THE ROLE OF DRIVER INATTENTION IN CRASHES; NEW STATISTICS FROM THE 1995 CRASHWORTHINESS DATA SYSTEM

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ABSTRACT

In 1995, NHTSA began employing the Crashworthiness Data System (CDS) to obtain more in-depth information on driver inattention-related crash causes, including drowsiness and many forms of distraction. CDS is potentially an important source of information on this issue because it is broadly representative of U.S. passenger vehicle towaway crashes and because its investigations are moderately in-depth. This research paper reports the results of the 1995 CDS data collection on this issue. The three major forms of driver inattention and their percent involvement in 1995 CDS crashes are: distraction (11.7%), looked but did not see (8.9%), and sleepy/fell asleep (3.1%). Findings from this CDS data collection have both similarities to, and differences from, previous research on the role of driver inattention in crashes.

Driver inattention, in its various forms, is probably the most prevalent cause of traffic crashes. The classic Indiana Tri-Level Study of the Causes of Traffic Accidents [Treat et al, 1979], perhaps the most in-depth study ever performed in the U.S. on crash causation, found that some form of “recognition failure” was involved in 56% of the in-depth crash cases analyzed. In the Indiana study, there were four principal forms of recognition failure: improper lookout (faulty visual surveillance, “looked but didn’t see”; 23%), “inattention” (preoccupation with competing thoughts; 15%), internal distraction (attention to competing event, activity, or object inside the vehicle; 9%), and external distraction (attention to competing event, activity, or object outside the vehicle; 4%). Driver drowsiness/fatigue or “asleep at the wheel” was classified separately under “critical non-performance” in the Indiana study causal factor taxonomy, and was a certain or probable factor in 2% of the cases.

Other more recent studies have corroborated the widespread role of inattention in crashes. Najm *et al* [1994] reported the results of a review of nearly 700 Crashworthiness Data System (CDS) and General Estimates System (GES) case files. In this study, experienced crash reconstructionists reviewed accident research case files and made a subjective determination of probable crash cause based on available information. The crash sample involved a variety of specific crash types, but was not wholly representative of these data files or of the national crash picture. Recognition errors were cited as the primary cause of 45 percent of the cases in the Najm *et al* sample; and additional 3.7 percent of these cases were identified as being caused primarily by driver drowsiness.

In an individual case review of 1,000 Michigan PARs by General Motors scientists [Deering, 1994] a combined 17 percent of the crashes were attributed to "daydreaming" and distraction. Improper lookout in right-of-way situations accounted for another 18 percent. One percent of sample crashes had the principal causal factor of "dozing."

Recent years have seen increased interest in driver inattention issues. To a great extent this has been due to the availability of new and more complex technologies in vehicles, including cellular phones, navigation systems and elaborate sound systems. Such devices have the potential to introduce or expand subsidiary task demands which can compete with the primary task of driving by increasing cognitive, motor and visual workload and thus degrade safety. Wierwille and Tijerina (1994) described a method for linking high visual demand created by various devices in vehicles to crash incidence using detailed police narratives from the State of North Carolina. By applying keyword searches and detailed review of almost 18,000 records, the authors were able to isolate inattention/distraction related crashes. Through further analysis by Wierwille in Tijerina (1995), a quantitative relationship between in-vehicle visual demand (weighted by in-vehicle device use) and crash incidence for those crashes identified earlier was developed. **Figure 1** presents results from the earlier study showing the number of crash cases from the 1989 North Carolina database attributed to driver inattention/distraction. These data are further subdivided into interior (in-vehicle) sources of distraction and dash/console/steering column distraction sources.

Figure 1. Crash Frequency Distribution by Sources of Attentional Distraction (Source: Wierwille and Tijerina, 1994)

Concurrent with the increased interest in driver inattention/distraction during the past few years, there has been increased public and scientific interest in driver drowsiness/fatigue/ ”asleep-at-the-wheel” as a driving safety concern [e.g., National Commission on Sleep Disorders Research, 1993]. NHTSA has published studies addressing the vagaries of determining drowsiness/fatigue as a factor in crashes [e.g., Knipling and Wang, 1994, 1995; Knipling, Wang, and Kanianthra, 1996] and providing agency estimates and characterizations of the problem.

NHTSA has recognized that available statistics on driver inattention, including drowsiness, are not definitive. This is primarily because studies to date have generally been based on samples of questionable representativeness (e.g., the Tri-Level Study, a study of crashes in rural/small town Indiana) and because Police Accident Report (PAR)-based data are generally superficial and not designed to provide a scientific determination of crash causation. Accordingly, in 1995 NHTSA began employing the National Accident Sampling System (NASS) Crashworthiness Data System (CDS) to obtain more in-depth information on driver inattention-related crash causes. A CDS data variable specifically addressed the role of driver inattention, including both drowsiness and many forms of distraction. This CDS data may be among the best available data yet gathered on this issue because the CDS is both broadly representative (of U.S. passenger vehicle towaway crashes) and because it is more in-depth than PARs since it includes driver interviews, crash scene inspection, and other supporting data sources. This research paper reports the results of the 1995 CDS data collection on this issue.

METHOD

The principal methodology employed in this study is statistical analysis of data from the 1995 CDS with emphasis on the new 1995 data variable named *Driver Distraction/Inattention to Driving* (DD/ID). CDS is one of the two major crash data systems of the NASS; the other is the General Estimates System (GES). There are 24 CDS field research teams that study about 5,000 towaway crash annually involving passenger vehicles; i.e., passenger cars, pickup trucks, and vans. Crash cases are selected for investigation based on a stratified random sampling scheme. The CDS data collection regimen includes review of the PAR, vehicle and crash site investigation, reconstruction of crash trajectories, interviews with drivers and other persons, and review of medical records to determine the nature and severity of crash injuries. Approximately 360 data variables relating to the crash, involved vehicles, and involved occupants are coded on standardized data forms. Two NASS Zone Centers review all CDS cases to ensure accuracy and consistency of data. The actual (unweighted) number of cases (crashes) in the 1995 data file was 4,551; these cases contained a total of 6,506 driver files. Consistent with the sampling methodology, each case is assigned a national weight (i.e., a number of crashes represented) based on its severity and its sampling location. The sum of these weights for any identified category of crashes is the national estimate for that category.

Data from the Driver Distraction/Inattention to Driving (DD/ID) variable were retrieved and compared to other important crash variables such as crash type, crash severity, hour of day, atmospheric condition (weather), and light conditions. The total Ns for these crash variables correspond to the estimated total number of passenger vehicle crashes represented by the data file (2,374,000). If any involved driver was coded as exhibiting some form of driver inattention, the whole crash was classified under that category. The implicit assumption was made that an inattention-related factor coded for an involved driver (e.g., distraction) was a principal causal factor in the crash. Crashes involving one "attentive" driver and one "unknown" driver were coded as "unknown." In order for a crash to be classified "attentive," all involved drivers had to be so classified.

Other variables examined related specifically to drivers (or their vehicles) as opposed to crashes. These included driver age, sex, pre-crash maneuver, and other variables relating to pre-crash events. The total Ns relating to these variables correspond to the estimated total number of crash-involved *drivers* represented by the data file (4,189,000). **[IN TABLE 6, WHY IS N= 2,965,000??????]**

The methodology also included comparison of the CDS statistics (which address towaway crashes only) to some similar statistics from the General Estimates System (GES), which samples the full population of police-reported (PR) passenger vehicle crashes (i.e., towaway plus non-towaway passenger vehicle crashes). The 1995 GES crash population includes approximately 6 million passenger vehicle crashes annually (as well as crashes involving other vehicle types such as heavy trucks). The principal difference between CDS and GES is the large number of low-severity non-towaway crashes represented in GES but not in CDS. These low-severity PR crashes differ from higher-severity (i.e., towaway) PR crashes in their causal factor profiles.

In the CDS data collection regimen, investigators completed a Driver Distraction/Inattention to Driving (DD/ID) variable along with other related crash variables on the basis of driver interviews, crash scene inspection, and other supporting data sources. These data constitute the results of this study.

RESULTS

Table 1 presents the weighted percentage involvement for each data element of the Driver Distraction/Inattention to Driving variable. The two data columns represent drivers and crashes, respectively. All percentages are rounded to the nearest 0.1% except that for "dialing cellular phone," which is rounded to the nearest 0.01%. The crash percentages were derived using the order of precedence rules described above. The weighted percentages may be applied to the total applicable populations of 1995 passenger vehicle towaway crashes (2,374,000) and involved drivers (4,189,000) to estimate the actual number of crashes or involved drivers for each factor. Two important caveats relating to the use of these statistics are that CDS represents towaway crashes only (not all PR crashes) and that categories with low percentages are likely to have relatively high random sampling variation.

Table 1. Percentage of CDS Crashes Involving Inattention/Distraction-Related Crash Causes

#	Data Element	% of Drivers	% of Crashes
01	Attentive or not distracted	46.5%	28.9%*
02	Looked but did not see	5.1%	8.9%
03	Distracted by other occupant [specified]	1.0%	1.8%
04	Distracted by moving object in vehicle [specified]	0.2%	0.3%
05	Distracted while talking or listening to cellular phone [location and type of phone specified]	0.1%	0.1%
06	Distracted while dialing cellular phone [location and type of phone specified]	0.03%	0.05%
07	Distracted while adjusting climate controls	0.1%	0.2%
08	Distracted while adjusting radio, cassette, CD [specified]	1.0%	1.8%
09	Distracted while using other device/object in vehicle [specified]	0.1%	0.2%
10	Sleepy or fell asleep	1.8%	3.1%
11	Distracted by outside person, object, or event [specified]	1.7%	2.7%
12	Eating or drinking	0.1%	0.2%
13	Smoking-related	0.1%	0.2%
97	Distracted/inattentive, details unknown	1.3%	2.3%
98	Other distraction [specified]	1.1%	1.9%
99	Unknown/No Driver	39.7%	47.4%

Weighted driver N = 4,189,000; weighted crash N = 2,374,000; * In order for a *crash* to classified "attentive," all involved drivers had to be classified "attentive."

Combining all driver inattention categories, it is estimated that 13.8% of driver involvements in 1995 passenger vehicle towaway crashes, and 23.8% of the crashes themselves, involved driver inattentiveness as a causal factor. These percentages must be regarded as conservative due to the high number of unknowns.

The statistics in Table 1 are perhaps most meaningful when they are aggregated into five categories: sleepy/fell asleep (10), distracted (data elements 03-09, 11-98), looked but did not see (02), unknown/no driver present (99,00), and attentive/not distracted (01). The Table 1 percentages for these five categories (driver and crash percentages, respectively) are sleepy/fell asleep (1.8%, 3.1%), distracted (6.9%, 11.7%), looked but did not see (5.1%, 8.9%), unknown/no driver present (39.7%, 47.4%), and attentive/not distracted (46.5%, 28.9%). A small but negligible number of crashes (7 cases) involved multiple drivers with distractions; e.g., one driver distracted by the radio/tape player and one driver distracted by an outside person, object, or event.

Bivariate comparison of these driver inattention-related factors to other crash variables yielded many insightful results. **Table 2** shows the DD/ID variable by crash type percentage distribution. Within each cell, the top percentage is the row percentage; the bottom percentage is the column percentage. Table 2 shows a relatively large role for sleepiness in rear-end/lead vehicle moving (RE/LVM) and single vehicle crashes. Distraction played its largest role in rear-end/lead vehicle stopped (RE/LVS), RE/LVM, and single vehicle crashes. The largest role for looked but did not see (LBDNS) was seen in RE/LVS, intersection/crossing path (I/CP), and lane change/merge (LCM) crashes.

Table 2. DD/ID by Crash Type

Crash Type Row % Column %	Sleepy	Distract	LBDNS	Unk.	Attentive	Total
Single Vehicle	5.3 50.3	16.0 40.4	0.2 0.7	29.5 18.0	49.0 50.1	100.0 29.5
Rear-End/LVM	23.2 45.3	16.4 8.8	2.9 2.0	44.3 6.1	13.3 2.9	100.1 6.4
Rear-End/LVS	0.3 1.1	23.0 23.8	18.9 25.1	45.7 12.3	12.0 5.0	99.9 12.2
Int/Cross Path	0.0 0.3	6.0 18.8	13.9 57.0	60.5 46.5	19.5 24.5	99.9 36.2
Lane Change/Merge	0.1 0.1	4.3 1.2	13.8 4.9	43.1 2.9	38.7 4.2	100.0 3.2
Head-On	1.0 1.2	7.8 2.4	5.0 2.0	50.5 3.8	35.7 4.4	100.0 3.6
Other	0.5 1.7	3.0 4.6	14.5 8.3	49.6 10.4	32.4 8.9	100.0 8.9

Total Crashes	3.1 100.0	11.7 100.0	8.9 100.0	47.4 100.0	28.9 100.0	100.0 100.0

Notes: N = 2,374,000; Abbreviations: LBDNS = Looked but did not see; LVM = lead-vehicle moving; LVS = lead-vehicle stopped; Int. = intersection, Unk. = unknown.

A bivariate comparison was made of the DD/ID variable to crash severity, measured here by the maximum abbreviated injury scale (MAIS) injury in the crash. No major trends were evident in the percentage involvement of drowsiness and distraction in crashes of various severity levels. LBDNS played a relatively larger role in crashes of lower severity than in those of higher severity (i.e., MAIS 4-6).

Table 3 shows the DD/ID variable by atmospheric condition (weather). In Table 3 and subsequent tables, individual data elements totaling less than 1.0% of the total were either aggregated into larger categories or were omitted. This is due to the problem of relatively high sampling errors for these low-frequency categories. For example, in Table 3 the categories “snow,” “hail,” and “sleet” were aggregated and the categories “fog” and “other” was omitted. Table 3 shows that crashes were less likely to be classified “attentive” when the crash occurred during clear weather. This may be due to drivers paying greater attention when weather conditions are adverse, and/or it could be that an inattention-related factor is more likely to stand out as a crash factor under clear weather conditions when there are fewer environmental factors to attributed.

Table 3. DD/ID by Atmospheric Condition

Condition Row% Column %	Sleepy	Distract	LBDNS	Unk.	Attentive	Total
Clear	3.2 82.3	12.3 85.9	9.6 88.2	49.6 84.9	25.3 71.2	100.0 81.3
Rain	3.2 14.2	8.4 9.9	5.0 7.7	39.9 11.6	43.5 20.6	100.0 13.7
Snow/Hail/Sleet	1.4 2.0	11.6 4.2	7.0 3.3	34.8 3.1	45.1 6.6	99.9 4.2
Total Crashes	3.1 100.0	11.7 100.0	8.9 100.0	47.4 100.0	28.9 100.0	100.0 100.0

Notes: N = 2,374,000; Crashes occurred under unknown weather (0.2% of all crashes) condition distributed proportionately; Fog-related conditions and “Other” (combined 0.8% of total) not shown.

Table 4 shows the DD/ID variable by roadway speed limit distribution. Sleepiness is heavily overrepresented on 65mph roadways. Distraction shows no major differences, while LBDNS plays its greatest role in crashes on low speed limit roadways. The overrepresentation of 65mph roadways in sleepiness-related crashes was characteristic of both single vehicle and RE-LVM crash types (not shown in Table 4).

Table 4. DD/ID by Roadway Speed Limit

Speed Limit (MPH) Row % Column %	Sleepy	Distract	LBDNS	Unk.	Attentive	Total
0-35	1.2 16.4	10.7 39.3	9.4 45.3	49.8 44.8	28.8 42.6	99.9 42.8
40-50	1.9 22.4	12.8 41.4	11.6 49.0	51.3 41.0	22.5 29.4	100.1 37.7
55-60	2.4 11.3	12.2 15.5	3.4 5.7	39.8 12.5	42.2 21.6	100.0 14.8
65 & Above	33.4 49.9	9.5 3.8	0.1 0.0	17.1 1.7	39.9 6.4	100.0 4.7
Total	3.1 100.0	11.7 100.0	8.9 100.0	47.4 100.0	28.9 100.0	100.0 100.0

Notes: N = 2,374,000; Crashes occurred at unknown speed limit (0.2%) roadways distributed proportionately.

Table 5 shows the DD/ID variable by alcohol involvement in the crash. Note that a crash was coded "alcohol involved" if any driver in the crash was judged by the reporting police officer to have used alcohol. No major trends are discernible except that LBDNS plays its greatest role in non-alcohol crashes. Almost by definition, LBDNS involves an *inadvertent* perceptual error by a driver. Thus, it is not surprising that it is less frequently cited in alcohol-involved crashes where the crash is more likely to be attributed to the alcohol itself or to some intentional unsafe act by the intoxicated driver.

Table 5. DD/ID by Alcohol Involvement

Alcohol Involved Row % Column %	Sleepy	Distract	LBDNS	Unk.	Attentive	Total
Yes	3.6 11.3	8.8 7.7	2.7 3.0	54.1 12.2	30.8 11.6	100.0 10.6

No	3.3 88.7	12.4 91.3	10.3 97.0	46.4 87.8	27.7 88.4	100.1 89.4
Total	3.1 100.0	11.7 99.0	8.9 100.0	47.4 100.0	28.9 100.0	100.0 100.0

Notes: N = 2,374,000, Crashes with unknown alcohol involvement (9.4%) distributed proportionately.

A further analysis of the role of alcohol in sleepiness-related crashes indicated a heavy alcohol involvement in single vehicle crashes (19.5% of all sleepiness-related single vehicle crashes) but a small role in sleepiness-related RE-LVM crashes (less than 1%). More than 90% of sleepiness-related/alcohol-involved single vehicle crashes occurred between 11:30pm and 6:30am.

Figure 2 shows the time-of-day distribution (three-hour rolling averages) for sleepy/asleep, distraction, LBDNS, and attentive crashes. Sleepy/asleep-at-the-wheel crashes peak in the early a.m. hours and have a second smaller mid-day peak. These data are consistent with past studies [e.g., Pack *et al*, 1995; Knipling and Wang, 1994] and expected fatigue-related crash frequencies based on human circadian rhythms [Office of Technology Assessment, 1991]. Both distraction-related and LBDNS crashes show a morning rush-hour peak and a late afternoon/evening peak. Crashes coded "attentive" have a wide peak beginning in the early afternoon and extending throughout the evening to midnight. Note that the Figure 2 statistics are not corrected for variations in mileage exposure by time-of-day (e.g., high exposure for morning and evening rush hours).

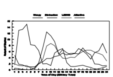

Figure 2. Time of Day Comparison; 3-Hour Rolling Averages

A crash type analysis of the sleepy/asleep crashes in Figure 2 indicated that the RE-LVM crashes occurred almost entirely at night (i.e., midnight to 6am) whereas the single vehicle roadway departure crashes had dual peaks in the late night/early morning and in the early afternoon.

A comparison of the incidence of DD/ID to driver age indicated that the 25-34 year-old age group was heavily overrepresented in sleepiness-related crashes. Fifty-seven percent of sleepy drivers were of this age group versus 23% of all CDS crash-involved drivers. Older drivers (age 65+) were slightly overrepresented in LBDNS crashes and significantly *under*represented in sleepiness-related crashes compared to their percentage involvement in all crashes. Of all the age groups, drivers aged 65+ were most likely to be coded "attentive."

Table 6 shows the DD/ID variable by the driver sex distribution. Sleepiness is apparent in a much larger percentage of the crash involvements of male drivers than those of female drivers -- indeed, the male percentage (3.8%) is seven times greater than the female percentage (0.5%). On the other hand, females were more than twice as likely as males to be cited for LBDNS (9.2% versus 3.7%). The N in Table 6 represents all towaway crash-involved passenger vehicle drivers. Thus it is higher than the Ns of previous tables, which represented crashes.

Table 6. DD/ID by Driver Sex

Driver Sex Row % Column %	Sleepy	Distract	LBDNS	Unk.	Attentive	Total
Male	3.8 91.4	8.8 62.5	3.7 37.0	32.0 63.5	51.6 57.2	99.9 59.2
Female	0.5 8.6	7.7 37.6	9.2 63.0	26.7 36.5	55.9 42.8	100.0 40.8
Total Drivers	2.5 100.0	8.5 100.1	5.9 100.0	30.3 100.0	52.8 100.0	100.0 100.0

Notes: N = 2,965,000; drivers with unknown driver sex (1.0% of all drivers) distributed proportionately.

Analysis of pre-crash movements indicated that 90% of sleepiness-related crash involvements had the precrash movement of "going straight," versus 51% of all crash involvements. The vehicle was negotiating a curve for 18% of distraction-related crash involvements, versus 11% of all crash involvements. The precrash movement was turning left in 33% of LBDNS crash involvements, versus 13% of all crash involvements.

Table 7 shows the DD/ID variable by attempted avoidance maneuver. Note in the "total" column to the right that only 35.2% of all CDS drivers were known to have attempted an avoidance maneuver before their crash; 36.5% made no avoidance maneuver and 28.3% were unknown. Among drivers who were sleepy or fell asleep, only 10.7% were known to have attempted an avoidance maneuver before impact.

Not surprisingly, attentive drivers were most likely to have attempted an avoidance maneuver. Nevertheless, nearly one-half (46.7%) of "attentive" drivers attempted no avoidance maneuver prior to impact.

Table 7. DD/ID by Attempted Avoidance Maneuver

Attempted Maneuver Row % Column %	Sleepy	Distract	LBDNS	Unk.	Attentive	Total
Yes	0.5 10.7	8.6 43.8	5.8 40.0	21.0 18.8	64.1 48.5	100.0 35.2
No	3.4 70.7	6.5 34.4	7.7 55.1	22.8 21.1	59.5 46.7	99.9 36.5
Unknown	1.2 18.6	5.3 21.7	0.9 4.9	84.6 60.1	8.0 4.9	100.0 28.3
Total Vehicles	1.8 100.0	6.9 100.0	5.1 100.0	39.6 100.0	46.6 100.0	100.0 100.0

Notes: N = 4,189,000.

DISCUSSION

As the name "Crashworthiness Data System" suggests, the CDS was not originally intended to collect crash causation data. Nevertheless, CDS appears capable of providing useful "medium depth" data on the driver inattention issue. This is because the CDS data collection regiment includes driver interviews addressing the crash scenario as well as other supporting investigative activities including vehicle inspection, scene inspection, and review of medical reports.

Regarding the critical dimension of sample representativeness, these CDS data are perhaps superior to those of other causal studies cited (e.g., Treat *et al*, 1979; Najm *et al*, 1995, Deering, 1994). CDS was specifically designed to be nationally-representative, and all the data from 1995 were used to ensure comprehensiveness. The one-year case total of 4,551 is higher than that of these other studies and the addition of data from future years will further increase the statistical reliability of the CDS data. On the other hand, the three cited studies included low-severity (non-towaway) PR crashes whereas the CDS data do not. The CDS statistics cited in this report should *not* be considered representative of the entire U.S. PR crash population. A comparison of the CDS crash sampling population and that of the GES illustrates this point. For 1995, only 35% of the PR crashes in GES would qualify as towaway passenger vehicle crashes for the CDS.

Notwithstanding the above differences in crash populations, a few comparisons and contrasts can be made between the results of this study and the other three causal factor studies cited. In general, the CDS results yielded somewhat lower percentages for the involvement of driver inattention in crashes than had the previous three cited studies. A notable specific difference between the current results and the Indiana findings was the high incidence of "preoccupation with competing thoughts" (e.g., “daydreaming”) in the latter. Fifteen percent (15%) of the Indiana in-depth cases were classified as having this factor as a certain or probable crash cause. No data element in the new CDS data specifically represented this cause, although such cases would presumably be classified under data element 97 ("distracted/ inattentive, details unknown") of the DD/ID variable. Only 2.3% of the CDS crashes were classified under this data element. NHTSA will consider modifying the DD/ID variable in the coming years to attempt to better capture competing thoughts/“daydreaming” as a crash cause.

The CDS sleepiness/asleep at the wheel percentage of 3.1% of crashes appears at first glance to be substantially greater than other recent NHTSA statistics on this issue. For the years 1989-93, 0.90% of GES cases were coded as having driver drowsiness/fatigue as a principal crash causal factor [Knipling and Wang, 1994]. Based on a case review of 1993 GES cases, NHTSA [Knipling and Wang, 1995] revised this estimate to a range between 1.2% and 1.6%. Statistics from the 1982-84 NASS Continuous Sampling Subsystem (CSS), a data system similar to the current CDS but representative of all PR crashes, indicated a percentage of 1.5% [Knipling and Wang, 1995]. Because of the differences in the crash sampling populations of the CDS and the data files representing all PR crashes (i.e., GES and the NASS CSS), the current CDS results can be compared to all-PR-crash statistics only by extrapolation. The authors performed this extrapolation by dissaggregating 1995 GES crashes into CDS-qualifying (35%) and CDS-non-qualifying (65%) crashes. Approximately 1.9% of the CDS-qualifying crashes in the 1995 GES were coded as drowsiness/fatigue related, as opposed to only 0.35% of the non-CDS-qualifying crashes. (This disparity is consistent with previous findings [e.g., Knipling and Wang, 1995] that the incidence of drowsiness/fatigue in PR crashes is strongly related to crash severity.) The drowsiness/fatigue percentage for all 1995 GES crashes was 0.91%. If one assumes that the current 3.1% CDS percentage is more valid than the CDS-qualifying 1995 GES percentage of 1.9% due to greater depth of investigation, and further that the difference (3.1%/1.9% = ~160%) can be extrapolated to all 1995 GES cases, one obtains a revised 1995 GES estimate of 1.5% of crashes. While each of these all-PR-crash estimates (1.5% from the 1982-84 NASS CSS, 1.2 to 1.6% from the case review of 1993 GES crashes, and 1.5% from the current study) might individually be regarded as tenuous, the high degree of concordance among these estimates from three different all-PR-crash data sources is remarkable, especially for a crash causal factor as nebulous as drowsiness/fatigue.

The most surprising aspect of the CDS data on the characteristics of sleepy/asleep-at-the-wheel crashes was the large number of RE-LVM crashes classified under this causal factor. Nearly one-half (45.3%) of the sleepy/asleep-at-the-wheel crashes were RE/LVM, and these crashes accounted for nearly one-fourth (23.2%) of all 1995 CDS RE/LVM crashes. These percentages are an order of magnitude higher than those reported in other recent studies of drowsy driver crashes [e.g., Knipling and Wang, 1994, Pack *et al*, 1995] and rear-end crashes [Najm *et al*, 1995, Wilson, 1995, Knipling *et al*, 1993]. This finding will be scrutinized in continuing NHTSA research.

Another surprising finding in the current study was the lack of a significant involvement of LBDNS, and inattention in general, in the crashes of older drivers. Indeed, drivers aged 65 and older were the age group most likely to be coded "attentive" in the current study. Past studies [e.g., Chovan *et al*, 1994; Fancher *et al*, 1994] have indicated a high involvement of LBDNS in the crashes of older drivers, especially in intersection/crossing path situations. The present study did find a high involvement of LBDNS in intersection/crossing path crashes (see Table 2) and in left-turn maneuvers, but did not find a significant over involvement of LBDNS for older drivers as a group.

The present CDS results yielded lower overall percentages for driver inattention than the Indiana study but much higher percentages than the North Carolina narrative data cited earlier. The North Carolina narrative data included only those crashes where property damage exceeded $500 or where there was personal injury -- criteria similar to the CDS. In the North Carolina narrative data only 1.5% of the crashes were identified as being related to inattention or distraction. In comparison, CDS attention/distraction-related crashes accounted for nearly one-quarter of the crashes. This suggests that where specific data collection elements such as "distracted" are not included in the PAR, significant underreporting will occur.

Although the percentages were very different, the *relative* magnitudes of several comparable sources of distraction were similar in the North Carolina study and the current study. Comparing Figure 1 to Table 1, four specific sources of distraction are directly comparable in the two studies: other occupant, radio/cassette/CD, climate controls, and cellular phone (talking or dialing). The relative percentages of these four sources of distraction were very similar between the two studies, with the first two factors appearing more frequently than the second two factors.

[MIKE: PARAGRAPH ON "COGNITIVE EQUIVALENCE" ISSUE; I.E., LBDNS COGNITIVELY EQUIVALENT TO DISTRACTION/INATTENTION????]

There was a high number of unknowns on the DD/ID variable: 39.4% of drivers and 47.4% of crashes. The latter percentage reflects in part the precedence rules established for classification of crash causes (e.g., a two-vehicle crash involving one attentive and one "unknown" driver was classified "unknown."). One analytical option would be to impute all the "known" percentages; that is, distribute all unknowns proportionately across the knowns. This procedure was not followed in the current analysis because there is no basis for assuming that the unknowns can be distributed proportionately. It is recognized that the conservative approach of not imputing results in probable undercounting of driver inattention in its various forms in the current study.

A special problem in crash causation research relates to the determination of the causes of *fatal* crashes. Most studies of fatal crash causation have indicated that this class of crashes has a different causal profile than do crashes in general. In particular, impaired driver states (e.g., alcohol, fatigue) and unsafe driving acts (e.g., speeding) are more frequently seen in fatal crashes than in crashes in general. Driver inattention-related causes (other than drowsiness) are probably relatively *less* prevalent in fatal crashes. However, this finding is difficult to confirm. It may simply reflect the *relative* salience of driver state/unsafe behavior-related causes versus driver inattention in fatal crashes. This issue is complicated by the frequent inability to interview the involved driver(s), who may be fatally-injured.

A more fundamental methodological limitation relates to crash investigation in general. Crash investigation is inherently a retrospective, reconstruction process rather than an empirical process. There are no "instant replays." Therefore, even the best and most in-depth crash investigations are, to some extent, conjectural. To supplement crash investigation data, NHTSA has developed a capability to use sophisticated, unobtrusive vehicle instrumentation suites to obtain *in situ* data on safety-related driver performance and behavior. The agency has designed and fabricated a prototype portable Data Acquisition System for Crash Avoidance Research (DASCAR) which employs miniature video cameras (of the driver and the roadway) and multiple measures of driving performance [Oak Ridge National Laboratory, 1995]. DASCAR-based studies will provide direct empirical data on many forms of driver inattention, including the three principal categories addressed in this report. Initial DASCAR studies will gather baseline data on normal driving, including data on driver alertness and attention. Later studies will determine the driver attentional correlates of performance-failure events, such as the longitudinal encroachment of the test vehicle to vehicles ahead in the same travel lane (i.e., a rear-end crash "near miss"). Such performance failure events would be identified using braking and headway detection sensors. Video recordings and other data would be used to classify the accompanying driver state (e.g., drowsy, distracted, apparently daydreaming, LBDNS, or fully attentive). DASCAR studies are not likely to capture significant numbers of crashes, but they will be capable of capturing many driver attentional errors associated with near misses, thus providing a new dimension of information relating to this important class of crash causes.

REFERENCES

Chovan, J.D., Tijerina, L., Pierowicz, J.A., and Hendricks, D.L. Examination of Unsignalized Intersection Straight Crossing Path Crashes and Potential IVHS Countermeasures. Report for Volpe National Transportation Systems Center, DOT HS 808 152, DOT-VNTSC-NHTSA-94-2, August, 1994.

Fancher, P., Kostyniuk, L., Massie, D., Ervin, R., Gilbert, K., Reiley, M., Mink, C., Bogard, S., and Zoratti, P. Potential Safety Applications of Advanced Technology. Technical Report Number FHWA-RD-93-080, January, 1994.

Knipling, R.R., Mironer, M., Hendricks, D.L., Tijerina, L., Everson, J., Allen, J.C., and Wilson, C. Assessment of IVHS Countermeasures For Collision Avoidance: Rear-End Crashes. NHTSA technical report, Publication Number DOT HS 807 995, May, 1993.

Knipling, R.R., and Wang, J.S. Crashes and Fatalities Related to Driver Drowsiness/Fatigue, NHTSA Research Note, November, 1994.

Knipling, R.R. and Wang, J.S. Revised Estimates of the U.S. Drowsy Driver Crash Problem Size Based on General Estimates System Case Reviews. *39th Annual Proceedings, Association for the Advancement of Automotive Medicine*, Chicago, October, 1995.

Knipling, R.R., Wang, J.S., and Kanianthra, J.N. Current NHTSA Drowsy Driver R&D. *Fifteenth International Technical Conference on the Enhanced Safety of Vehicles*, Melbourne, Australia, May, 1996.

Najm, W.G., Mironer, M., Koziol, J.S.Jr., Wang, J.S., and Knipling, R.R. Examination of Target Vehicular Crashes and Potential ITS Countermeasures. Report for Volpe National Transportation Systems Center, DOT HS 808 263, DOT-VNTSC-NHTSA-95-4, June, 1995.

National Commission on Sleep Disorders Research. Wake Up America: A National Sleep Alert; Executive Summary and Executive Report, U.S. Dept of Health and Human Services, January, 1993.

Oak Ridge National Laboratory. Data Acquisition System for Crash Avoidance Research, Paper Presented at ITS America NHTSA Peer Review Workshop, Baltimore, MD, December 11-12, 1995.

Office of Technology Assessment, U.S. Congress. Biological Rhythms: Implications for the Worker, OTA-BA-463, September, 1991.

Pack, A.I., Pack, A.M., Rodgman, E., Cucchiara, A., Dinges, D.G., and Schwab, C.W. Characteristics of Crashes Attributed to the Driver Having Fallen Asleep. Accid. Anal. and Prev., 1995.

Tijerina, L., Kiger, S. M., Rockwell, T. H., & Wierwille, W.W. Final Report supplement -- Task 5: Heavy Vehicle Driver Workload Assessment Protocol (DOT Contract DTNH22-91-C-07003) (in press), 1995.

Treat, J.R., Tumbas, N.S., McDonald, S.T., Shinar, D., Hume, R.D., Mayer, R.E., Stansifer, R.L., & Catellan, N.J. *Tri-Level Study of the Causes of Traffic Accidents: Final Report Volume I: Causal Factor Tabulations and Assessments*, Institute for Research in Public Safety, Indiana University, DOT Publication No. DOT HS-805 085, 1979.

Treat, J.R.[Indiana University], A study of precrash factors involved in traffic accidents. *The HSRI Research Review*, University of Michigan Highway Safety Research Institute [now UMTRI]. Vol. 10, No. 6/Vol. 11, No.1., 1980.

Wang, J.S. and Knipling, R.R. Single Vehicle Roadway Departure Crashes: Problem Size Assessment and Statistical Description, NHTSA technical report, Publication Number DOT HS 808 113, March, 1994.

Wierwille, W.W., & Tijerina, L., An Analysis of Driving Accident Narratives as a Means of Determining Problems Caused by In-vehicle Visual Allocation and Visual Workload. In A. Gale et al. (Eds.), Vision in Vehicles V. Amsterdam: North-Holland (in press), 1994.

Wilson, T., Bulter, W., McGehee, D.V. Dingus, T.A., IVHS Countermeasures for Rear-End Collisions, Driver Warning System Performance Guidelines. *ITS America Sixth Annual Meeting: Intelligent Transportation: Realizing the Benefits*, Houston, Texas, April 15-18, 1996.

TRASH:

Table 3. DD/ID by Crash Severity (MAIS)

Crash Severity Row % Column %	Sleepy	Distract	LBDNS	Unk.	Attentive	Total
MAIS 4-6 (Severe, Critical, Fatal)	3.8 1.3	11.1 1.0	2.8 0.3	68.5 1.6	13.8 0.5	100.0 1.1
MAIS 3 (Serious)	3.9 3.0	7.0 1.4	11.3 3.0	45.0 2.3	32.7 2.6	99.9 2.4
MAIS 2 (Moderate)	3.5 6.0	12.2 5.5	14.1 8.4	36.9 4.2	33.2 6.1	99.9 5.3
MAIS 1 (Minor)	2.7 35.9	11.3 39.8	9.1 42.2	49.9 43.9	26.9 38.2	99.9 41.3
MAIS 0 (No Injury)	3.7 53.1	12.8 48.9	8.9 44.7	40.9 49.9	33.7 51.8	100.0 44.9
Injured, Unknown Severity	0.5 0.8	8.0 3.4	2.5 1.4	84.5 9.0	4.5 0.8	100.0 5.0
Total Crashes	3.1 100.1	11.7 100.0	8.9 100.0	47.4 110.9	28.9 100.0	100.0 100.0

Notes: MAIS = Maximum Abbreviated Injury Scale injury in the crash;
Notes: N = 2,374,000; “Unknown if injured” (0.9% of total) distributed proportionately; MAIS 4-6 aggregated due to small Ns.

Table 5 shows the DD/ID variable by light condition. Not surprisingly, sleepiness plays its greatest role under dark conditions. Distraction shows no major differences, while LBDNS plays its greatest role during daylight conditions.

Table 5. DD/ID by Light Condition

Light Condition Row % Column %	Sleepy	Distract	LBDNS	Unk.	Attentive	Total
Daylight	1.6 33.4	12.3 66.7	12.0 85.7	48.4 64.2	25.7 56.1	100.0 63.2
Dark	2.6 10.8	7.5 8.3	1.3 2.0	35.5 9.8	53.1 23.9	100.0 13.0

Dark But Lighted	8.4 54.4	12.2 21.3	4.3 9.8	52.2 22.5	22.9 16.2	100.0 20.4
Dawn/Dusk	1.4 1.4	13.2 3.6	6.9 2.5	47.5 3.5	31.0 3.8	100.0 3.5
Total	3.1 100.0	11.7 99.9	8.9 100.0	47.4 100.0	28.9 100.0	100.0 100.1

Notes: N = 2,374,000

Table 8 shows the DD/ID variable by the driver age distribution. For this and subsequent tables, the total N is all towaway crash involved passenger vehicle drivers. Thus these Ns are greater than the crash Ns presented in previous tables. Sleepiness is overrepresented in the crashes of 25-34 year-old drivers. Of all age groups, drivers aged 65 and older were most likely to be coded "attentive."

Table 8. DD/ID by Driver Age

Driver Age Row % Column %	Sleepy	Distract	LBDNS	Unk.	Attentive	Total
15-24	1.3 17.8	8.3 32.1	6.8 38.1	28.9 32.4	54.6 33.9	99.9 33.1
25-34	6.1 57.0	8.5 23.1	6.1 24.0	30.0 23.7	49.3 21.7	100.0 23.4
35-54	1.9 20.7	10.1 32.5	4.5 20.9	33.3 31.1	50.2 26.1	100.0 27.7
55-64	1.2 2.5	5.2 3.1	6.8 5.9	37.5 6.6	49.4 4.8	100.1 5.2
65 and Older	0.5 2.0	7.5 9.2	6.3 11.2	17.1 6.1	68.6 13.6	100.0 10.5
Total Drivers	2.5 100.0	8.5 100.0	5.9 100.1	30.3 99.9	52.8 100.1	100.0 99.9

Notes: N = 2,965,000; drivers with unknown driver age (1.3% of all drivers) distributed proportionately.

Table 10. DD/ID by Common Pre-Crash Movements

Driver Sex Row % Column %	Sleepy	Distract	LBDNS	Unk.	Attentive	Total
Going Straight	3.2 90.4	8.2 60.4	4.8 47.7	40.8 52.3	43.1 47.0	100.1 50.8
Decelerating	0.0 0.0	5.2 3.2	0.4 0.3	38.2 4.1	56.2 5.1	100.0 4.2
Stopped	0.0 0.0	1.0 1.6	0.2 0.5	39.5 10.9	59.3 13.8	100.0 10.9
Turning Left	0.0 0.1	5.8 11.2	12.8 33.4	33.0 11.2	48.5 13.9	100.1 13.4
Negotiating Curve	1.4 8.7	11.3 18.2	0.8 1.8	33.8 9.5	52.7 12.6	100.0 11.1
Total Vehicles	1.8 100.0	6.9 100.0	5.1 100.0	39.6 100.0	46.6 100.0	100.0 100.0

Notes: N = 4,189,000.