Working Together to Understand Driver Fatigue: Report on Symposium Proceedings

Highway Safety Roundtable

FEBRUARY 2008

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Driver fatigue is a deadly problem

On May 16, 2007, Insurance Bureau of Canada, on behalf of the Highway Safety Roundtable and with the support of the Ontario Ministry of Transportation, sponsored a symposium in Toronto called “Working Together to Understand Driver Fatigue.” The symposium brought together about one hundred stakeholders including driver educators, fatigue experts, medical doctors, academics, police and political leaders.

This report of the symposium proceedings includes an overview of the presentations made by four authoritative Ontario researchers, the Deputy Commissioner of the Ontario Provincial Police (OPP) and Ontario’s Minister of Transportation. Notes and references from the presentations of doctors Tasca, Elzohairy, Moller and Smiley, along with a comprehensive bibliography of driver fatigue research, are included as appendices to this report.

The following are key points that were raised at the symposium:

- Dr. Tasca: We have underestimated fatigue as a significant risk factor in crashes.
- Dr. Elzohairy: A statistical model suggests 17.9%, a tragically high number, of all fatal crashes are fatigue-related.
- Dr. Moller: Fatigue impairment is a disorder of information processing—the more we understand information processing, the better able we will be to prevent the disorder.
- Dr. Smiley: It is more effective for a driver to plan ahead and take countermeasures against fatigue before getting behind the wheel than to try to compensate for drowsiness while driving.
- Deputy Commissioner Carson: Fatigue-related fatalities are senseless and can be prevented.

With a concentrated effort, fatigue-related injuries and fatalities on our roads can be prevented.
The theme that recurred throughout the symposium was that driver fatigue is a very significant threat to road safety that needs much more attention from all levels of society. With a concentrated effort, fatigue-related injuries and fatalities on our roads can be prevented.

On behalf of Insurance Bureau of Canada, I am proud to be part of the Highway Safety Roundtable, which is actively pursuing a number of initiatives put forward at the symposium, including working with the Ontario government to find ways to make Ontario’s roads and highways safer.

Mark Yakabuski
President & CEO, Insurance Bureau of Canada
Chair of the Highway Safety Roundtable
February 2008

The Highway Safety Roundtable is composed of representatives from the following organizations:

• Brewers Association of Canada
• Canada Safety Council
• Canadian Automobile Association
• Insurance Bureau of Canada
• Railway Association of Canada
• Tourism Industry Association of Canada
Introductory Session – Driver Fatigue Literature: A Review

Leo Tasca, Ontario Ministry of Transportation
(For a full list of references cited in this summary, please see Appendix A.)

Leo Tasca, from the Ontario Ministry of Transportation, began the working sessions by giving an overview of fatigue impairment as documented in road safety research literature. Tasca reviewed the key fatigue impairment documents, beginning with the Commercial Motor Vehicle Driver Fatigue and Alertness Study (1997) conducted by the US Federal Motor Carrier Safety Administration and Transport Canada.

The landmark study observed 80 commercial vehicle operators, aged 25 to 65, on 360 trips that covered a total of 200,000 miles. Tasca highlighted the following findings:

- Time of day was the single best predictor of decreased driving performance.
- 19 minutes out of the 244,667 minutes of video showed drivers falling asleep.
- A 13-hour drive with a night-time start was associated with the most sleep deprivation.
- There was little correlation between subjective and objective performance measures.
- Age was not a significant factor in fatigue.
- No collisions occurred during the study.

In Development of Fatigue Symptoms During Simulated Driving (Nilsson et al. 1997) 80 young males were asked to drive for as long as they comfortably could. Subjects varied in how long they were able to continue driving, but they all had similar fatigue scores when they decided to stop.

Nilsson and colleagues implied that it was better to teach drivers to recognize the signs of fatigue impairment than to tell them to rest after some specified number of hours of driving.

An Australian study, Developing Measures of Fatigue Using Alcohol Comparison (Williamson et al. 2001), compared the effect of remaining awake for 28 hours with the effect of varying doses of alcohol (up to 1.0 BAC) on the same driver. Subjects were most affected after 17 to 19 hours of wakefulness, demonstrating performance similar to what they achieved with .05 BAC scores.

Why Do People Have Drowsy Driving Crashes? (Stutts et al. 1999), a study conducted in North Carolina, was based on interviews with 1,403 drivers involved in crashes where police had coded the driver’s condition as fatigued or asleep. The results of these fatigued and asleep groups were compared to two control groups consisting of drivers with no record of collisions and drivers involved in collisions not related to fatigue.

Stutts and colleagues reported the following odds ratios (compared to the non-crash control).

<table>
<thead>
<tr>
<th>Condition</th>
<th>Odds Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Night-shift worker</td>
<td>13.6</td>
</tr>
<tr>
<td>Sleeps less than 5 hours</td>
<td>7.0</td>
</tr>
<tr>
<td>Sleeps 5 to 6 hours</td>
<td>3.8</td>
</tr>
</tbody>
</table>
A study conducted in the UK, *Driver Sleepiness and Risk of Serious Injury* (Conner et al. 2002) was based on interviews of 571 drivers involved in serious collisions; 65% of these interviews took place within 48 hours of the collisions. The study found:

- an eight-fold increase in risk if drivers reported sleepiness;
- a five-fold increase in risk when driving between 2:00 a.m. and 5:00 a.m.; and
- a three-fold increase in risk when driving with less than five hours of sleep.

*Fatigue-Related Crashes* (Australian Transport Safety Bureau [ATSB] 2002) was an analysis of fatigue-related crashes on Australian roads.

The ATSB used its database of fatal accidents to analyse crashes in Australia.

The study identified fatigue-impaired collisions in the database by first excluding all crashes where the database showed other factors were involved. Collisions involving the following were eliminated:

- BAC over .05
- Pedestrian(s)
- Speed limit less than 80 km/h
- Unlicensed driver

The ATSB took the remaining collision data and included the following types of collisions in their study:

- all single-vehicle collisions occurring between 12:00 a.m. and 6:00 a.m., and between 2:00 p.m. and 4:00 p.m.; and
- all head-on crashes where neither vehicle was passing.

Using this selection process, the researchers found that 16.6% of fatal crashes were fatigue-related. Tasca noted the study was not designed to find an absolute number of fatigue-related crashes, but to create an index of relative incidence.

*Drowsy Driving*, a 2004 Traffic Injury Research Foundation survey of 1,209 Canadians, published in Road Safety Monitor, found the following:

<table>
<thead>
<tr>
<th>Condition</th>
<th>Percentage</th>
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<tbody>
<tr>
<td>Poor sleeper</td>
<td>12.1</td>
</tr>
<tr>
<td>Drives late at night</td>
<td>6.5</td>
</tr>
<tr>
<td>Slept less than 4 hours the night before</td>
<td>19.2</td>
</tr>
<tr>
<td>Awake 15 to 20 hours</td>
<td>10.4</td>
</tr>
<tr>
<td>Awake more than 20 hours</td>
<td>56.6</td>
</tr>
<tr>
<td>Epsworth Sleepiness Scale (ESS) score of 11-15</td>
<td>4.2</td>
</tr>
<tr>
<td>ESS score of 16</td>
<td>15.2</td>
</tr>
</tbody>
</table>
• One in five drivers reported nodding off at the wheel at least once in the previous 12 months.

• Because of the lifestyle choices they tend to make, young people were at greater risk of drowsy driving.

• Male drivers reported being more susceptible to fatigue than did female drivers.

The authors of *Subjective and Predicted Sleepiness While Driving in Young Adults* (Smith et al. 2005) developed a model to predict sleepiness levels based on comparing sleep diary data with feelings of sleepiness as reported by subjects. Subjects recorded 2,518 driving trips. They reported being sleepy during 23% of the trips. Eighty-two trips (3.4%) occurred when subjects had been awake for more than 18 hours. There was not one instance where a subject chose not to drive because of sleepiness.

An on-road study entitled, *Fatigue, Sleep Restriction and Driving Performance* (Philip et al. 2005), tested the performance of 22 healthy males aged 18 to 24. They drove 1000 kms on a divided highway in five 105-minute sessions. Subjects drove the route twice – once with 8.5 hours of sleep the previous night and once with 2.5 hours of sleep the previous night.

In the normal sleep condition (8.5 hours of sleep the previous night), drivers demonstrated a significant increase in risk by the fourth session. In the sleep-deprived condition, drivers demonstrated a significant increase in risk by the second session.

Tasca concluded by noting that fatigue very definitely affects driving performance. He said we have, up until now, underestimated fatigue as a significant risk factor in crashes.

After Leo Tasca’s presentation, the symposium broke into two sessions.

**Session One**

**Fatal and Injury Fatigue-Related Crashes on Ontario’s Roads**

Yoassry Elzohairy, Senior Safety Research Advisor at the Ontario Ministry of Transportation

(For a full list of references cited in this summary, please see Appendix B.)

Yoassry Elzohairy, Senior Safety Research Advisor at the Ontario Ministry of Transportation, presented a review of fatigue-related crashes on Ontario’s roads.

Elzohairy noted that, according to police reports, less than 2% of all collisions are fatigue-related. He observed that provided the drivers remain awake in cases where fatigue plays a factor, these cases are not generally recognized as fatigue-related. He noted that there is no straightforward fatigue-measuring device for police to use at the roadside.

Elzohairy proposed a method for estimating the prevalence of crashes related to drowsy driving, based on a refinement of the Australian operational definition.

Elzohairy considered a collision to be fatigue-related if it adhered to one or more of the following selection criteria:

• Vehicle condition: No apparent defect
- Driver did not exceed the speed limit or drive too fast for conditions
- Driver was not impaired by alcohol or drugs
- Driver had no medical or physical disability
- Crash occurred on dry pavement
- Driver initiated the crash
- Initial impact: Head-on collisions where neither driver was passing; rear-end collisions; or single-vehicle crashes

Crashes involving pedestrians, unlicensed drivers or animals were excluded.

Using this model, Elzohairy discerned the following:

- In 2004, 17.8% of all fatal crashes and 25.5% of crashes causing injury were fatigue-related.
- Men were involved in 65% of fatigue-related crashes.
- An average of more than 200 out of every 10,000 drivers aged 17 to 20 were involved in fatigue-related crashes. This is twice as many drivers as the 35 to 44 demographic.
- Bus drivers (Class C licences) were involved in fatigue-related crashes at a rate of 225 per 10,000 drivers, compared to 169 per 10,000 for school bus drivers (Class B), 146 per 10,000 for tractor trailer drivers (Class A) and 74 per 10,000 for other bus drivers (Class G). (At this point a participant in the symposium pointed out that Ontario collision reports did not provide the option of noting when, for instance, a bus driver is in a collision while driving his or her car.)
- 40% of all fatigue-related crashes occurred on roads where the speed limit was 50 km/h.
- The most common errors committed by fatigued drivers were following too closely (59%) and losing control (28%).

Other points drawn from the model showed that most fatigue-related crashes occur between three and six in the afternoon and on Fridays. The Greater Toronto Area (GTA) has the highest rates of fatigue-related crashes and the summer months are the most dangerous. (At this point, several participants noted that if Ontario’s data were related to kilometres driven, the conclusions drawn could be much sharper. A participant said Ontario’s data need to be tied to Statistics Canada’s Canadian Vehicle Survey.)

All Symposium participants received a copy of Akilla, In the blink of an Eye: A drowsy driving handbook, the first driver education book about fatigue courtesy of Martin Jenkins.

The Handbook is available at
New Zealand Sleep Safety Limited
P.O. Box 10386, The Terrace Wellington 6143
New Zealand
http://www.akilla.co.nz
Dr. Henry Moller, a physician-researcher and professor in University of Toronto’s Department of Psychiatry, provided a medical perspective on driver drowsiness, fatigue and alertness.

Moller demonstrated that fatigue impairment is not only confined to crashes resulting from drivers who fall asleep at the wheel; fatigue also dramatically affects the performance of drivers when they are awake, impairing the ability to process information.

Moller began by citing a 1998 Lancet article that urged banishing the word “accident” from the road safety lexicon because the word denotes chance and unpredictability.

He proposed a cybernetic model of driver performance based on four factors:

1. External environmental factors – time of day, weather, duration of drive, etc.
2. Driver factors – age, gender, driving experience, affective state, fatigue, etc.
3. Vehicle factors – steering, brakes, tires
4. Distractions – food, radio, cell phone, email, passengers

Dr. Moller stated that there was still debate around the operational definition of “fatigue” and he indicated that his research could inform that debate.

From a medical-psychological standpoint, fatigue is characterized by a lack of alertness and reduced mental and physical performance. It is often accompanied by drowsiness. It manifests in forgetfulness, poor communication, impaired decision-making skills, slow reaction time, microsleep, mood disturbance and/or irritability.

In relation to driving, Moller defined fatigue impairment as a “disorder of information processing” causing difficulty in human/vehicle or human/environment interaction.

Driving requires different levels of cognitive activity. The lowest is skills-based behaviour and is automatic or effortless (sensory-motor perception), such as steering a vehicle. The next level of cognitive activity is rules-based and requires a driver to perform a prescribed manoeuvre to deal with changing circumstances (e.g., passing a slower car). The highest level of cognitive activity uses knowledge for problem-solving (e.g., when a rule-based manoeuvre is insufficient). Here, creativity is required from an individual in order to deal with complexity. While older models of fatigue and information processing (Rasmussen 1987) tended to focus on the effects of fatigue on the first level of cognition, Moller’s research suggests that all three levels of cognition are affected by fatigue.

Epidemiological studies have established circadian variation in the incidence of fatigue-related motor vehicle accidents, with the greater risk occurring in late-afternoon and late-night periods. In addition, typical circumstances/conditions of what Moller terms a “Type I” crash involving fatigue are: involvement of a single vehicle; lack of external stimulation; boredom/under-arousal, leading to a lowering of brain activity; and rural or long monotonous stretches of highway.
However, when fatigue is seen as a disorder in information processing, crashes may occur with a set of completely different factors. “Type II” may involve: multiple vehicles; multi-tasking/over-arousal on the part of a driver (over-stimulation results when mental tasks are excessively complex and sustained); an urban setting/intersection location; and heavier traffic volumes.

Moller places drivers in the two types of motor vehicle accidents on a “neurocognitive performance spectrum of fatigue.”

<table>
<thead>
<tr>
<th>TYPE I CRASHES</th>
<th>TYPE II CRASHES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Under-Arousal</td>
<td>Over-Arousal</td>
</tr>
<tr>
<td>Drowsiness</td>
<td>Cognitive Overload</td>
</tr>
<tr>
<td>Errors of Omission</td>
<td>Errors of Commission</td>
</tr>
<tr>
<td>“Sleep” Mode</td>
<td>“Overload” Mode</td>
</tr>
</tbody>
</table>

Moller speculates that maladaptive driving behaviour may be fatigue-related. Road rage, for example, is thought to be purely volitional on the part of the driver. But changing socioergonomic factors – impacts of sprawl, congestion, a three-fold increase in commute times since the 1970s – may move the brain state from information underload to overload. Under these circumstances, fatigue-induced irritability transforms into rage.

The use of mobile communications devices and social expectations (e.g., the demand for multi-tasking) are other variables in the driver-vehicle, driver-environment mix and are generally under-researched in terms of their impact on driver fatigue.

Much of Dr. Moller’s latest work has concentrated on brain function during task execution and the introduction of distractions. Brain imaging shows increased activation of the occipital (i.e., visual) cortex – the simple visual tracking of distractions – but also in the prefrontal cortex, where the brain works harder to process information.
Moller’s clinical practice with patients suffering from sleep disorders has given him specific insights into fatigue and crash risks. By far, the most common cause of fatigue is self-imposed sleep loss. However, some medical factors can also be at work.

While it is true that sleep quality deteriorates with age, statistics bear out the fact that older drivers tend to be more sensible and risk averse. An area for investigation will be whether this holds true over the current demographic shift, i.e., baby boomers vs. their parents.

The most common medical disorder is untreated sleep apnea and is most prevalent in middle-aged men (5% to 15%). A condition characterized by interrupted breathing, which starves the brain of oxygen, sleep apnea runs from mild (occasional occurrence during sleep) to severe (frequent occurrences).

Narcolepsy is extremely rare (affecting 5 people in 1,000), but very dangerous because the brain is subject to sudden, unpredictable sleep attacks.

Neurological disorders such as stroke, MS, Parkinson’s, etc., can affect the brain physically (lesions), so impairment (and therefore risk) can be compounded when combined with sleep apnea.

For patients with insomnia, it is questionable whether they have a higher risk of falling asleep when driving. Insomnia patients complain mostly of fatigue in carrying out daily tasks.

Patients with psychiatric disorders are similar to insomnia patients in terms of the symptoms they report, but patients with psychiatric disorders who are treated with drug therapy may experience other symptoms or side effects. Practitioners must weigh the symptoms and side effects of treatments for psychiatric disorders in terms of a patient’s overall ability to process information and safety operate a vehicle.

Shift work is controversial in the medical community when it comes to sleep and sleep disorders. While one subject copes well with shift work, another does not. There are those who believe the latter has a disorder that can be treated. Others say that fatigue resulting from shift work is a “social construct” and should not be medicalized. It is possible that some people are simply better at adapting to shift work.

The role of medication in fatigue can vary. Some medications may produce hangovers the following day. Antidepressants can have sedative effects, but can also improve brain function. In such cases, the job of evaluating the risk of allowing the patient to operate a vehicle would be left to a particular patient’s doctor.

Finally, Attention Deficit Disorder (ADD) – a problem in the frontal lobe that affects the ability to process competing bits of information – may increase the risk of fatigue in young people. The young, who already have four times the crash risk of the general population, are more prone to ADD and engage in more risk-taking behaviour. Recent research suggests interconnections between sleep disturbance and attention. Nevertheless, Dr. Moller warned against inferring too much without proper research and experimentation.

Hospitals and clinics have been conducting sleep lab tests, which can be informative with regard to fatigue and driving. Overnight tests examine the brainwave activity of sleeping subjects. Daytime experiments with conscious subjects, such as the Multiple Sleep Latency Test (MSLT), look at how ready patients are to sleep on command. A more valuable daytime test is the Maintenance of Wakefulness Test (MWT) that tries to determine how likely a subject is to fall asleep in the absence of external stimuli when attempting to remain awake.
What is not being done by hospitals and clinics to any great extent, and what Moller said the Ontario Ministry of Transportation (MTO) may want to consider undertaking, are simulated or actual road tests. The available daytime tests outlined above do not measure interaction with the environment, i.e., that which is pertinent to Type II crashes. This means that the experiments discussed above do not have good ecological validity, nor good sensitivity because they tend to look at impairment resulting from 15- to 30-second sleeps as opposed to 1- to 3-second microsleeps (Moller defined “microsleep” as an intrusion of sleep-related brainwave activity into waking consciousness).

Recently, Moller conducted simulator tests at Toronto Western Hospital to assess driver performance and the occurrence of microsleeps. The tests simulated road position, varying speed, reaction time (using wind gusts) and crashes, over four circadian periods throughout the day, for a study published in the *Journal of Psychosomatic Research* (Moller et al. 2006).

Data were gathered from 27 subjects with higher sleepiness scores, or those reporting having fallen asleep while driving at least once in the past year, and from 27 healthy subjects used as a control. The major findings showed that both groups were impaired during particular circadian periods (late afternoon, late night), which is consistent with previous studies. But there were also greater levels of impairment for those with disorders; their rate of crashes more than doubled in the late-afternoon period. The most robust finding of this study pertained to reaction times (sudden wind gusts) that went from 1 second to 1.5 seconds for patients with sleep disorders.

Dr. Moller chose a three-second brainwave activity figure as constituting microsleep, based on the well-reported measure that it takes an unresponsive driver only three seconds to traverse a four-meter-wide highway shoulder at a speed of 100 km/h.

Microsleep, the intrusion of sleep-related brainwave activity (alpha/theta) into waking consciousness, was examined. Microsleep episodes tended to increase with time awake. Moreover, subjects tended to be unaware that microsleep was occurring. Microsleep
precedes actual loss of consciousness and is a “warning sign of the brain before it goes into sleep mode.” Neither healthy subjects nor those with disorders had any sense of brainwave fluctuation throughout the day (subjects with disorders may have felt less alert but were, nonetheless, unaware). Moller suggests that a homeostatic model of a subjective state of fatigue is one where there is an adaptive response – almost a healthy tendency – to ignore the feeling when one is a little bit tired, irritable or fatigued (i.e., getting on with the day, even when one is tired, is a normal behaviour).

In Moller’s study, before a subject was aware of a problem, both brain activity and performance had already begun to deteriorate. By the time the subject realized there was a problem, the subject’s brainwaves had already been indicating some level of impairment.

In terms of future research, Moller said there should be an effort to conduct some research outside hospitals and clinics, and greater cooperation among the medical, transportation and automotive fields. The need for evidence-based solutions to driver fatigue is a practical issue for medical professionals because, under the Ontario Highway Traffic Act, s. 203, physicians are responsible for communicating with the MTO about anyone whose driving skills may be affected by illness. Since medical testing isn’t definitive in determining the degree to which an individual may be impaired by a disorder, there may be a place for the development of automotive systems, for example, that could lessen the burden of responsibility on the medical profession.

Biometric monitoring is being explored through the use of instruments (mostly camera-based systems) measuring pupillometry, gaze analysis or head tracking. So far, these types of monitoring have proven subject to limitations; often by the time a problem is detected, it is too late. The systems are invasive as well, so public buy-in may be difficult to secure. The commercial industry is particularly interested, but Moller worries that things are moving too quickly and that purported solutions remain unvalidated.

Researchers should therefore focus on empirical studies with standardized protocols while investigating simulation-type activities (intrinsic designs), including monitoring devices. Extrinsic designs of testing conditions (e.g., precise time of day, prolonged vs. shorter periods of time, night vs. day) and where testing is conducted (e.g., in simple research settings, clinical practices with better monitoring systems or even at MTO or licensing bureaus for screening of subjects) should all be considered carefully. Many look forward to the day when roadside tests are conducted using a “sleepalyzer” – something analogous to breathalyzer instruments used to measure blood alcohol content – but, Moller states, we simply “are not there yet.”

Prevention will likely remain the focus of mitigation strategies. In April 2006, the Massachusetts legislature passed Law H.5378 mandating more education for young drivers because of their higher risk behaviour. The Sleep Research Society gave its endorsement for the law because it provides instruction about driver fatigue, in addition to the usual components emphasizing seatbelt use, and the dangers of alcohol and excessive speed. Dr. Moller felt that such legislation would prove useful in Ontario.

In summary, the next steps in detection, prevention and screening should be more comprehensive, with a design combining in-hospital, in-vehicle and roadside research. Evidence-based, interdisciplinary knowledge dissemination should be central to education and public awareness. Public policies, strategies and law must involve members of the medical and law enforcement communities, as well as government and the automotive industry.
Session Three
Countermeasures: Strategies for Reducing Fatigue-Related Crashes

Alison Smiley, President, Human Factors North Inc.

(For a full list of references cited in this summary, please see Appendix D.)

Alison Smiley, president of Human Factors North Inc., is a leading expert in traffic safety and driver behaviour. For Dr. Smiley, looking at factors involved in fatigue-related crashes is the best way to find measures that will prevent, or “counter,” fatigue-related crashes.

For individuals, countermeasure that are pre-planned (i.e., measures taken before driving) are more effective than post-driving countermeasures (i.e., measures taken when a driver is already en route and requires a remedy for tiredness and fatigue).

Smiley cited a number of studies with significant implications for fatigue-related crashes. The first, entitled Why Do People Have Drowsy Driving Crashes (Stutts et al. 1999), compared fatigue/sleep-related crashes with nonfatigue-related crashes. The study showed drivers on night shifts were approximately six times more likely to have a crash due to fatigue than to have a crash related to other causes. The likelihood of a crash caused by fatigue also related to length of time at the wheel, length of time awake and hours slept the night before.

A French study (Arbus et al. 1991) of 110 male drivers aged 18 to 70 and subdivided into two groups of roughly 40% healthy and 60% with disorders, also showed that time of day was a very important factor in fatigue-related crashes. In the healthy group, 80% had experienced short-term sleep deprivation, an almost identical figure (79%) for the crash time period from 2 a.m. to 6 a.m. (For the remaining 21% the average time was 4 p.m.)

Comparative data (when alcohol is removed as a control) from Australia, the UK and Sweden corroborate that the 2 a.m. to 6 a.m. time period is the riskiest for single-vehicle crashes. Avoiding driving during this dangerous period should be a part of all drivers’ preparations. Commercial drivers (and their employers) – often compelled to work overnight shifts – should be especially conscious of this risk factor and plan accordingly.
Sleep quality/quantity is also a pertinent issue. A National Transport Safety Board (NTSB) study of commercial drivers and single-vehicle crashes where fatigue was involved, found that those drivers had, on average, 5.5 hours of sleep. For those crashes where fatigue was not a factor, the driver had 8 hours of sleep, on average. Eighty percent of all drivers in this study rated their sleep as “good” or “excellent,” implying that fatigued drivers were often unaware of their condition.

Unsurprisingly, shift workers are especially vulnerable to fatigue-related crashes. Smiley noted that North American work schedules are very inappropriate and should be redesigned. For example, she said shift workers should not be allowed to work overtime because it is difficult enough for individuals to cope with the physical stresses of shift-work schedules without adding overtime hours. As with commercial drivers, redesigning shift-work schedules may require the involvement of employers. (Later in the symposium, Smiley suggested this might be an area for Ministry of Labour involvement.)

Treatment is an important countermeasure for drivers who suffer from sleep apnea. Those with this condition are nine times more likely to be involved in a single-vehicle crash than are healthy drivers. Fortunately, apnea treatment has a high rate of success.

A final suggestion in the area of pre-planning is directed at individuals using medication, particularly sedative medication with side effects. Here, timing is very important because some sedative medications have lengthy hangover periods that can affect an individual’s level of fatigue well after he or she feels the medication should have worn off.

Smiley’s discussion of post-driving remedies for fatigue began with discussion about the ubiquitous use of caffeine. She notes that caffeine can improve driver performance for 1 to 1.5 hours after consumption, but has limited effectiveness thereafter.

Rest breaks are also initially effective. A study (Mackie and Miller 1978) of commercial drivers who took rest breaks every three hours showed that by the third break, there was no improvement in performance. Other studies of rest breaks also show their effectiveness has an ultimate limitation, and Dr. Smiley emphasized that when drivers reach that point they require something more than a break.

A nap may be a restorative solution when a rest break is not enough. However, under certain circumstances even a nap is not enough. A 30-minute nap after a night of no sleep has no impact on driver performance. On the other hand, one experiment demonstrated that a 15-minute afternoon nap in the car after a driver consumed coffee, resulted in substantially improved performance. Further, a meta-analysis (of 12 studies) showed that a 15-minute nap can improve performance for up to 6.75 hours; a 2-hour nap can improve performance for up to 9.5 hours. Dr. Smiley emphasized that naps have an ultimate point of ineffectiveness when an individual requires nothing less than proper sleep. Studies of shift workers, for example, reveal naps’ effectiveness on the first night of a sequence of shifts, but effectiveness declines on subsequent nights.

In terms of highway design, a number of countermeasures can be employed to reduce fatigue-related crashes. For example, secure rest areas can encourage drivers to pull off the road to take naps.

Roads with shoulder rumble strips have 18 to 21% fewer single-vehicle crashes. This is a huge number, says Smiley, who rates their cost-benefit ratio very high. Similarly, centre-line rumble strips show a 25% reduction of target injury (head-on) crashes.
Clear zone improvements – such as clearing roadside obstacles or creating a traversable slope – significantly reduce the risk of crash injuries, should a driver leave the road.

Intelligent technology systems (ITS) – though these are still in the prototype stage – are possible countermeasures to be used in the future. However, Dr. Smiley did mention some concerns with their possible effectiveness. In a Transport Canada study of subjects on seven-hour drives, devices that warned drivers when they were leaving the road had no effect on decisions to take voluntary breaks.

Finally, the role of public education is essential in any strategy seeking to counter fatigue-related crashes. Populations should be made aware that pre-planning before driving is the most effective way to avoid fatigue-related crashes and that while there are effective countermeasures for post-driving situations, these are subject to limitations. Provincial and municipal governments already have a number of options for the design of roads and highways that can help reduce the incidence of fatigue-related crashes. New and emerging technologies may also prove valuable in combatting fatigue-impaired driving, but their application lies in the future.

Session Four
The Policing Perspective

John Carson, Deputy Commissioner, Ontario Provincial Police (OPP)

OPP Deputy Commissioner John Carson is a member of both the Canadian Association of Chiefs of Police Traffic Committee and the International Association of Chiefs of Police’s Auto Theft and Highway Safety Committee.

Deputy Commissioner Carson began his remarks by stating that driving is high-risk behaviour and police officers understand this very well. Although many may think the greatest risk for police officers comes from violence directed toward their persons, police services lose far more personnel in traffic-related incidents and collisions than they do in violent situations. Therefore, the issue of highway safety in general, and fatigue-impaired driving in particular, is a matter of occupational health and safety for police officers.
In Canada, the most likely cause of death for people between the ages of 3 and 35 is a motor vehicle crash. This is the unfortunate consequence of a highly mobile society.

The OPP’s traffic program is constantly looking at enforcement and the causes of motor vehicle collisions. The big three causes – alcohol, lack of seatbelt restraints and aggressive driving – remain a concern. With the addition of fatigue and distraction to any of these three causes of collisions, the regrettable result is a situation of disastrous proportions.

Carson said the OPP has conducted extensive education programs in schools. The OPP looks to its partners, such as public schools, to help them educate the public, to learn and to better understand the issues involved in road safety, enabling the OPP to make the best choices.

There were 444 fatalities on OPP-enforced highways last year; 111 of the victims were vehicle occupants who were non-restrained. Carson argued that people seem to turn a blind eye to the obviously dangerous behaviours that cause traffic injuries and deaths. Traffic fatalities are treated relatively lightly by a society where one would think that, because the causes of death are so well known and preventable, there would be much more in the way of resources made available to combat these catastrophes.

The Deputy Commissioner prefaced his comments with regard to collision investigation by stating that no motor vehicle collision is truly an accident and that no collision is unimportant because all collisions involve human beings. A significant number of collisions fall into the “fatigue” category. Fatigue-related collisions tend to exhibit specific patterns. For example, single-vehicle crashes tend to be fatigue-related. The single-vehicle crash presents problems because, frequently, the only witness is the driver who is obliged by law to give the investigating officer a statement. Most people who are not bound by law to give statements are reluctant to implicate themselves in a crash, especially when the outcome may be a ticket or a careless driving charge.

Officers can and do chase down evidence; for example, police pursue independent witnesses when they exist. And officers who have been in the field for a couple of years easily recognize the signs and circumstances of fatigue-related crashes. In cases where the driver is the sole witness, time and again police hear similar stories about crashing to avoid hitting a black dog or a raccoon, or other stories that are impossible to substantiate.

Moreover, even when there is sufficient evidence of driver drowsiness, it is often difficult to mount a successful prosecution. Prosecution takes a tremendous amount of effort and resources, and there are many competing interests and pressures within the policing community. Wrapping up a suspected case of fatigue-impaired driving then, is not simply a matter of conducting a proper interview.

If enforcement, investigation and prosecution are problematic, prevention becomes an even more critical element in the work to find solutions to stop fatigue-related driving. Carson reiterated the importance of partnerships and cited the “Driver Reviver” stations – organized by detachments in Bracebridge, Huntsville and South Georgian Bay during the summer season – as an example of a successful partnership. Police departments also take an interest in highway design and are very supportive of the installation of rumble strips.

More generally, Deputy Commissioner Carson noted that the Canadian Association of Chiefs of Police and its international counterpart are committed to the Road Safety Vision process. The Deputy Commissioner completed his observations by saying that the only surefire way to reduce the incidence of senseless fatalities behind the wheel is to find the social will to do what it takes to prevent such tragedies.
Closing Remarks from Ontario’s Minister of Transportation

The Honourable Donna Cansfield, MPP Etobicoke Centre

The minister began her address to the symposium by stating that the dangers of fatigue-impaired driving need to be at the centre of public concern, like drinking and driving. The challenge is to communicate the importance of being well rested before driving, and Cansfield added that this message must stress personal responsibility.

Minister Cansfield stated that the problem of fatigue-impaired driving presents more difficulties than alcohol impairment. Police investigations of fatigue-related collisions are complicated by the fact that drivers have been “shocked” awake by the collision. And while there are some promising developments in the realm of technology for detecting fatigue, there is nothing at present that can match the precision of measuring blood alcohol content (BAC).

Minister Cansfield made reference to Ontario’s various initiatives that address the issue of driver fatigue. For example, reflecting federal regulations, Hours of Service regulations for drivers of commercial vehicles came into effect on January 1, 2007. The Ontario government has also taken note of Transport Canada studies that show driving for 19 hours results in performance levels equivalent to those achieved at a BAC level of 0.05.

Bus drivers and drivers of large commercial vehicles are a particular concern at MTO, and the Minister said it was hard to understand any reason, or more accurately excuse, for a driver to be behind the wheel for 16 hours.

Fatigue impairment is being addressed in other areas, such as in the government of Ontario’s peer-to-peer “I Drive” educational program aimed at young drivers, which has fatigue awareness content. The ministry can also promote awareness through its website and its driver handbook, and by ensuring that its highway safety partners include information about the dangers of drowsy driving in their road safety campaigns.

The minister pointed out that there are 23 service centres along highways 400 and 401 (each about 1 hour or 84 kms apart), where drivers can rest and get essential services. In addition, there are approximately 200, mostly seasonal, rest areas on other provincial roads.

In the north, especially along the Trans-Canada, the province is working to plow areas where truck drivers can pull over when they are fatigued. And rumble-strip installations along provincial roads will continue.

Working with its jurisdictional partners in the Canadian Council of Motor Transport Administrators (CCMTA), the province will also rely on its other organizational partners to promote the various initiatives in the broader road safety framework. The minister mentioned specifically the RoadSafe alliance, comprised of Human Resources and Skills Development Canada, Insurance Bureau of Canada, the Ministry of Labour, the OPP, Transport Canada, the Transportation Health and Safety Association, and the Ontario Workplace Safety and Insurance Board.

Minister Cansfield closed her speech by graciously thanking the Highway Safety Roundtable for its contributions to raising awareness of driver fatigue impairment and by inviting all those who were interested in road safety to work with Ontario’s Ministry of Transportation.
Drowsy Driving: An Overview of the Safety Research Literature

Leo Tasca, Ph.D.
Safety Policy and Education Branch
Ontario Ministry of Transportation
Objectives

- Survey research literature and identify key studies during the past decade
- Provide some background regarding what we know about fatigue and sleep deprivation and how they may affect both driving performance and collision risk

Commercial Motor Vehicle (CMV) Driver Fatigue and Alertness Study\(^1\)

- Landmark $4.45 million, 7-year over-the-road study on driver fatigue and alertness published in 1997
- Objectives:
  - Measure relationships between driver activities and physiological and psychological indicators of fatigue and reduced alertness
  - Identify and evaluate effectiveness of legal alertness-enhancing measures
  - Provide scientific basis for evaluation of hours-of-service requirements
- 80 properly qualified male CMV drivers aged 25 to 65 in U.S. and Canada
- 4 different groups of 20 subjects drove under 4 contrasting driving schedules
  - 10-hour daytime
  - 10-hour rotating
  - 13-hour night start
  - 13-hour day start
- The 4 schedules provided different amounts of time off between trips
- 360 trips (200,000 miles) including about 4,000 hours of video data and 9,000 hours of physiological recordings
- Strongest and most consistent factor influencing driver fatigue and alertness was time of day
- Time of day a better predictor of decreased driving performance than hours spent driving
- No difference in amount of drowsiness observed in video records of comparable daytime segments of 10-hour and 13 hour trips
  - Study design did not provide for comparison of night time segments
- Just over 19 minutes out of 244,667 minutes of driving analyzed were identified as instances of driver actually falling asleep
- There were no crashes during the study
- No significant relationships found between driver age and fatigue
- 14% of the drivers accounted for 54% of the observed drowsiness episodes
- 13-hour night start condition associated with most sleep deprivation
- Little correlation between subjective ratings of drowsiness and objective performance measures

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\(^1\) *Driver Fatigue and Alertness Study, Federal Motor Carrier Safety Administration and Transport Canada, Technical Summary, 1997, (PB97129688) and the project final report (PB98102346), National Technical Information Service (NTIS), Springfield, Virginia.*
Development of Fatigue Symptoms During Simulated Driving²

- (Nilsson et al., 1997) used part-task simulator to obtain cumulative record of 80 young male subjects who discontinued driving as function of time
- Subjects’ accelerator position monitored continuously and their subjective fatigue level monitored every 20 minutes
- Subjects varied in how long they were able to continue the driving task (range from 90 to 240 minutes; about three-quarters stopped by 180 minutes)
- Remarkable similarity in fatigue scores when subjects did decide to stop
- May be better to alert drivers to symptoms of fatigue, rather than suggest resting after a specified time


Driver Performance: Fatigue and Alcohol Comparison³

- Australian study (2001) compares effects on a driver of remaining awake continuously for 28 hours with how varying doses of alcohol up to 0.1 BAC affect the same driver
- Objective is to assess relative sensitivity of 8 computerized performance tests known to be affected by fatigue and compare effects of fatigue with those of alcohol
  - Alcohol is a useful benchmark because its performance effects are well-documented
- Study also investigates individual abilities to cope with sleep deprivation
- Computerized performance tests:
  - Simple Reaction Time
  - Unstable tracking
  - Dual task
  - Mackworth clock vigilance test
  - Symbol digit coding
  - Visual search task
  - Sequential spatial memory
  - Logical reasoning
- Two types of test especially sensitive to fatigue:
  - Monotonous or required passive concentration (Mackworth clock vigilance test)
  - Involved difficult visual discrimination (simple reaction time, unstable tracking and dual task)
- Sleep-deprived subjects became most affected after 17-19 hours of wakefulness
- Showed performance similar to that found in the alcohol subjects at 0.05% BAC
- Logical reasoning and visual search showed little or no fatigue effects after 28 hours of sleep deprivation
- Alcohol was shown to impair performance on ALL tests
  - Significant performance effects occurred between 0.05 and 0.1 BAC.

North Carolina Case-control Study\(^4\)

- (Stutts et al., 1999) conducted first case-control study of drowsy driving crashes
- Telephone interviews of 1,403 drivers
- Cases were drivers involved in police-reported crashes who were coded as either asleep (n=312) or fatigued (n=155)
- Two control groups:
  - Drivers in non-sleep related crashes (n=529)
  - Drivers not involved in crashes (n=407)

<table>
<thead>
<tr>
<th>Category at risk</th>
<th>Odds ratio(^1)</th>
<th>Category at risk</th>
<th>Odds ratio(^1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Night-shift worker</td>
<td>13.6</td>
<td>ESS(^2) 11-15</td>
<td>4.2</td>
</tr>
<tr>
<td>Holds 2 jobs</td>
<td>2.1</td>
<td>ESS =16</td>
<td>15.2</td>
</tr>
<tr>
<td>Sleeps &lt;5 hrs</td>
<td>7.0</td>
<td>Driving late at night</td>
<td>6.5</td>
</tr>
<tr>
<td>Sleeps 5-6 hrs</td>
<td>3.8</td>
<td>Slept &lt; 4 hrs night before</td>
<td>19.2</td>
</tr>
<tr>
<td>Poor sleeper</td>
<td>12.1</td>
<td>Awake 15-20 hrs</td>
<td>10.4</td>
</tr>
<tr>
<td>Sleep disorder</td>
<td>1.9</td>
<td>Awake &gt; 20 hrs</td>
<td>56.6</td>
</tr>
</tbody>
</table>

1 Compared to non-crash controls
2 Epworth Sleepiness Scale - subjective assessment of daytime sleepiness


Systematic Review of Epidemiological Studies

- Systematic review of 19 scientific studies on driver fatigue (Connor et al., 2001\(^5\)) that met review criteria: included only studies with fatigue-related exposure measure, a crash or crash injury outcome measure and/or a comparison group
- 18 studies were cross-sectional; 1 case-control study
- 13 out of 19 studies report increase in risk of crash involvement or injury
Many of these studies, however:
- Were poorly designed or had small sample sizes
- Did not test causal hypotheses adequately
- 14 of 19 studies focused on patients with sleep disorders not healthy drivers who were sleep-deprived for non-medical (lifestyle) reasons

Identified a need for a well-designed, observational epidemiological study


Driver sleepiness and risk of serious injury to car occupants

(Connor et al., 2002**) estimated collision risk associated with driver sleepiness

Conducted interviews and administered two sleepiness scales to 571 car drivers involved in crashes where at least one occupant admitted to hospital or killed
- 65% of interviews with crash-involved drivers done within 48 hours of crash

588 drivers selected at random on public roads (controls)

Proxy interviews sought for drivers who were killed or seriously injured

Strong association reported between measures of acute sleepiness and risk of involvement in injury collision

Independent of effects of acute alcohol consumption and other confounding factors (eg. age and gender)

Eight-fold increase in risk if drivers reported sleepiness

Almost three-fold risk for drivers who drove with less than 5 hours of sleep

Five-fold risk for driving between 2 am and 5 am


Australian Transport Safety Bureau (ATSB) Fatality Crash Databases Study

(ATSB, 2002) conducted an innovative analysis of fatigue-related crashes on Australian roads in 1998

ATSB used its Fatality Crash Databases (fatal crash data based on coroner and police reports)

Proposed operational definition based on crash characteristics

Not intended to measure absolute number of fatigue-related crashes

May provide index of relative incidence of fatigue-related crashes

Used stepwise selection process:
- First:
  - exclude all crashes where the driver had a blood alcohol concentration (BAC) greater than 0.05g/100ml
  - exclude all crashes involving any unlicensed drivers or unlicensed motorcycle riders
– exclude all crashes involving a pedestrian
– exclude all crashes where the speed limit is less than 80km/h

• Then:
  – include all single vehicle crashes occurring between 12 a.m.-6 a.m. and 2 p.m.-4 p.m.
  – include all head on crashes where neither vehicle overtaking

> Selection process identified 251 of 1,511 (16.6%) fatal crashes as fatigue-related
> Comparison of fatigue-related crashes identified by coroners/police to those identified by operational definition
> 46 fatigue-related crashes identified by both operational definition and coroners/police
> Additional 53 identified as fatigue-related only by coroners/police
  • Mainly because crash occurred outside critical time period
> 205 crashes identified as fatigue-related only by operational definition
  • However, in 34.6% of these crashes, coroners/police identified drugs and/or alcohol or excessive speed as a factor

### Fatal Crashes With Fatigue Involvement

<table>
<thead>
<tr>
<th>Region</th>
<th>Per Cent</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>New South Wales</td>
<td>22.0</td>
<td>97</td>
</tr>
<tr>
<td>Victoria</td>
<td>15.6</td>
<td>55</td>
</tr>
<tr>
<td>Queensland</td>
<td>16.7</td>
<td>42</td>
</tr>
<tr>
<td>South Australia</td>
<td>13.1</td>
<td>19</td>
</tr>
<tr>
<td>Western Australia</td>
<td>9.2</td>
<td>18</td>
</tr>
<tr>
<td>Northern Territory</td>
<td>16.9</td>
<td>10</td>
</tr>
<tr>
<td>Tasmania</td>
<td>14.9</td>
<td>7</td>
</tr>
<tr>
<td>Capital Territory</td>
<td>15.0</td>
<td>3</td>
</tr>
</tbody>
</table>

### Fatal Crashes With Fatigue Involvement Per 100 Million Vehicle Kilometers Traveled

[Graph showing regional differences in fatalities per million vehicle kilometers traveled]

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Drowsy Driving Survey

- 2004 Traffic Injury Research Foundation Road Safety Monitor featured Canada-wide survey results that focussed on drowsy driving
- 1,209 households responded to the survey
  - data were weighted to ensure results were representative of the national population
- There is a 95 per cent chance the percentages estimated by the survey are + or – 2.8% of the actual population percentage
- 57% of Canadian drivers believe drowsy driving is a serious or very serious problem
- Over half of them report driving when tired or fatigued, at least occasionally
- One in five Canadian drivers – an estimated 4.1 million reported nodding off or falling asleep at least once while driving in the past 12 months
- Falling asleep at the wheel varies as a function of age with younger drivers at greater risk due to lifestyle choices:
  - 35% of drivers aged 20-24 reported doing so compared to only 6% of drivers aged 65 and over
- Male drivers are more likely than female drivers to report having nodded off at the wheel
- Falling asleep at the wheel most commonly occurs late at night and during the afternoon
- Drivers who report nodding off while driving are also more likely to report
  - less than 8 hours sleep per night
  - “poor” sleep quality
  - greater daytime sleepiness

Subjective and predicted sleepiness while driving in young adults

- (Smith et al., 2005) assessed the relationship between predicted and perceived sleepiness while driving
- Subjects ranged in age from 18 to 25 and completed both a sleep diary and driving diary over a 4-week period.
- Weekly interviews to ensure compliance
- Subjects pre-screened for sleep disorders, driving attitudes and driving behaviour
- Sleepiness levels during study predicted by a model that incorporated the sleep diary data and compared to subjective sleepiness reported by subjects
- Subjects recorded 2,518 driving trips during the 4-week period
- They reported being ‘sleepy’ during 23% of trips taken
- 63 (2.6%) trips were identified as occurring at a ‘critical’ level of alertness
- 116 trips (4.7%) occurred when alertness was ‘reduced’
- 82 (3.4%) trips occurred when subject had been awake for more than 18 hours

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9 Smith et al., 2005 assessed the relationship between predicted and perceived sleepiness while driving
Not a single instance of a subject reporting they chose not to drive due to sleepiness.


Fatigue, sleep deprivation and driving performance

(Philip et al., 2005) tested the effects of sleep deprivation on 22 healthy male subjects ranging in age from 18 to 24
- Prior testing confirmed none of the subjects had sleep disorders

Subjects drove 1,000 km on a divided highway maintaining posted speed limit over a 10-hour period consisting of five 105 minute driving sessions
- Cars equipped with dual controls and subjects accompanied by professional driving instructor

Subjects drove route twice:
- with 8.5 hrs of sleep the previous night
- with 2 hrs of sleep the previous night

Obtained measurements of:
- self-rated fatigue
- a video camera recording of driving sessions used to count the number of inappropriate line crossings while driving
- at each rest stop subjects’ simple reaction time was measured

Results confirm sleep deprivation affects performance

Key measure is the number of interventions by the accompanying driver:
- None during the rested condition
- 61 during the sleep-deprived condition

Sleep-deprived subjects who could not continue a session:
- One sleep-deprived subject had to be driven back to rest stop during 4th driving session
- Another subject was driven back to rest stop during both the 2nd and 4th driving session

Sleep-deprived subjects driven back to rest stop were, after resting, able to complete the scheduled drive

Video recordings showed a significant increase in inappropriate line crossings
- 66 in normal sleep condition
- 535 in sleep-deprived condition

This means sleep deprivation increased risk of inappropriate line crossing 8.1 times

Relative risk of sleep-deprived drivers was higher for all driving sessions

When risk of line crossing compared to first morning session within each group:
- drivers with normal sleep condition saw significant increase in risk by 4th session
- sleep-deprived drivers saw significant increase in risk by 2nd session

Conclusions

- We are underestimating the incidence of fatigue-related collisions
- Fatigue and sleep-deprivation can significantly affect our performance on the road
- Well-designed studies to estimate collision risk and/or adverse effects on driving performance are in short supply
- Well-designed studies are essential for policy development and program spending justification
Fatal and Injury Fatigue-Related Crashes on Ontario’s Roads: A 5-year Review

Yoassry Elzohairy, Ph.D., P.Eng.
Senior Advisor
Ministry of Transportation
Why do We Need An Operational Definition of Fatigue-Related Crashes

- Cases where fatigue is a factor, but drivers remain awake are generally not recognized as fatigue-related collisions.
- Police are not provided with special training to identify sleepiness/fatigue as a contributing factor.
  - Less than 2% of all fatal and injury police-reported crashes can be attributed to driver sleepiness or fatigue as a contributing factor.
- Currently, there is no a straightforward fatigue-measuring device for roadside use by police.
- There is also an absence of definitive criteria for establishing the level of fatigue that increases crash risk.
- A method is needed to allow accurate estimates of the true prevalence of drowsy-driving crashes.

Operational Definition of Fatigue-Related Crashes

- Selection Criteria include crashes where
  - Police or coroner identified fatigue as a contributing factor.
  - Vehicle condition: No Apparent Defect
  - Driver did not exceed speed limit and did not travel at speed too fast for condition at the time of the crash.
  - Driver was not impaired by alcohol or drug.
  - Driver has no medical or physical disability.
  - Crash occurred on a dry pavement.
  - Initial Impact Type (head-on collisions where neither vehicle was overtaking at the time of collision, rear-end collision and single vehicle collisions)
  - Crashes that involve unlicensed drivers are excluded.
  - Crashes that involve pedestrians or animals (wild or domestic) are excluded.
  - Driver initiated the crash (i.e.; D01 = 1).

Is Fatigue a Concern on Ontario’s Roads?

<table>
<thead>
<tr>
<th>Year</th>
<th>Fatigue-Related Crashes (Operational Definition of Fatigue)</th>
<th>All Fatal and Injury Crashes 2000-2004</th>
<th>Per Cent Fatigue-Related</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Class of Collision</td>
<td>Total</td>
<td>Class of Collision</td>
</tr>
<tr>
<td>2000</td>
<td>124 : 14,240</td>
<td>14,983</td>
<td>737 : 57,279</td>
</tr>
<tr>
<td>2001</td>
<td>123 : 14,638</td>
<td>14,781</td>
<td>733 : 54,479</td>
</tr>
<tr>
<td>2002</td>
<td>154 : 16,017</td>
<td>16,171</td>
<td>770 : 56,516</td>
</tr>
<tr>
<td>2003</td>
<td>126 : 13,650</td>
<td>13,776</td>
<td>751 : 52,757</td>
</tr>
<tr>
<td>2004</td>
<td>128 : 12,744</td>
<td>12,872</td>
<td>718 : 49,948</td>
</tr>
<tr>
<td>Total</td>
<td>685 : 71,918</td>
<td>72,583</td>
<td>3,742 : 270,979</td>
</tr>
</tbody>
</table>
Severity of Injury in Fatigue-Related Crashes, 2000-2004

<table>
<thead>
<tr>
<th>Year</th>
<th>Non</th>
<th>Minimal</th>
<th>Minor</th>
<th>Major</th>
<th>Fatal</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000</td>
<td>21,951</td>
<td>14,540</td>
<td>8,786</td>
<td>834</td>
<td>149</td>
<td>44,360</td>
</tr>
<tr>
<td>2001</td>
<td>20,664</td>
<td>14,077</td>
<td>7,103</td>
<td>846</td>
<td>143</td>
<td>42,836</td>
</tr>
<tr>
<td>2002</td>
<td>23,363</td>
<td>14,970</td>
<td>7,960</td>
<td>1,036</td>
<td>169</td>
<td>47,496</td>
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<tr>
<td>2003</td>
<td>19,519</td>
<td>12,765</td>
<td>6,866</td>
<td>835</td>
<td>138</td>
<td>40,173</td>
</tr>
<tr>
<td>2004</td>
<td>17,595</td>
<td>11,115</td>
<td>6,782</td>
<td>731</td>
<td>140</td>
<td>36,396</td>
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<tr>
<td>Total</td>
<td>103,090</td>
<td>67,597</td>
<td>35,502</td>
<td>4,285</td>
<td>739</td>
<td>211,213</td>
</tr>
</tbody>
</table>

Who is at RISK?

Fatigued Drivers: Who Are They?

Fatigued Drivers: Who Are They? (Cont)

APPENDIX B
When Do Fatal and Injury Fatigue-Related Crashes Occur?

- **Day of Week:**
  - Monday: 10,000
  - Tuesday: 11,000
  - Wednesday: 10,500
  - Thursday: 11,200
  - Friday: 14,000
  - Saturday: 11,000
  - Sunday: 8,000

- **Month:**
  - January: 1,000
  - February: 1,500
  - March: 2,000
  - April: 3,000
  - May: 4,000
  - June: 5,000
  - July: 6,000
  - August: 7,000
  - September: 8,000
  - October: 9,000
  - November: 10,000
  - December: 11,000
Fatal and Injury Fatigue-Related Crashes By Road Alignment

Fatal and Injury Fatigue-Related Crashes By Road Jurisdiction
Hotspots for Fatal and Injury Fatigue-Related Crashes

1. TORONTO
2. OTTAWA
3. LONDON
4. HAMILTON
5. MISSISSAUGA

Fatal and Injury Fatigue-Related Crashes By Speed Limit

Fatalities and Serious Injuries By Involved Person
Most Common Errors Committed by Fatigued Drivers

- Following too close: 58%
- Speed too fast for condition: 0%
- Speed Exceed Limit: 0%
- Improper Lane Change: 4%
- Improper Turn: 2%
- Speed too Slow: 0%
- Disobey Traffic Controls: 2%
- Fall to Yield: 4%
- Lost Control: 28%
- Improper Passing: 1%
- Wrong Way on One Way Road: 0%
Medical Perspective: Driver Drowsiness, Fatigue and Alertness

Henry Moller  MD, MSc, FRCPC, DABSM
University Health Network
University of Toronto
Sleep Research Unit
henry.moller@uhn.on.ca
Summary

- Review of relationship between sleep-related driving impairment and crash risk
- Focus on evidence-based medical review
- Implications on public policy and education

Background

1999
- High profile vehicular manslaughter case involving elderly driver

2002
- Inquest jury recommends the design of a “diagnostic screening tool for doctors to identify drivers at risk”

Defining “accidents” better

- 250,000 injuries 3000 deaths per year in Canada due to vehicle crashes
- accident* (suggests role of fate, and implies unpredictability) vs. “crash/collision”
- Fatigue, inattention and sleepiness implicated in major “accidents” in occupational/industrial context

* Lancet (1998); O’Neill

Road Traffic Injuries-Global Burden

- Recent 1st UN / WHO Global Road Safety Week
- Traffic fatalities leading cause of death among youth aged 10-25 years
- In high-income countries most young victims are novice drivers
- Role of fatigue and inattention under-researched

Traffic Fatalities:
Established & Emerging Driver Risk Factors

- Established
  - Drinking
  - Speeding/Risk-taking
  - Seat-belt non-use
- Emerging
  - Distraction
  - Fatigue and sleep-related

Drowsy and Inattentive Driving:
The Next Frontier in Public Awareness?

- Public policy development analogy to drunk driving
- Expanding knowledge of the medical science of sleep, fatigue and inattention
• Including as preventable cause of driving impairment

Several recent high-profile studies have found sleep loss as impairing as alcohol intoxication
• (e.g. Arnedt et al., JAMA, 2006)

Quantifying Impairment
• Difficult to measure impairment objectively (e.g. BAC for alcohol use)
• Impairment = 
  • (medication effects) + (baseline medical condition) + (sleep deprivation) + (alcohol/substance)

• Legal/Categorical standards versus physiological parameters
• Societal debate regarding thresholds of acceptability

Cybernetic Model of Driving Performance

What is fatigue?
• Complex state characterized by a lack of alertness and reduced mental and physical performance, often accompanied by drowsiness

• Signs and symptoms:
  • Forgetfulness, Poor Communication, Impaired decision making skills, slow reaction time, microsleep, mood disturbance, irritability
  • A disorder of information processing
Information-processing model of driving behaviour *(Rasmussen, 1987)*

- 3 levels of cognitive control for complex task performance
  - (1) Skill-based behaviour
    - automatic/effortless (sensory-motor perception)
  - (2) Rule-based behaviour
    - prescribed maneuver (e.g. passing) to deal with changing driving circumstances (e.g. slower car)
  - (3) Knowledge-based behaviour
    - if rule-based maneuver not sufficient, conscious knowledge-based problem solving

Drowsiness and Driving

- Epidemiological studies have established circadian variation in the incidence of sleepiness-related motor vehicle accidents

  *Lavie, et al. Frequency of sleep-related traffic accidents and hour of the day. Sleep Research (1986)*

Two major crash categorizations define spectrum of collision related to fatigue

- **Type I**
  - Single vehicle
  - Lack of external stimulation
  - Boredom/underarousal, leads to lowering of brain activity
  - Rural/Long monotonous stretch of highway
  - Circadian component

- **Type II**
  - Multi-vehicle
  - Overstimulation results when mental tasks excessively complex and sustained
  - Multi-tasking/overarousal
  - Urban/intersection
  - More often related to traffic volume

Neurocognitive performance spectrum of fatigue

<table>
<thead>
<tr>
<th>Underarousal</th>
<th>Overarousal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drowsiness</td>
<td>Cognitive Overload</td>
</tr>
<tr>
<td>Errors of Omission</td>
<td>Errors of Omission</td>
</tr>
</tbody>
</table>

**TYPE I CRASHES**  
“Sleep” mode

**TYPE II CRASHES**  
“Overload” mode

Type 3?: “Road Rage”

- Relatively under-researched
- Implication is that maladaptive driving behavior is volitional
- Possible relationship to brain ‘set shift’ between under- and overarousal driving scenarios
- May be unmasked by fatigue, prolonged commutes
Socioergonomic Factors

- Increased Traffic Congestion/Urban Sprawl
- Increased trend towards ‘Multi-tasking’ while driving: cell-phones, GPS, pagers, e-mail, etc.
- The role of fatigue on these tasks is under-researched

Effect of Distraction on Brain Function
(Simulator task with visual distractions)

- Increased activation of bilateral visual cortex (Area MT) (monitoring distracters) and prefrontal cortex
- Implication: brain is working harder to stay focused under distracting conditions
- (Drummond et al., 2005) Compensatory recruitment after sleep deprivation and the relationship with performance

Drowsiness and crash risk

- State (Sleep Loss) versus Trait (Sleep Disorder)
- By far, most common cause is self-imposed sleep loss
- Some Medical Factors:
  - Aging
  - Untreated Sleep Apnea
  - Narcolepsy
  - Neurological: Stroke, MS, Parkinson’s, etc.
  - Insomnia (?)
  - Psychiatric (?)
  - Shift-work, acute/chronic
  - Role of medications
    - Sleeping pills, antidepressants, analgesics, antihistamines, etc.

Attention Deficit and Driving

- Young drivers vs. Sociological trend?
- Sleep disorders in teens may be present with ADD
  - Link to decreased frontal cortex inhibition
- 4X Crash risk (Reimer et al 2005), more frequent speeding, traffic citations (Barkley, 2004)

Medicolegal: Physician’s Perspective

- Ontario Highway Traffic Act, S. 203
  - “Each physician is required by law to report to the MOT any individual whose driving skills may be affected as a result of an illness or injury”
  - Sleep Disorders to be assessed in sleep lab
How to assess drowsy driving risk?

- Subjective Report
- Physical Exam
- Mental Status Exam
- Sleep Laboratory Testing
  - Overnight Sleep Study
  - MSLT
  - MWT
- Neurological Tests: EEG, CT
- Psychometric Tests
- Simulator Tests
- Road Tests

Current Daytime Sleep Lab Tests

- MSLT (Multiple Sleep Latency Test)
  - 4 X 20 minute nap opportunities
  - “How readily are you able to go to sleep on command?”

- MWT (Maintenance of Wakefulness Test)
  - 4 X 30 minute sessions
  - “How likely will you fall asleep sitting in a dark room?”

- Neither test interactive
- Ecological validity vis a vis driving?
- Sensitivity – does not take into account microsleep

Driving Performance and Microsleeps

- Simulator Testing at 10:00/12:00/14:00/16:00
- Road Position
- Speed
- Reaction Time

Driving Impairment and Drowsiness

How much sleep is too long while driving?

- It takes an unresponsive driver only three seconds to traverse a four-meter-wide highway shoulder at a speed of 100 km/h and an angle of departure of three degrees

Microsleep

- Intrusion of sleep-related brainwave activity (alpha/theta) into waking consciousness
- Increases with time awake, fatigue level and length of drive
- Driver may be unaware
- Precedes onset of actual loss of consciousness

Insight into Impairment

- Drivers often unaware of impairment, report no change in subjective state
2A Homeostatic Model of Subjective State

- Adaptive response to ignore/discount fluctuations in internal states, at mild to moderate levels
- Conscious Awareness of potential impairment arises at more extreme states of sleepiness
- Objective evidence of impairment (performance/microsleeps) precedes conscious awareness

Current Policy/Research Issues

- Co-operation between Medical, and Transport and Automotive systems to develop evidence-based solutions
- Medicolegal responsibility controversial
- Clinic-based monitoring
- Built-in ‘auto-monitor’
- Graduated/Reverse graduated licensing
- Road Design

Biometric Monitoring

- EEG monitoring
- Blink/eyelid closure analysis (PERCLOS)
- Pupillometry
- Gaze analysis
- Head tracking
- Most of these involve camera-based systems
- Unlikely public acceptance
- Commercial Drivers

Current Research Issues

- Beware of unvalidated claims
- Need for empirical research
- Need for standardized protocols
  - Simulator type (intrinsic)
  - Testing conditions (extrinsic)
- Where to test?
  - Research Setting
  - Routine Clinical
  - MOT/Licensing
  - Roadside ‘sleepalyzer’?
  - In-car monitoring alert system
Summary

- Fatigue is a state of impaired brain function
  - often related to sleep loss
  - may relate to medical factors that can be screened for
  - difficult to measure/quantify impairment
  - strongly influenced by driver-environment interaction

- Ontario physicians required to report if suspect underlying medical condition

- However, no currently available reliable fatigue monitoring system to predict/prevent crashes makes this obligation controversial

Next Steps in Reducing Collisions due to Fatigue and Inattention

- Detection/Prevention/Screening
  - In-hospital
  - In-vehicle
  - Roadside

- Education Public Awareness
  - Interdisciplinary knowledge dissemination
  - Medical/Law-enforcement/Governmental/Auto Industry

- Evidence-based Public Policy/Strategy/Law

- Requires multidisciplinary research efforts

Weighing the costs of prevention vs. treatment

henry.moller@uhn.on.ca
University Health Network Sleep Research Unit
www.driving-assessment.org
4th International Driving Symposium on Human Factors in Driving Assessment, Training, and Vehicle Design
July 9-12, 2007 Stevenson, Wash, USA
Strategies for Reducing Fatigue-Related Crashes

Alison Smiley, PhD, CCPE
Human Factors North Inc.
Toronto, Ontario
Fatigue-Related Crashes

- 1403 drivers (407 nc, 529 cc, 467 fatc)

- Fatigue/sleep crash drivers vs. non-fatigue crashes:
  - At wheel significantly longer before their crash
  - Awake for longer that day

- Drivers on night shift – 6x more likely to have a crash due to fatigue vs. other causes

- Fatigue crash likelihood related to length of time at wheel, length of time awake and hours slept the night before

  *Stutts et al., 1999*

- 110 male drivers aged 18 – 70

- 38% healthy 80% short-term sleep deprivation
  - 20% chronic insomnia
  - 79% crash time 2 – 6 a.m.
  - 21% average time 4 p.m.

- 62% not healthy
  - 16% sedating drugs
  - 31% sleep apnea
  - 10% narcolepsy
  - 12% daylight sleepiness
  - Unknown cause
  - 47% other

  *Arbus et al., 1991*

Countermeasures

- Pre-planning
- Treatment for Sleep Disorders
- Caffeine
- Rest breaks
- Naps
- Highway design
- ITS – fatigue warning systems
- Public Education

Pre-Planning (1)

- High risk of single vehicle crashes in the 2 – 6 a.m. time period
**Pre-Planning (2)**

- Higher risk of crashes if inadequate prior main sleep period

**Inadequate Sleep and Crashes**

- 107 single vehicle nighttime crashes
- 58% fatigue probable cause

Fatigue related:

- 5.5 vs. 8 hours previous sleep
- 80% rated sleep good or excellent NTSB, 1995

*NTSB, 1995*

**Sleep Apnea and Crashes**

- Car drivers with sleep apnea have 9x risk of single vehicle crash as compared to healthy drivers

*Haraldsson et al., 1990*

**Sleep APNEA and Performance**

- Sleep apnea patients performed similarly to drivers at 0.08% BAC
- Treated patients performed similarly to healthy subjects

*George et al., 1996*
Sedating Drugs

- Benzodiazepines such as valium impair driving performance for as much as 5 hours after 10 mg
  
  *Smiley, 1987*

- Benzodiazepines increased crash risk by 1.5 times

- Antidepressants (amitriptyline) increased crash risk by 2.2 times
  
  *Ray et al., 1992*

Caffeine

- Improved performance on tracking, visual search and reaction time 1 hours after consumption
  
  *Moskowitz and Burns, 1991*

- Driving commenced 1.5 hours after consumption

- Reaction time performance improved during first 1.5 hours over a 3-hour drive
  
  *Lisper et al., 1990*

Rest Breaks (1)

- For rest breaks every 3 hours, 3rd break did not result in improved performance or heightened arousal
  
  *Mackie & Miller, 1978*

Rest Breaks (2)

- Rest breaks during night driving only reduced the frequency of eyelid closures for 12 minutes on average
  
  *Vincent et al., 1998*

Rest Breaks (3)

- 12 drivers age 20 – 30
- Start time 10:00 a.m. or 4:00 p.m.
- 28 instances of microsleeps
- After falling asleep once, mean time to fall asleep again: 24 minutes
- After falling asleep 3 times, break and brisk walk, mean time to fall asleep again: 25 minutes
  
  *Lisper et al., 1986*
Naps: Length and Effectiveness

- 30-minute morning nap after night of no sleep ineffective
  
  Lenne et al., 2004

- 15-minute afternoon nap in the car after coffee substantially improved performance
  
  Reyner and Horne, 1997

- Meta-analysis of 12 studies showed that a 15-minute nap can improve performance up to 6.75 hours and a 2-hour nap up to 9.5 hours
  
  Driskell & Mullen, 2005

Naps: Timing and Effectiveness

- Proactive naps are better than reactive naps:
  - Lab study of 56 hours awake showed that even although sleep lighter, earlier 2-hour nap had stronger and longer lasting performance benefits than later nap
  
  Dingess et al., 1987

- Naps (proactive and reactive) appear to be most effective on the first night of a sequence of shifts
  
  Schweitzer et al., 2000; Purnell et al., 2002

Highway Design

- Secure rest areas to nap
- Shoulder-edge and centreline rumble strips
- Forgiving roadside

Shoulder Rumble Strips

- 18-21% reduction in single vehicle crashes on freeways

Centreline Rumble Strips

- 25% crash reduction for target injury crashes

Clear Zone Improvement

- By 1.5m – 13% reduction in crashes
- By 6m – 44% reduction in crashes

ITS Countermeasure

- Detection of loss of alertness through:
  - Steering and other control movement changes
  - Eyelid closures
May have limited effectiveness: study of 7-hour drives showed warning signals had no effect on length or timing of voluntary breaks

Vincent et al., 1998

Potential Public Education on Fatigue

- Avoid driving during the early morning hours when crash risk is substantially increased
- Be rested before long drives
- Get treatment for chronic daytime sleepiness
- Limit driving to under 8 hours per day
- Pull off and nap when tired
- Avoid taking drugs with sedating side effects within 2 – 3 hours of driving

Summary

- Pre-planning is the best countermeasure for fatigue: avoid driving 2 – 6 a.m. and start well-rested
- Caffeine and rest breaks help for short periods, but once a driver gets sleepy, a nap is needed
- Once a driver has been up for 16 to 18 hours, sleep is required
- Sleep apnea treatment is effective
- Shoulder edge rumble strips reduce run-off-road collisions by 15%
- Centreline rumble strips reduce head-on collisions by 25%
- A wide clear zone (>10m) is very effective in reducing crash severity
- ITS countermeasures will soon be available and may reduce crash frequency
- Public education is required
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Produced by the Strategies to Reduce Impaired Driving by Fatigue Sub-Group of the Canadian Council of Motor Transport Administrators
April 2007
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Countermeasures


Caffeine


Continuous Shoulder Rumble Strips


Environmental Improvements


Legal Aspects and Public Policy


**Napping**


**Public Education**


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Scope and Nature


Scope and Nature—International Studies


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**Circadian Rhythms**


Sleepiness Indicators & Measurement


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