CHARACTERISTICS OF CRASHES ATTRIBUTED TO THE DRIVER HAVING FALLEN ASLEEP

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Abstract—While it has been known for some time that crashes can result from the driver falling asleep at the wheel, this issue has received less attention in traffic safety programs than the role of alcohol or speed of the vehicle. The present study was done to investigate the characteristics of crashes attributed to the driver being asleep. The study utilized the database at the Highway Safety Research Center at the University of North Carolina that is based on the uniform crash reporting system in that state. Over the years 1990–1992, inclusive, there were 4333 crashes in which the driver was judged to be asleep but not intoxicated. The crashes were primarily of the drive-off-the-road type (78% of the total) and took place at higher speeds (62% in excess of 50 mph). The fatality rate was of similar magnitude to that in alcohol-related crashes with fatalities in 1.4% of such crashes (alcohol crashes had fatalities in 2.1%). The crashes occurred primarily at two times of day—during the nighttime period of increased sleepiness (midnight to 7.00 a.m.) and during the mid-afternoon “siesta” time of increased sleepiness (3.00 p.m.). These crashes occurred predominately in young people. Fifty-five percent of these were in individuals 25 years of age or younger, with a peak age of occurrence at age 20 years. Sleepiness may play a role in crashes other than those attributed by the police to the driver being asleep. Determining the magnitude of this role is a challenge to the traffic safety community.

Keywords—Sleep, Alcohol, Vehicular crashes, Circadian rhythm

INTRODUCTION

Even in non-sleep-deprived persons, sleepiness occurs at two particular periods of the day, i.e. during the night at the time of normal sleep and in the early afternoon, at the time of the siesta in certain cultures. This can be shown by measuring the physiological tendency to sleep as the latency to sleep in brief naps (Richardson et al. 1982). Increases in sleepiness can result from sleep deprivation (inadequate sleep) or from sleep disorders such as narcolepsy, chronic insomnia, and obstructive sleep apnea. Subjects who are excessively sleepy, from whatever cause, have performance lapses and slowed reaction times and an accelerated loss of attentional vigilance (Dinges 1992). They, moreover will exhibit the phenomenon of “microsleeps”, i.e. sleepy subjects may briefly fall asleep in an unpredictable fashion and be temporarily unaware of their surroundings.

These behavioral changes that occur in sleepy individuals can have important consequences. These consequences will depend on the environment that the subject is in. Perhaps the most dangerous situation is while driving. Crashes occur in individuals who fall asleep at the wheel. Such crashes can be serious with resulting fatalities (Parsons 1986). That this occurs has been known for some time (for review of earlier work in this area, see Shinar 1978).

The goal of the study described in this report was to investigate, in detail, the characteristics of crashes attributed on the police report to the driver having fallen asleep. The study was a retrospective analysis of data from the state of North Carolina. We analyzed data for the years 1990–1992, inclusive. The data are maintained in the database at the Highway Safety Research Center (HSRC), University of North Carolina.
METHODS

North Carolina uses a standard crash report form which, by state law, must be filled out by an officer of the law for each and every crash occurring on a public access area where there was personal injury or at least $500 of total property damage. These reports, completed within 24 h of the crash are sent to the Motor Vehicles Collision Reports Section for editing and entry into a computer. These data are given to HSRC for use in their database.

Particularly important variables in the database for the questions posed here are the following:

(a) Physical condition of the driver. This has the following codes: 0, not stated; 1, normal; 2, ill; 3, fatigued; 4, asleep; 5, other physical impairment; 6, impairment due to medicine/drugs; 7, restriction not complied with; 8, condition not known. The judgment is made by the investigating officer based on personal interview of the driver, circumstantial evidence or testimony of eye witnesses (this could be the other driver or drivers in the accident).

(b) Driver intoxication. This has the following codes: 0, not stated; 1, the driver had not been drinking or using drugs; 2, drinking, ability impaired; 3, drinking, unable to determine impairment; 4, unknown; 5, drinking, not impaired. This coding is done by the investigating officer. It is not necessary for the driver, who was judged to be intoxicated, to have been arrested.

(c) Injury severity. The injury codes are a standard five level KABCO scale where 0 = no injury; C = no visible sign of injury but complaint of pain or momentary unconsciousness; B = non-incapacitating injury (not A or K) but injury evident at the scene; A = incapacitating injury, i.e. injury serious enough to prevent carrying on normal activities for at least 24 h, e.g. massive loss of blood, or fractures; K = killed.

The database is maintained in a SAS system data file which was used for all the analyses reported below.

RESULTS

During the years 1990–1992, inclusive, there were 5104 crash reports in which the driver was judged to have fallen asleep. In 771 of these the driver was also thought to have been intoxicated. We excluded these so that we could examine the characteristics of "pure" fall-asleep crashes. Thus, excluding those with intoxication there were 4333 reports in which the driver was judged to be asleep. It is the characteristics of this group of crashes that we first describe.

Characteristics of fall-asleep crashes and comparison to alcohol-related and all other crashes

Fall-asleep collisions, which represented 0.46% of the total number of drivers in crashes, had certain characteristics. These are given in Table 1 and compared to those in alcohol-related crashes and those from all other causes. They were primarily crashes in which the driver drove off the road to the right or left (78.5% of the total). This was more common than in the alcohol-related (48.4%) or in the other categories (9.0%). They were also primarily, and more commonly, single vehicle (77.5%) (see Table 1 for other numbers). They were also most commonly at high speed (62.4% were at speeds judged to be in excess of 50 mph). This percentage of crashes at speeds in excess of 50 mph was higher than in alcohol-related reports (41.6%) and those due to other causes (15.0%). As a group fall-asleep crashes were more serious crashes being of a similar level of severity to crashes in which the driver was judged to be intoxicated (see Table 1).

Fall-asleep crashes occurred predominantly in young people. The peak age of occurrence was at age 20 years and 55% of the crashes occurred when the driver was 25 years of age or younger (see Fig. 1). The mean (median) age of the driver was younger than in the alcohol-related or other crashes (see Table 1). Fall-asleep crashes also predominantly occurred in male drivers as did the other crash types.

Circadian plots of crashes of various types

The temporal distribution of those crashes attributed to the driver being asleep followed that antici-

Table 1. Comparison of characteristics of the following types of crashes: those attributed to the driver falling asleep; those where the driver was judged to be intoxicated but not asleep; all other crashes

<table>
<thead>
<tr>
<th>Characteristic of Crash</th>
<th>Fall-asleep</th>
<th>Alcohol-related</th>
<th>All others</th>
</tr>
</thead>
<tbody>
<tr>
<td>% of Reports*</td>
<td>0.46</td>
<td>2.99%</td>
<td>96.55%</td>
</tr>
<tr>
<td>Type of Crash</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>% Drive off the road</td>
<td>78.5%</td>
<td>48.4%</td>
<td>9.0%</td>
</tr>
<tr>
<td>% Single vehicle</td>
<td>77.5%</td>
<td>50.7%</td>
<td>8.7%</td>
</tr>
<tr>
<td>% Speed in excess of 50 mph</td>
<td>62.4%</td>
<td>41.6%</td>
<td>15.0%</td>
</tr>
<tr>
<td>Level of Injury</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No personal injury</td>
<td>40.6%</td>
<td>35.2%</td>
<td>59.1%</td>
</tr>
<tr>
<td>Level C injury (mildest grade)</td>
<td>21.7%</td>
<td>20.6%</td>
<td>25.4%</td>
</tr>
<tr>
<td>Level B injury</td>
<td>22.8%</td>
<td>24.3%</td>
<td>9.9%</td>
</tr>
<tr>
<td>Level A injury (severest grade)</td>
<td>13.5%</td>
<td>17.8%</td>
<td>5.1%</td>
</tr>
<tr>
<td>Fatality</td>
<td>1.4%</td>
<td>2.1%</td>
<td>0.5%</td>
</tr>
<tr>
<td>Characteristics of Driver</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean (median) age of driver (yr)</td>
<td>30.2 (23.5)</td>
<td>31.5 (28.5)</td>
<td>35.9 (31.5)</td>
</tr>
<tr>
<td>% Male driver</td>
<td>74.5%</td>
<td>83.4%</td>
<td>57.9%</td>
</tr>
</tbody>
</table>

*The numbers given here are the percentage of drivers/total drivers in all crashes.
Fig. 1. Frequency histogram of number of crashes (Y axis) at different ages (X axis) in which the driver was not intoxicated but judged to have been asleep. Data for years 1990–1992, inclusive.

Fig. 2. Frequency histogram of time of occurrence during the day of crashes in which the driver was judged to be asleep but not intoxicated. Data for years 1990–1997, inclusive.

### DISCUSSION

Certain of the findings in this study are not unexpected. The temporal occurrence of the crashes in which the driver was judged to be asleep corresponds to the known circadian variation in sleepiness; there is a major peak during the night with a secondary peak at the siesta time in the afternoon (3.00 p.m.). This temporal occurrence of “fall-asleep crashes” has been reported previously for single car crashes in Israel (Lavie et al. 1986) and Texas (Langlois et al. 1985) (for review, see Mitler et al. 1988). The temporal occurrence of these crashes is a function of age. Up to the age of 45 years these crashes occur most commonly during the night. Over the age of 45 years this is, however, not the case. This may be the consequence of changes in lifestyle with age, i.e. older individuals are less likely to be on the road during the night-time or around 7.00 a.m. The crashes with the driver asleep were largely of a particular type–drive-off-the-road. They were also predominately single vehicle. Driving off the road may reflect the behavior that occurs when the driver falls asleep. It is, however, conceivable that there is a reporting bias since in such crashes, as compared to...
Fig. 3. Time of occurrence of crashes in drivers of different ages in which the crashes were attributed by the police to the driver being asleep but in which alcohol was not judged to have been involved. The four panels show plots for drivers of the following ages: (A) drivers aged 25 years of age or younger; (B) drivers between 26 years of age and 45 years, inclusive; (C) drivers between 46 years of age and 65 years, inclusive; and (D) drivers over 65 years of age. In each plot the X axis is time of day and the Y axis is number of crashes. However, the scale of the Y axis is different for the different plots. The data are for the years 1990-1992, inclusive.

Fig. 4. Frequency histogram of number of crashes (Y axis) at different times throughout the day (X axis) in which the driver was judged to be intoxicated. Data are for one year, 1991. Data in the other years were essentially identical.

other types, it may easier for the investigating officer to come to a conclusion that the driver fell asleep. Alcohol-related crashes are also commonly of the drive-off-the-road type. Conceivably, therefore, in some of the fall-asleep crashes alcohol could have played a role. This is, however, speculation since we do not know the exact criteria that police employ.

Since the driver asleep is essentially "comatose," and not taking corrective action, it is not surprising that the crashes tend to be associated with serious injury or fatality. Indeed, fatalities occurred in 1.4% of such crashes. The crashes were of a similar level of
intervals) (X axis) for crashes where the driver is < 25 years of age but was neither judged to be asleep nor intoxicated. Data are for driver being asleep were by far the most common in sleep fragmentation and excessive sleepiness (Pack). Decreased total sleep time, later bedtimes, and an increased level of daytime sleepiness (Carskadon) are particularly common disease with a prevalence of the order of 0.067% (Dement et al. 1973). Thus, there may be many more crashes in which sleepiness plays a role than that described here. Sleepiness may contribute, therefore, to crashes attributed to loss of attention. Moreover, sleep deprivation markedly augments the impaired driving performance that results from alcohol ingestion (Roehrs et al. 1994). Thus, excessive sleepiness could play a much larger role in causing crashes than the number of fall-asleep crashes would imply. The actual scope of the problem will be difficult to assess since currently there is no simple test for the investigating officer to apply. A recent population survey in Finland suggests, however, that the problem is large in scope (Martikainen et al. 1992). Fifteen percent of the middle-aged population reported having fallen asleep driving at least once; 4.8% of males reported falling asleep more than five times; and 1.3% of the population reported an accident or mishap due to having fallen asleep while driving.

The data presented here suggest the hypothesis that sleepiness could play a much larger role than the number of fall-asleep crashes would allow us to conclude. We have found that crashes in which the driver was neither asleep nor intoxicated had their peak time of occurrence at 3.00 p.m. (a time of increased sleepiness) both for those in young people (≤ 25 years of age) and for those where the driver drove off the road. This is earlier than the period of peak road use between 4.00 and 6.00 p.m. (Schwing 1990). It is, however, at a time that high school children could be out of school. It is difficult, however, to assess the role of sleepiness since other factors such as exposure, traffic congestion, will play a role. We did not observe in these data another peak during the night-time hours. This could be the result of the large difference in road usage at these different times (Schwing 1990). The temporal occurrence of these crashes therefore does not prove that sleepiness played a role. There is, however, a need for further studies to investigate the cause of these robust rhythms of temporal occurrence of crashes. It may be that crashes are more commonly attributed by the investigating officer to sleep during the night-time hours when sleep seems natural but not during the afternoon when sleep, at least in our society, is not acknowledged to be a biological imperative.

These data point to the difficulty of determining the role of sleepiness in a particular crash. As stated above, there is no measurable test that the investigating officer can employ. Moreover, following the crash the driver should regain full alertness and there will be no residual evidence of impaired performance as occurs with alcohol. Thus, the evidence that sleepiness plays a role is currently based on the self-report of severity to those in which the driver was judged to have been intoxicated.

Somewhat surprisingly the crashes due to the driver being asleep were by far the most common in young people with a peak age of occurrence at age 20 years. This is not the age at which one would anticipate a high prevalence of sleep disorders. At least two major sleep disorders have been shown to result in an increased risk of traffic crashes. First, sleep apnea is a condition in which there is recurrent obstruction of the upper airway during sleep; it results in sleep fragmentation and excessive sleepiness (Pack 1994). It occurs in about 4% of middle-aged males and 2% of middle-aged females (Young et al. 1993) and produces a 2- to 7-fold increase in the rate of traffic crashes (George et al. 1987; Findley et al. 1988) (for review, see Findley et al. 1992). But sleep apnea is not expected to be more prevalent in the 20-25 year age group. In contrast, narcolepsy, a disease which can result in uncontrollable sleepiness and increased risk of crashes (Aldrich 1989), usually starts in adolescence or early adult life. But this is not a particularly common disease with a prevalence of the order of 0.067% (Dement et al. 1973).

The high rate of fall-asleep crashes in young drivers is probably the result of them being excessively sleepy due to sleep deprivation secondary to lifestyle. Studies of sleep patterns in adolescents show decreased total sleep time, later bedtimes, and an increased level of daytime sleepiness (Carskadon 1990).

The characteristics that we have described are for crashes in which the driver was judged to be asleep. But sleepiness, even in the absence of frankly being asleep, also degrades performance with reduced vigilance, slowed reaction times and attentional deficits (Dinges 1992). Thus, there may be many more crashes in which sleepiness plays a role than that described here. Sleepiness may contribute, therefore, to crashes attributed to loss of attention. Moreover, sleep deprivation markedly augments the impaired driving performance that results from alcohol ingestion (Roehrs et al. 1994). Thus, excessive sleepiness could play a much larger role in causing crashes than the number of fall-asleep crashes would imply. The actual scope of the problem will be difficult to assess since currently there is no simple test for the investigating officer to apply. A recent population survey in Finland suggests, however, that the problem is large in scope (Martikainen et al. 1992). Fifteen percent of the middle-aged population reported having fallen asleep driving at least once; 4.8% of males reported falling asleep more than five times; and 1.3% of the population reported an accident or mishap due to having fallen asleep while driving.

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the driver or as a conclusion derived from excluding other factors, e.g. excessive speed, etc. Given the
inexact nature of this determination, it can be argued
that it is unrealistic to expect police to determine
whether sleepiness contributes to a crash. This has
been the conclusion in New South Wales, Australia,
where it has been asserted that police accident reports
underestimate the scope of this problem (Fell 1994).
They have developed criteria to identify a crash as a
likely fall-asleep crash. These criteria have, however,
not been validated. Based on these criteria they
estimate that driver sleepiness accounts for 6% of all
crashes, 15% of fatal crashes and 30% of fatal crashes
on rural roads (Fell 1994). These estimates are higher
than those provided by the police accident reporting
system in the U.S.A. The Fatal Accident Reporting
System provides estimates that falling asleep while
driving accounts for 3-4% of fatal crashes. The diffi-
culty in determining the role of sleepiness in crashes
should not lead to the assumption that this is a minor
problem in traffic safety. Rather, it should lead to the
design of new approaches to investigating and deter-
mining the scope of this problem. This issue is dis-

Another important consideration about such
Crashes is whether there are effective countermeasures.
Both the public and medical profession are largely
unaware about sleep, sleep disorders and sleepiness
as alluded to in the recent report of the U.S. National
Commission on Sleep Disorders Research (1993
National Commission on Sleep Disorders Research
1993). Thus, increased awareness of this issue is an
important first step. The public need to understand
the risks involved and that these risks are enhanced
by factors that increase the physiological pressure for
sleep, i.e. driving at times of increased sleepiness (e.g.
night-time), after long periods of prior wakefulness,
or when the driver has had a less than adequate
amount of sleep in the previous 24-hour period. Apart
from increasing awareness, there are other more
specific approaches. Devices are being constructed to
alarm the driver before they fall asleep (Knipling and
Wierwille 1994). Another approach—use of rumble
strips—seems highly effective for one class of such
Crashes. These strips are deep grooves at the side of
the road which cause a loud noise if the car does drift
off the road. They have been used on various turn-
pikes and major roads. A recent synthesis of all
reports on the effectiveness of this countermeasure
concludes that they produce a 30–50% reduction in
drive-off-the-road crashes (Gärder and Alexander
1995). This is a low-cost solution with benefit-to-cost
ratios of the order of 20:1 to 200:1 depending on
assumptions employed in this analysis (Gärder and
Alexander 1995).

In conclusion, we have described here, in detail,
the characteristics of crashes attributed to the driver
being asleep. There are beginning to be data about
the effectiveness of countermeasures such as con-
tinuous shoulder rumble strips. Sleep disorders and
sleepiness are growing issues in traffic safety and there
is a need to better define the scope of the problem
related to sleepiness, to develop and evaluate effective
countermeasures, and to increase public awareness of
the issue.

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