

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

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Note to readers: The statistics cited in this version of the paper differ very slightly from the those published in the Conference Proceedings went to press, several minor errors were found in the 1995 CDS data file. These included, for example, a small number of duplicate cases. The current version is based on analysis of the corrected data files. Thus, the statistics in this version should be cited in preference to those in the proceedings version. We regret any possible confusion or inconvenience caused by this

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 (13.3 %), looked but did not see (9.7 %), and sleepy/fell asleep (2.6 %). 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 indepth 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* [1995] reported the results of a review of nearly 700 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; an 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 Police Accident Reports (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.

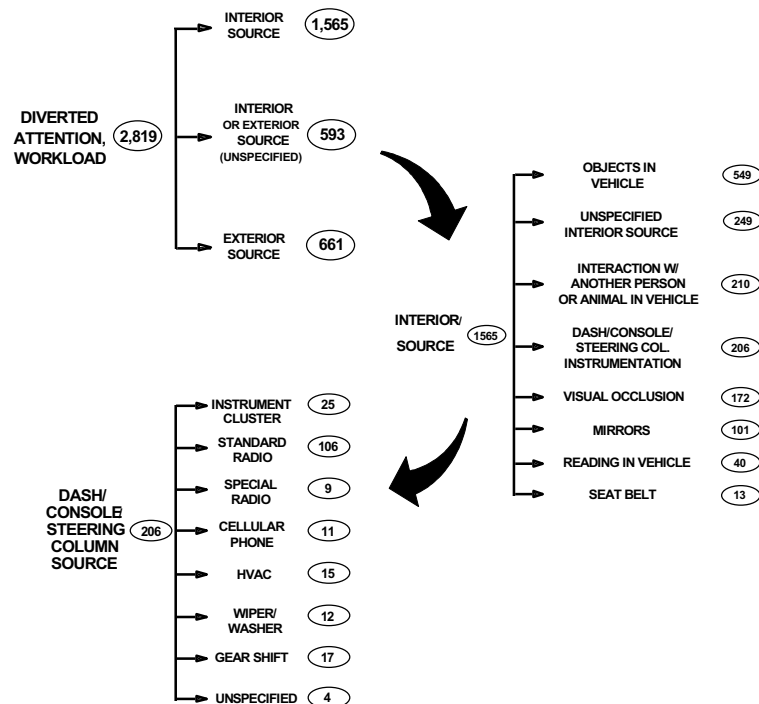


Figure 1. Crash Frequency Distribution by Sources of Attentional Distraction (Source: Wierwille and Tijerina, 1994)

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 Kaniyanthra, 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) 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 GES. There are 24 CDS field research teams that study about 5,000 towaway crashes 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 process 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 in the 1995 CDS was 4,536 crash files; 6,491 driver files (all drivers of towed-away vehicles), and 7,943 vehicle files (all involved vehicles/drivers). 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. Like any statistical sample, CDS estimates have sampling errors. A guide to determining these errors is provided in the CDS data report [NHTSA, 1995].

Data from the 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 roadway speed limits. The total population for these crash variables correspond to the estimated total number of passenger vehicle crashes represented by the data file (2,619,000). A key precedence rule of the analysis was that 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. For drivers age and sex, the total population corresponds to the estimated number of towed-away passenger vehicles (3,365,000). For pre-crash attempted avoidance maneuver, the total population corresponds to all involved vehicles/drivers (4,627,000).

The methodology also included comparison of the CDS statistics (which address towaway crashes only) to some similar statistics from 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 process, investigators completed a 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 DD/ID variable. The two data columns represent drivers and crashes, respectively. All percentages are rounded to the nearest 0.1 % . 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 (2,619,000) and involved drivers (4,627,000) 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.

Combining all driver inattention categories, it is estimated that 14.9% of driver involvements in 1995 passenger vehicle towaway crashes, and 25.6 % 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 and the difficulties of identifying pre-crash driver attentional lapses post crash.

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

Data Element	% of Drivers	% of Crashes
Attentive or not distracted	46.6%	28.4%
Looked but did not see	5.6%	9.7%
Distracted by other occupant [specified]	0.9%	1.6%
Distracted by moving object in vehicle [specified]	0.3%	0.5%
Distracted while dialing, talking, or listening to cellular phone [location and type of phone specified]	0.1%@	0.1%@
Distracted while adjusting climate controls	0.2%@	0.3%@
Distracted while adjusting radio, cassette, CD [specified]	1.2%	2.1%
Distracted while using other device/object in vehicle [specified]	0.1%	0.2%
Sleepy or fell asleep	1.5%	2.6%
Distracted by outside person, object, or event [specified]	2.0%	3.2%
Eating or drinking	0.1%	0.2%
Smoking-related	0.1%	0.2%
Distracted/inattentive, details unknown	1.5%	2.6%
Other distraction [specified]	1.3%	2.2%
Unknown/No Driver	38.5%	46.0%

Weighted driver N = 4,627,000 (7,943, unweighted); weighted crash N = 2,619,000 (4,536); In order for a crash to be classified "attentive," all involved drivers had to be classified "attentive." @ - estimate based on 5-9 cases.

The statistics in Table 1 are perhaps most meaningful when they are aggregated into five categories: sleepy/fell asleep, distracted, looked but did not see, unknown/no driver present, and attentive/not distracted. The Table 1 percentages for these five categories (driver and crash percentages, respectively) are sleepy/fell asleep (1.5 % , 2.6 %), distracted (7.8 % , 13.3%), looked but did not see (5.6 % , 9.7 %), unknown/no driver present (38.5 % , 46 %), and attentive/not distracted (46.6 % , 28.4 %). A small 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. In Table 2 and subsequent tables, cells containing 4 or fewer CDS are indicated by a *. This is regarded as too few cases to support a stable percentage estimate. Those containing 5-9 cases are indicated by the @ symbol. These percentage are given but should be interpreted with caution due to the small N.

Table 2. DD/ID by Crash Type

Crash Type Row % Column %	Sleepy	Distract	LBDNS	Unk.	Attentive	Total
Single Vehicle	5.8	18.1	0.2	31.8	44.0	99.9
	66.8	41.2	0.7	20.6	47.0	30.3
Rear-End/LVM	@ 12.7	21.3	@ 3.4	48.3	14.3	100.0
	27.9	9.6	2.0	6.4	3.0	6.0
Rear-End/LVS		23.9	11.4	52.6	11.8	100.0
	*	21.9	13.8	14.1	5.0	12.2
Int/Cross Path		7.0	17.9	52.8	22.3	100.0
	*	18.1	63.6	39.8	27.2	34.5
Lane Change/Merge		5.6	17.2	41.8	35.3	100.0
	*	1.6	6.7	3.4	4.7	3.8
Head-On	1.0	7.0	8.1	46.4	37.5	100.0
	1.7	2.2	3.5	4.3	5.6	4.2
Other		7.8	10.4	57.3	24.0	100.0
	*	5.4	9.8	11.4	7.6	9.1
Total Crashes	2.6	13.3	9.7	46.0	28.4	100.0
	100.0	100.0	100.1	100.1	100.1	100.1

Notes: N = 2,619,000 (4,536 unweighted); Abbreviations: LBDNS = Looked but did not see; LVM = lead-vehicle moving; LVS = lead-vehicle stopped; Int. = intersection, Unk. = unknown/ no driver. * = too few cases to make a stable estimate. @ = estimate based on 5-9 cases.

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 46).

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" were 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	2.6	14.1	10.6	46.7	25.9	99.9
	80.3	85.6	88.7	81.8	73.4	80.6
Rain	2.8	9.8	5.4	46.0	36.0	100.0
	14.2	10.0	7.5	13.6	17.1	13.5
Snow/Hail/Sleet		11.3	6.6	37.6	42.9	100.0
	*	4.4	3.6	4.3	7.9	5.2
Total Crashes	2.6	13.3	9.7	46.0	28.4	100.0
	100.0	100.0	100.0	100.0	100.0	100.0

Notes: N = 2,619,000 (4,536, unweighted); 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. * = too few cases to make a stable estimate

Table 4 shows the DD/ID variable by roadway speed limit distribution. Sleepiness is heavily over represented on 65mph roadways. Distraction shows no major differences, while LBDNS plays its greatest role in crashes on low speed limit roadways.

Table 4. DD/ID by Roadway Speed Limit

Speed Limit (MPH) Row % Column %	Sleepy	Distract	LBDNS	Unk.	Attentive	Total
0-35	1.3	12.2	9.7	48.9	27.8	99.9
	21.4	39.5	42.6	45.5	42.1	42.9
40-50	1.9	14.2	12.3	46.3	25.4	100.1
	26.2	39.7	46.7	37.6	33.1	37.1
55-60	2.3	14.0	6.6	42.1	35.1	100.1
	14.0	16.6	10.7	14.6	19.6	15.8
65 & Above	24.4	13.3		26.5	35.7	99.9
	38.4	4.2	*	2.4	5.2	4.1
Total Crashes	2.6	13.3	9.7	46.0	28.4	100.0
	100.0	100.0	100.0	100.1	100.0	99.9

Notes: N = 2,619,000(4,536, unweighted); Crashes occurred at unknown speed limit (0.1%) roadways distributed proportionately. * = too few cases to make a stable estimate.

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	4.0	9.9	3.1	59.1	24.0	100.1
	15.2	7.8	3.2	14.2	8.9	10.7
No	2.6	14.0	11.2	42.9	29.3	100.0
	84.8	92.2	96.8	85.8	91.1	89.3
Total Crashes	2.6	13.3	9.7	46.0	28.4	100.0
	100.0	100.0	100.0	100.0	100.0	100.0

Notes: N = 2,619,000 (4,536, unweighted); Crashes with unknown alcohol involvement (9.2%) distributed proportionately.

A further analysis of the role of alcohol in sleepiness-related crashes indicated a heavy alcohol involvement in single vehicle crashes (19.0% of all sleepiness-related single vehicle crashes) but a small role in sleepiness-related RE-LVM crashes (less than 1%). About 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, LEDNS, 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; Knippling and Wang, 1994] and expected fatigue-related crash frequencies based on human circadian rhythms [Office of Technology Assessment, 1991]. Both distraction related and LEDNS 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 even though 3-hour rolling averages are used, some of the trends seen in the Figure 2 are based on very small Ns for the individual time-of-day values. Note also 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).

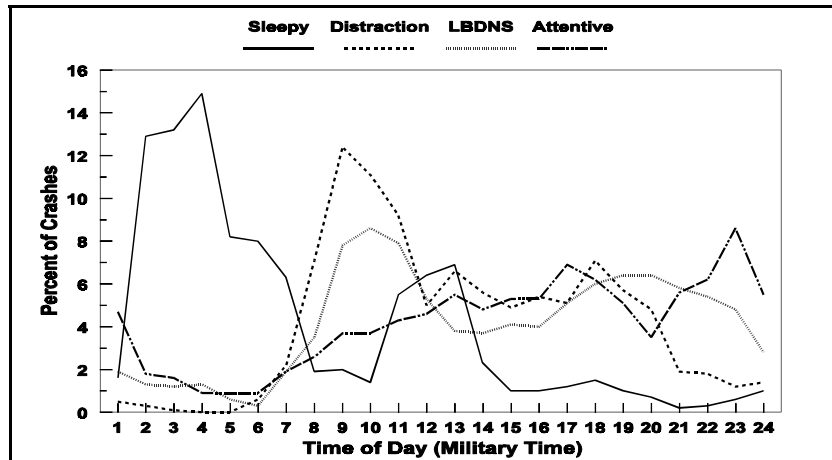


Figure 2. Time of Day Comparison; 3-Hour Rolling Averages

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 (of drivers of towed-away vehicles) indicated that the 25-34 year-old age group was heavily over represented in sleepiness-related crashes. Forty percent of sleepy drivers were of this age group versus 24 % of all CDS drivers of towed-away vehicles. Older drivers (age 65 +) were slightly over represented in LEDNS crashes and sharply under represented in sleepiness-related crashes compared to their percentage involvement in all crashes (although the sleepiness finding was based on only 9 cases). 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 (3.1 %) is five times greater than the female percentage (0.6 %). On the other hand, females were about twice as likely as males to be cited for LEDNS (8.6 % versus 4.9 %). 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.

Driver Sex Row % Column %	Sleepy	Distract	LBDNS	Unk.	Attentive	Total
Male	3.1 87.3	10.0 60.2	4.9 43.1	33.5 62.2	48.5 53.9	100.0 57.0
Female	0.6 12.7	8.7 39.8	8.6 56.9	27.0 37.8	55.1 46.1	100.0 43.0
Total Drivers	2.0 100.0	9.6 100.0	6.4 100.0	31.1 100.0	50.8 100.0	99.9 100.0

Notes: N = 3,365,000 (6,491, unweighted); drivers with unknown driver sex (1.0% of all drivers) distributed proportionately.

Table 6. DD/ID by Driver Sex

Analysis of pre-crash movements indicated that 86 % of sleepiness-related crash involvements had the precrash movement of "going straight," versus 49 % of all crash involvements. The vehicle was negotiating a curve for 21 % of distraction-related crash involvements, versus 12 % of all crash involvements. The precrash movement was turning left in 39 % of LEDNS crash involvements, versus 12 % of all the crash involvements.

Table 7 shows the DD/ID variable by attempted avoidance maneuver. Note in the "total" column to the right that only 34.2 % of all CDS drivers were known to have attempted an avoidance maneuver

before their crash; 37.2 % made no avoidance maneuver and 28.6 % were unknown. Among drivers who were sleepy or fell asleep, only 13.5 % 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 (45.8 %) 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	0.6 13.5	10.2 45.0	5.6 33.8	17.2 15.4	66.4 48.8	100.0 34.2
No	2.5 62.2	8.3 39.6	9.2 60.7	22.6 22.0	57.4 45.8	100.0 37.2
Unknown	1.3 24.3	4.2 15.4	1.1 5.5	84.7 62.6	8.7 5.3	100.0 28.6
Total Vehicles	1.5 100.0	7.8 100.0	5.6 100.0	38.5 100.0	46.6 99.9	100.0 100.0

Notes: N = 4,627,000 (7,943, unweighted).

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 process 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; Naja 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 4,536 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 2.6 % 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 2.6 % 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 disaggregating 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 2.6 % 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 ($2.6 / 1.9 \% = 140 \%$) can be extrapolated to all 1995 GES cases, one obtains a revised 1995 GES estimate of 1.3 % 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 1.3 % 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.

A 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 30 % the sleepy/sleep-at-the-wheel crashes were RE/LVM, and these crashes accounted for 13 % of all 1995 CDS RE/LVM crashes. These proportions are much higher than those reported in other recent studies of drowsy driver crashes [e.g., Knippling and Wang, 1994; Pack et al, 1995] and rear-end crashes [Najm et al, 1995; Wilson, 1995; Knippling et al, 1993]. However, this finding was based on a very small N of only 8 cases and thus must be verified by further research.

Another surprising finding in the current study was the lack of a significant involvement of LEDNS, 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 LEDNS in the crashes of older drivers, especially in intersection/crossing path situations. The present study did find a high involvement of LEDNS in intersection/crossing path crashes (see Table 2) and in left-turn maneuvers, but did not find a significant over involvement of LEDNS 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.

Nearly one-half of "attentive" drivers did not attempt an avoidance maneuver prior to impact. This result is somewhat surprising in view of the what would be expected from an attentive driver. While one explanation is that for these drivers there was not enough time to

respond to an imminent crash, another is that the "attentive" category in the CDS data includes some degree of inattention or distraction that is not being captured in the data coding process under the category "distracted/inattentive, details unknown." This notion is supported by the unexpected finding that drivers aged 65 and older were more likely coded in the "attentive" category. In examining the coding criteria it would appear that one element not specifically addressed is "cognitive" inattention/distraction, a category comparable to the Indiana category of "preoccupation with competing thoughts" mentioned earlier. Indeed, the former is not addressed by the LEDNS data element since these crashes involve drivers actively looking but missing conflict vehicles or objects. Hence the possibility that "cognitive" distraction/inattention (e.g., daydreaming) is not being reported or identified as such in the data may be a possible explanation for what may be substantial under reporting of attention/distraction related crashes. One exception to this is talking on a cellular phone where cognitive loading may be a factor. In the future, CDS data collection will specifically attempt to address the issue of cognitive inattention/distraction.

There was a high number of unknowns on the DD/ID variable: 38.2 % of drivers and 45.7 % 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, LEDNS, 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

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

Deering, R.K., General Motors Safety Center. Crash avoidance technologies to assist the driver, Presentation at the American Society of Civil Engineers Conference *Innovations in Highway Safety -- A Broad Perspective*, May 17, 1994.

Fancher, P., Kostyniuk, L., Massie, D., Ervin, R., Gilbert, K., Reiley, M., Mink, C., Bogard, S., and Zoratf, 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 Kaniathra, 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.D., 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-NTSC-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.

National Highway Traffic Safety Administration. National Accident Sampling System Crash worthiness Data System 1991-1993, DOT HS 808 298, August, 1995.

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, OAT-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.*, 27, 769-775, 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.

Wang, J.S.D. 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.