-analysis found that individuals with OSA have a greatly increased risk for a motor vehicle crash (Crash Risk Ratio = 2.72, 95% CI: 1.30-5.72: p = 0.008). Risk factors for crash among individuals with OSA included the presence and degree of daytime sleepiness, the severity of disordered respiration during sleep, blood SaO\textsubscript{2} levels, and body mass index.

Conclusion: In summary, the risk of an individual with OSA experiencing a motor vehicle crash is between 30% and 472% greater than individuals who do not have the disorder. The findings of this review of the available evidence confirm that individuals with OSA represent a significant risk to road safety. This risk increases with the severity of the disorder.
Panel: Issues in Fatigue and Performance
Model Implementation and Use
Fatigue and Performance Modeling (Track E)

This panel will focus on the numerous issues that can arise during actual fatigue and performance model implementations and will emphasize real-world examples of model applications. Issues to be discussed by the panel will include model usability, privacy, liability, and potential misuse. The panel will also focus on accident prediction, fitting fatigue and performance models into an overall fatigue risk management system, how government agencies oversee their model use, and potential labor management concerns.

Session Chair: Capt. David Neri,
Office of Naval Research

David Neri, CAPT/MSC/USN, is currently Deputy Director of the Warfighter Performance Dept. at the Office of Naval Research. As a researcher and manager, Dr. Neri has investigated a range of operational fatigue issues at several Navy medical research and development laboratories and as Team Leader of the NASA Ames Fatigue Countermeasures Program. With government and academic colleagues, he organized and hosted the Fatigue and Performance Modeling Workshop in June 2002 in Seattle.
Promise and Limitations of Fatigue and Performance Modeling as a Tool for Fatigue Risk Management in Transportation

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Objective: To provide an understanding of how biomathematical modeling provides an essential scientific foundation for fatigue risk management systems and important limitations of such methods.

Approach (or Methods): Fatigue leads to lapses in attention, slowed reactions, and impaired reasoning and decision-making, and has been shown to contribute to accidents, incidents and errors in a host of industrial and military settings. Biomathematical models of fatigue have been developed that can be used to predict performance changes in the work place. Validated models could be incorporated into scheduling tools to anticipate and avoid fatigue in operational settings. Most of the available models of fatigue and performance are based on three basic components: circadian variations in alertness and sleep propensity, homeostatic sleep/wake regulation, and sleep inertia. These processes vary over time as a function of sleep/wake patterns, and combine to produce changes in subjective alertness and cognitive performance capacity. Present-day models have been shown to be useful predictors of average performance of groups under variations in sleep opportunities or work schedules.

Results: Most fatigue models applied to transportation operations involve a two-step process: 1) estimate the likely pattern of sleep that would accompany the work schedule, and 2) estimate the predicted fatigue, alertness or performance resulting from that sleep pattern. Several software packages provide the tools necessary to conduct these estimates. These systems offer great promise to advance the precision and efficiency of fatigue risk management. There are, however, limitations that must be considered and addressed in any such application:

1. The sleep estimation algorithm is critical to the accuracy of the entire analysis and must be realistic and representative of the workforce being evaluated. The best methods involve actual sleep measurements to calibrate and tailor the algorithm to the specific conditions of the work environment.

2. Currently, all models are estimates of average performance and are not valid as predictors of a particular person’s capacity to performance. As such, they are not valid “fitness for duty” tests.

3. Fatigue models have been shown to be predictive of elevated accident risk. However, such estimates are probably specific to the industry. Relating fatigue or performance estimates to absolute levels of risk require additional epidemiological data that relate those estimates to probabilities of accidents, errors, or task deviations. In the absence of absolute estimates of risk, fatigue models remain valuable as tools for evaluating the relative fatigue associated with alternative schedules.

Conclusion: Evidence-based fatigue risk management systems provide the most powerful solution for worker fatigue and are a vital complement to government mandated hours of service regulation. Effective application of modeling must consider several important limitations.
Modeling - implementation and accident risk

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Summary: Publications of implementation of fatigue prediction models are rather rare. Most implementations occur in relation to consultancy of some sort. We have used the three-process model of alertness regulation for more than 20 years (Akerstedt et al, 2004). It has been applied to airline routes, trucking schedules, police schedules and other areas. The most common experience is that the use of the model leads to an instant insight of the scheduler with regard to the effects of different schedule alternatives. However, the understanding of curves (24h pattern of sleepiness for example) is not as common as one might think. An alternative is to give feedback as "time at risk" for particular schedule solutions. Another observation is the tendency to view a sleepiness prediction as an absolute truth, leading to absolute rejection of schedules that end up just above the criterion for sleepiness and acceptance for those below. This may be remedied through confidence intervals or "grey zones". Since the ability to predict individual differences in sleepiness is rather modest, there is also a risk of too heavy reliance on the output of a model.

A recent implementation is in fatigue monitors in cars, as a complement to driving and behavioral sensors. The model provides background advice in case of malfunction of the monitor (which is very common) and seems to be able strengthen the advice of the sensor system.

An ultimate use of fatigue monitors is to avoid human error due to sleepiness, that is, to reduce accident risk. Possibly also efficiency and similar outcomes may be predicted. There are as yet a couple of such studies available. In one of our own studies it was found that accident prediction could be added to our model, using existing road accident data (Akerstedt et al 2008). The results showed that model prediction of sleepiness was closely related to accident risk, such that the increase in risk of a road accident is increased ninefold from low to high predicted sleepiness (based on time awake, amount of prior sleep, and time of day). Presumably, inclusions of individual differences, and many other factors may increase precision more.

References


Fatigue Modeling: Opportunities and Challenges of the Transition into Every Day Use by Government Regulators and Industry Risk Managers

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Fatigue modeling is in the midst of a transition from research tool to accepted alternative to prescriptive work and rest hour regulations in the context of Fatigue Risk Management Systems. As such it faces all the opportunities and risks of any new technology making the leap from the lab to every day use. Once the domain of a small discipline of scientific experts who were well aware of the strengths and limitations of these models, they are now being enthusiastically embraced by government regulators and industry risk managers. This is a vital and exciting step, but one that places a burden on scientists to fully educate the users. If we fail at this critical stage fatigue models risk falling into disrepute, and losing their power and usefulness.

To illustrate the issues I will discuss case studies that illustrate the challenges, not to point any fingers, but to enable all of us to share openly in the steep learning curve of fatigue model use:

**Setting regulatory duty-rest limits:** In defining the rules (Ops Spec A332) for ultra long range (ULR >16 hours) flying, the FAA recently chose an arbitrary fixed score as the minimum allowable in a fatigue model, against the advice of an independent panel of fatigue/sleep scientists who told the FAA that fatigue models are much more reliable in defining relative risk than absolute risk. Indeed scores well below this FAA-adopted level are routinely found in many ULR and non-ULR flights with excellent safety records. Hopefully the FAA will wait for a planned aircrew data collection study of ULR and non-ULR flying before finalizing the Ops Spec.

**Need for exemptions from Hours of Service (HoS):** The century old prescriptive HoS regulations have a widely recognized fatal flaw – they make no distinction between the risks of day versus night operations, or the recuperative value of nocturnal versus daytime sleep. Dart Transit requested an HoS exemption from the FMCSA to enable their drivers to stop and sleep every night, and still deliver their loads on time, guided by a fatigue model. Despite strong supportive comments in the public docket from many of the world’s leading fatigue/sleep scientists, American Trucking Association and the Owner Operator Independent Drivers Association, the FMCSA decision is still pending.

**Accident investigation:** The accident report forms used by the police in the 50 US states widely differ in the questions they ask, and most miss critical items of information useful in establishing the probability that individuals involved in an accident were or were not fatigued. As a result there appears to be a significant under-reporting of fatigue related accidents. Fatigue modeling based tools can help establish the probability of fatigue but are only useful to the extent that the critical data inputs are gathered in accident investigation reports.

**Accident litigation:** A fatigue model was used as evidence in a fatal truck accident case to claim that the accident was caused by driver fatigue and to criminally prosecute the directors of the company for corporate manslaughter. Excessive reliance on fatigue models to determine precisely the proximate cause of an accident is fraught with peril since there is often no place to input into fatigue models unique factors or evidence that may influence a scientist’s expert opinion.
A Critical Review of Current Fatigue and Performance Models and Their Use

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Summary: In recent years, theoretical models of the sleep and circadian system developed in laboratory settings have been adapted to predict fatigue using the timing of prior sleep and wake or working hours as the primary input and a time-course of fatigue as the primary output. The stated aim of these models is to provide employers, unions and regulators with quantitative information on the likely level of fatigue associated with a pattern of work and, as a consequence, to better manage the risk of fatigue-related incidents. The first part of this review summarises the variables known to influence work place fatigue and concludes that some of the currently available software products derived from these models create an unwarranted sense of precision because they fail to acknowledge (1) the considerable variability attributable to individual and task variables not included in the models and (2) the complex, non-linear relationships between fatigue and work place risk.

The second part reviews the current fatigue models described in the scientific and technical literature and classifies them according to whether they predict fatigue directly using prior sleep and wake (one-step models) or indirectly using work schedules to infer an average sleep-wake pattern that is used to predict fatigue(two-step models). In general, one-step models provide well-validated estimates of fatigue in continuous sleep deprivation protocols but are less reliable when used to predict chronic sleep restriction. Critically, none of the two-step models have sufficient published data to validate their ability to infer average sleep wake behaviour in field settings. As a consequence, we suggest that the current generation of models may only provide an estimate of average work-related fatigue or ‘sleep opportunity’ across a group and are therefore unsuited to prediction at the individual or event level.

The third part of the review looks at the use of fatigue models in field settings by organisations and regulators. In general, the current generation of models oversimplify the prediction of fatigue and fail to acknowledge adequately the significant inter- and intra- individual variability. When used by non-experts, this oversimplification can lead to significant risk of inappropriate use due to over-interpretation or over-reliance. As such the current generation of models are appropriate to use only as an element of a fatigue risk management system (FRMS) but lack sufficient validity to be used in isolation.

The final section of the review looks at the future of these models and recommends a standardised approach for their use as an element of the ‘defenses-in-depth’ approach to fatigue risk management. It then makes a series of recommendations on the most appropriate regulatory frameworks necessary to ensure the best use of fatigue models and a series of suggestions on how the current generation of models might be modified to improve fatigue risk management.
Ocular Measures and Technologies for Detecting Drowsy Drivers
Supporting Technologies (Track D)

From the successes of early research in establishing the validity of eye closure as a key drowsiness detection measure, there has been much research investigation variations of ocular measures. This session highlights some new research in this area. This session will present research on electro-oculography, microsleep detection, PERCLOS, and technologies to continuously monitor operator drowsiness.

Session Chair: Paul Rau, Ph.D.
National Highway Traffic Safety Administration

Paul Rau has 24 years of U.S. Government science and technology program management experience. He joined NHTSA in 1996 where he has focused on driver assistance and training systems, driver fatigue, indirect viewing, heavy vehicle safety, and driver vehicle interaction. He specializes in experimental design and statistical analysis, human performance and modeling, cognitive neuroscience, artificial intelligence, and electronic engineering system design and manufacturing.
Method and apparatus for generating an indication of a level of vigilance of an individual
US Patent # 7,435,227

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Objective: Validate the capacity of the Sleepiness Detection System – SDS™ to detect hypovigilance and micro-sleep occurrences on human subjects in simulator and real truck driving situations.

Approach: We conducted a first phase of laboratory simulations with 10 novice and expert truck drivers to characterize current SDS™ technology. These data have shown that hypovigilance and micro-sleep states can be detected. The planned lab simulations were intended to assess performance characteristics of current SDS™ technology, a required step before on the road testing. In these simulations, the SDS™ was benchmarked against EEG (Electro-Encephalogram), the medical reference in hypovigilance research. A second phase has been on the road testing. These road trials were required to assess true performance of current SDS™ technology in real-world truck driving conditions. Transport Robert, a trucking company, collaborated for these trials. In total, 5 experienced and novice truck drivers were each monitored on roundtrips using simultaneous SDS™ and EEG.

Results: The laboratory tests have shown some limitations of the initial SDS™ design that was modified before the road tests. Mainly, these limitations were with lighting conditions and eye-tracking. The road tests, between Montreal and Toronto, have shown the correct detection of both hypovigilances and micro-sleeps among truck drivers in daytime and night-time conditions. In these trials, a parallel was established between most SDS™ hypovigilance and micro sleep detections and EEG reference readings, but must be considered with caution given the small number of subjects. An example of correlation between SDS™ micro-sleep detections, in raw data, and EEG reading are shown in the figure 1.

Conclusion: The Sleepiness Detection System – SDS™ is a reliable device to generate an indication of a level of vigilance of an individual in real-life situations and conditions. The unit can be used to detect and warn drivers or machine operators when hypovigilances and micro-sleeps are occurring. Doing so, the SDS™ can reduce the number of accidents due to sleepiness, drowsiness or lack of vigilance.

References:

Validation of the PERCLOS Loss of Alertness and other Oculometric Measures as an Index of Clinical Causes of Driver Impairment

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Worldwide there is growing concern about alarming drive safety statistics relating to chronic sleep deprivation. In the U.S. over 200,000 traffic accidents each year may be sleep-related, causing thousands of fatalities, injuries and billions of dollars in economic loss, healthcare cost and lost productivity. Addressing these statistics, the Eye-Com Biosensor-Communicator-Controller (EC-6), as a wearable, wireless or tethered electronic eye-frame, was designed as a hybrid, in-vehicle, real-time operator ocular monitoring technology implemented in a car/truck drive simulator. Designed for detecting and responding to driver impairment, including loss of sleepiness awareness, lapses in attention, micro-sleeps or loss of consciousness, this oculometric device distinguishes human factors from machine failure.

Objective: The objectives of this jointly sponsored USDOT/USDOD study included: 1) validation of the PERCLOS-loss of alertness and other oculometric measures (e.g. Eye Blink Duration/Frequency [EBD/EBF], Eye-Gaze, Pupil Size) as reliable indices of driver impairment; 2) using the knowledge gained to improve EC-6 ergonomic design and bio-physiological systems integration; and 3) developing predictive oculometric performance/vigilance-related algorithms for safety response.

Method: With the objective of validating oculometric measures as reliable indices of drive safety impairment, 31 subjects, as controls or with either sleep apnea, narcolepsy or attention disorder, completed a 34-hour sleep deprivation study, where 6 drive simulator sessions spaced 6 hours apart were sequentially scheduled with objective and subjective measures of alertness/performance (e.g. TOVA, MWT, EEG, Stanford Sleepiness Scale).

Results: PERCLOS, EBD and EBF were strong predictors of deteriorating drive safety measures for all subjects, regardless of their diagnostic group, reaching their highest impairment levels in correlation with all other objective and subjective measures of alertness/performance, particularly during Sessions 4 and 5 (i.e. between 2 to 8 A.M. on Day 2) of the study. These oculometric measures showed the effects of sleep deprivation coupled to the effects of long, monotonous time-on-task drive simulation and performance vigilance activities, as well as circadian effects. Remarkably, there appears to be a very close correlation with research outcomes in a recent study by the Bureau of Transportation Statistics (BTS) (Morris, 2008), relating motor vehicle occupant injury and fatality risks to late night early morning hours. While the original BTS study was unable to assess fatigue as a cause, attributing the occupant fatalities and fatality rates to speed- and drunken driver-relatedness, we agree with Morris (Abstract, 2009) that fatigue may be a major underlying factor for most of these occurrences.

Conclusions: Besides shedding light on the performance/vigilance and drowsiness/fatigue-PERCLOS relationships, this study contributes to early design of a statistically derived, Composite Oculometric Fatigue Index (COFI) algorithm based on repeated measures of drive simulator performance (e.g. speed, collisions, off road accidents and road edge excursions) and real time oculometric measures of PERCLOS, EBD and EBF with selecttable minima and maxima values. COFI can be used to trigger visible, audible or tactile alarms or to alert, warn and awaken the driver, passengers or distant monitors of impending danger. This could eventually be used in any fitness-for-driving lab or any other operator’s domain, including in on-the road studies.

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Use of an Ocular Method for Monitoring the Drowsiness of Drivers

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Objectives: Many road crashes are believed to be caused by drivers falling asleep at the wheel. We have previously described a device (Optalert™) for monitoring the drowsiness of drivers continuously. It uses the Johns Drowsiness Scale (JDS) based on a weighted combination of several characteristics of the driver’s eyelid movements measured by infrared (IR) reflectance oculography using a special glasses frame with embedded IR transducers. A JDS score (0-10) is produced every minute on-line. Drivers receive a cautionary warning if their JDS score exceeds 4.5 and a critical warning above 5.0, when they would be expected to stop driving as soon as it was safe to do so. In the present study we investigated the JDS scores of young adults driving in a car simulator with and without sleep deprivation.

Methods: Sixteen healthy young adults drove in a high fidelity car simulator for 70 min before and after sleep deprivation (missing a night’s sleep). A lane-departure episode was said to occur whenever all 4 wheels of the car were outside the lane. However, drivers continued to drive without intervention. One-way ANOVA was used to compare JDS scores in alert drivers, those who were sleep-deprived but did not have any lane-departure episodes, and those who were sleep deprived and who had lane-departures. We also calculated the percentage of lane-departure episodes that were preceded by a JDS score of at least 5.0 during different periods, up to 5 or up to 30 min before each episode.

Results: None of the 16 subjects had any lane departure episodes without having been sleep-deprived, but six subjects had a total of 102 unintentional lane-departures after sleep deprivation. The mean JDS score for all subjects before sleep deprivation was 3.4 +/- 1.9 (SD). After sleep deprivation, the 10 drivers but who still did not have any lane-departures had a mean JDS score of 4.3 +/- 2.0, and the 6 drivers who had lane-departures had a mean JDS score of 6.5 +/- 2.2 (ANOVA, p<0.001; all post-hoc Scheffe tests, p<0.001). The percentage of lane-departure episodes associated with JDS scores of 5.0 or higher during the preceding 5 min was 88.2%, and that increased to 100% for 30 min before each episode.

Conclusion: This device provides an objective measure of drowsiness while driving, based on the driver’s JDS score each minute. In sleep-deprived drivers, the risk of unintentional lane-departure, with all its potential dangers, is greatly increased when a JDS score of 5 or more has been reached during the preceding few minutes. This is consistent with our previous research which showed that the risk of performance failure increased exponentially with JDS scores. A cautionary warning at JDS = 4.5 could enable drivers to manage the earliest stages of their own drowsiness, of which they are often not aware, before they fall asleep at the wheel and crash. This device is being used by drivers in the road transport and mining industries in Australia and elsewhere.
Sensitivity and specificity of a driver drowsiness detection device: the CRAM

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Objective: Drowsiness decreases an individual’s ability to operate a vehicle safely and increases the risk of human error that can lead to fatalities and injuries. Furthermore, it has been shown to slow reaction time, decrease awareness, and impair judgment. A number of technologies aimed at detecting driver drowsiness have been developed in the past or are currently being developed. The difficulty to the potential buyer of such technologies is that objective performance data have yet to be published. Kircher et al. (2002) indicate that as a minimum, sensitivity and specificity of such technologies should be determined.

Method: CRAM is a driver drowsiness detection technology currently being developed by ECT. As a preliminary validation, this study evaluated its performance in a truck driving simulation. Ten subjects (9 males, 1 female) aged 36.5 ± 10.3 (mean ± SD) years participated in this study. All had a valid driver license and 16.4 ± 8.7 (mean ± SD) years of driving experience. A total of 14 driving sessions lasting 124 ± 7 (mean ± SD) min were conducted. Driver drowsiness was assessed continuously with a CRAM mounted on the desk in front of the subject. Continuous EEG measurements were used as a reference of driver drowsiness. The subject's face was videotaped throughout the driving task. Prior to starting and immediately at the end of the driving task a PVT and the KSS scale were administered to the subject. Each driving session data were divided into 15-sec windows and for each one the following were described: True Positives (TP: driver drowsy per EEG and CRAM reporting drowsiness), False Positive (FP: driver alert per EEG but CRAM reporting drowsiness), False Negative (FN: driver drowsy per EEG but CRAM reporting alertness), True Negative (TN: driver alert per EEG and CRAM reporting alertness).

Results: Results indicate that the simulated driving task led to significant cognitive performance reduction as measured by simple reaction time (RT) in 12 out of the 14 sessions (F1,17 =15.92, p< 0.0009). In 5 of the 12 sessions the number of lapses (RT > 500 ms) increased, indicating an important reduction in cognitive performance. Drowsiness as measured with KSS increased in 9 of the 12 sessions. The driving task clearly did induce drowsiness. Owing to technical problems, the CRAM data for 5 out of the 14 sessions were discarded. For the 9 usable driving sessions, frequency of microsleeps as detected by EEG measurements, ranged from 0.29/min to 2.3/min with a mean of 0.98/min (SD = 0.56/min). The CRAM's performance was determined for 20 algorithms each based on a different combination of key drowsiness parameters. Sensitivity (TP÷(TP+FN)) —the probability of the CRAM detecting a microsleep in the same 15-s time window as the EEG— ranged from 0.15 to 0.71 with a mean of 0.49 (SD = 0.19) among the 20 algorithms. 1-Specificity (1 - TN÷(TN+FP)) —the probability of the CRAM reporting a false alarm— ranged from 0.02 to 0.38 with a mean of 0.22 (SD = 0.12). Sensitivity and 1-specificity were closely related through a slightly curvilinear relationship (R²=0.997, F1,18= 2980.5, p<0.0001). Accuracy —the probability of the CRAM reporting the true state of the driver in any 15-s time window— ranged from 0.69 to 0.72 with a mean of 0.71 (SD = 0.008).

Conclusion: These results reflect the raw performance of the detecting component of the CRAM in its current form. They must be interpreted with care since a filtering component part of the user interface determines whether or not an alarm signal is communicated from the detecting component to the driver. This filtering component uses quality criteria that are expected to further reduce the probability of false alarms, hence enhancing final performance of the device. There is little doubt that the algorithms can be further refined through more research so as to improve sensitivity and reduce false alarm rate. For instance, integrating data on subjects' characteristics should help increase performance. Considering that the CRAM detects on average better than 50% of the microsleeps, a condition where the driver is not yet fallen asleep, is very encouraging. The CRAM device in its current evolution can already help increase driver safety.
Conference Banquet Address

Keynote Speaker: Senator Richard T. Moore

Massachusetts State Senator and Senate Chairman of the Committee on Health Care Financing

Senator Richard T. Moore, as Senate Chairman of the Massachusetts Legislature’s Committee on Health Care Financing, has been in the forefront of issues affecting the health of the people of Massachusetts since his appointment in 1999 to lead the health committee by then-Senate President Thomas Birmingham. His imprint can be found on nearly every piece of health care legislation enacted in Massachusetts during the past decade. Perhaps, Senator Moore’s greatest health policy achievement is his crucial role in creating legislation to extend health care to every resident in Massachusetts—now called “Health Reform I.” He was also the primary sponsor of two major bills and other pieces of legislation on which the landmark Massachusetts Health Reform Law (C. 58 of the Acts of 2006) is based. By 2008, Massachusetts achieved nearly universal health coverage with an estimated 97% of her citizens with health insurance. These reforms have received much attention and praise both here at home and across the nation.

Still another priority for Senator Moore is the expanded use of health information technology. He has been at the forefront of efforts in the state, and nationally, to promote electronic health records, electronic prescribing, and computerized physician order entry systems. Senator Moore was instrumental in the allocation of funds to the Massachusetts Technology Collaborative, the health information technology fund, and the Massachusetts eHealth Institute to advance the use of health information technology.

On the national level, Senator Moore serves as Vice President of the National Conference of State Legislatures (NCSL), and is poised to lead this important association of the nation’s 7328 state legislators and legislative staff in the next two years. NCSL provides research, training, technical assistance, and opportunities for policy makers to exchange ideas on the most pressing state issues. NCSL is considered the most effective and respected advocate for the interests of state government before the Congress and federal agencies. In addition, Senator Moore co-chairs Health Information Champions (HITCh), a health information technology project sponsored by the National Conference of State Legislatures. He also serves as one of only four state legislators on the steering committee of the State Alliance for eHealth, a project of the National Governor’s Association’s Centers of Excellence.

Senator Moore holds a Bachelor’s Degree in History from Clark University (1966), Master’s Degree in Student Personnel Administration from Colgate University (1967). He is the recipient of numerous awards and honors, including an honorary Doctor of Science degree from the Massachusetts College of Pharmacy and Health Sciences (2006). Senator Moore served as 2008 President of the Clover Club of Boston – a prominent cultural and social organization of Irish-Americans in the Greater Boston area since 1883. The Vatican State has also honored Senator Moore with a knighthood-Knight Commander of the Equestrian Order of the Knights of the Holy Sepulchre of Jerusalem, the oldest order of chivalry of the Vatican State, founded in 1099.
Closing Plenary Session:
Cross-Conference Evaluation

Keynote Speaker: Michael Quinn Patton, Ph.D.
Former President of the American Evaluation Association

Michael Patton, Ph.D. is an organizational development and program evaluation consultant for Utilization-Focused Evaluation. He is former President of the American Evaluation Association and author of Utilization-Focused Evaluation (4th ed. Sage, 2008). He is on the faculty of The Evaluators’ Institute, George Washington University and conducts workshops and lectures around the world.
Closing Plenary Session: Cross-Conference Evaluation

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“The question we ask today is not whether our government is too big or too small, but whether it works. Where the answer is yes, we intend to move forward. Where the answer is no, programs will end. Those of us who manage the public’s dollars will be held to account — to spend wisely, reform bad habits, and do our business in the light of day — because only then can we restore the vital trust between a people and their government.”

– President Obama, Inaugural Address

Objective: To help move fatigue research into actual practice, and ultimately to bring about more practical use of research findings. More specifically, the cross-conference evaluation attempts to better identify what fatigue interventions work and do not work, in practice under normal operating conditions. The evaluation findings will lay the groundwork for broader dissemination of effective interventions to user organizations, and more effectively move the transportation industry towards reducing fatigue-related accidents and injuries by enabling operating agencies and organizations to identify the most cost-effective practices.

Summary: In this closing plenary session, Dr. Patton will lead a dialogue about evaluation practice and use for each of the conference’s five thematic tracks with a specific emphasis on the objectives outlined above. For each of the track discussions Dr. Patton will facilitate an interactive discussion between a professional evaluator and one of the fields leading experts on that tract, followed by comments from the audience.

Prior to the plenary session, multiple evaluation methods will have been used to investigate the degree to which the aforementioned objectives of the conference’s evaluation track were met, and what could be learned from current fatigue research and intervention evaluation practices for guiding future directions, including:

1. A preconference sample survey designed to assess registrants knowledge and use of evaluation, which will be followed by a six-month post-conference sample survey and in-depth interviews with a sample of attendees;
2. Preconference seminars for government, industry, and academic leaders designed to demonstrate how evaluative thinking can inform practical decision making as well as enhance and improve leadership, policy making, and program implementation;
3. Review of conference abstracts and papers by expert evaluators to identify cross-conference evaluation themes;
4. Observations of conference sessions by teams of expert evaluators and content experts to increase understanding of major evaluation themes and issues for the track and to build evaluation capacity. Observers sought to gather information about (1) the general nature of fatigue-related interventions studied, (2) the focus and scope of evaluation of fatigue-related interventions (e.g., implementation/process, outcomes/impact) and (3) utilization of evaluation findings;
5. Presentation of an interactive evaluation case in which audience participants engaged in a discussion of key evaluation issues portrayed by the case with particular attention to factors that can affect the use of evaluation findings, implications for acting on the findings and further evaluation studies that, over time, can affect policy and practice in an entire sector, which will provide the audience participants with insider knowledge of what it is like to perform an evaluation in a real setting; and
6. Synthesis of the nature and role of evaluation and evaluative decision making as part of fatigue-related research and interventions across all of the conference’s tracks.

Dr. Patton will conclude the session with a summary and synthesis of evaluation findings across all tracks of the 2009 International Conference on Fatigue Management in Transportation Operations, with recommendations for future directions.

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