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DEPARTMENT OF MOTOR VEHICLES

Teen and Senior Drivers

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This report updates statistical information on California teen and senior drivers as published in earlier reports prepared by the California Department of Motor Vehicles: *Teen Driver Facts* (Huston, 1986), *Senior Driver Facts* (Huston & Janke, 1986), and *Teen and Senior Drivers* (Romanowicz & Gebers, 1990; Gebers, Romanowicz, & McKenzie, 1993; Aizenberg & McKenzie, 1997 [with the Beverly Foundation]). The information is meant to assist highway safety administrators in making program and policy decisions affecting teen and senior drivers, and may also be of use to the insurance industry, traffic safety researchers, and the general public.

The report also summarizes international research on the driving safety and driving-related abilities of teen and senior drivers, and on accident countermeasures for these two groups.

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PREFACE AND ACKNOWLEDGMENTS

This report updates information on teenaged and senior drivers previously published in a series of earlier California Department of Motor Vehicles (DMV) reports, one of which was prepared in collaboration with the Beverly Foundation of Pasadena, California. The primary purpose of these reports has historically been to provide traffic safety administrators and legislators with useful information for formulating policy and law. A very important secondary purpose is to provide information on teenaged and senior drivers (in the context of the general driving population) to the insurance industry, to researchers in the field of highway safety, and to the general public.

The relationship between age and driving record has been explored for many years by numerous researchers, often under the auspices of the National Highway Traffic Safety Administration. These investigations have frequently been based on data from the national Fatality Analysis Reporting System (formerly Fatal Accident Reporting System), in which fatal accident rates for various age groups are expressed per person (driver or not) within age group, using census data. Probably one reason for this is that, where national age-group rates have been computed per driver rather than per person, they are subject to error due to unreliability of age-group driver license counts in some states (Federal Highway Administration, 1991). But a drawback of using per-person rates is that not all of the people in the denominator are drivers, and the percentage who are drivers will vary with age. California driver license counts are relatively accurate (bearing in mind that people who are licensed do not necessarily drive, and that not all those driving on the road are licensed), so the present report gives incident rates per licensed driver as well as incident rates per driver per mile driven, using Nationwide Personal Transportation Survey data for California residents of various ages to estimate mileage as a function of age.

For accident and violation data, the present report is based on two primary sources of driver record information: (1) DMV's California driver record file, and (2) California Highway Patrol's accident record database (Statewide Integrated Traffic Records System, or SWITRS).

The authors would like to acknowledge the contributions of the following individuals and agencies to this project. For the SWITRS data used in the report, the authors wish to extend special thanks to Bev Christ and Doris Gibson of the Management Information Section, California Highway Patrol. Our appreciation also goes to Elizabeth Hoag and Nicola Standish of the Department of Finance for providing California population numbers and projections, and to Bonnie Collins of the Department of Justice for providing counts of DUI and hit-and-run arrests. This study was conducted under the supervision of Robert Hagge, Research Manager II; Cliff Helander, Chief of the Research and Development Branch, provided general direction to the project.

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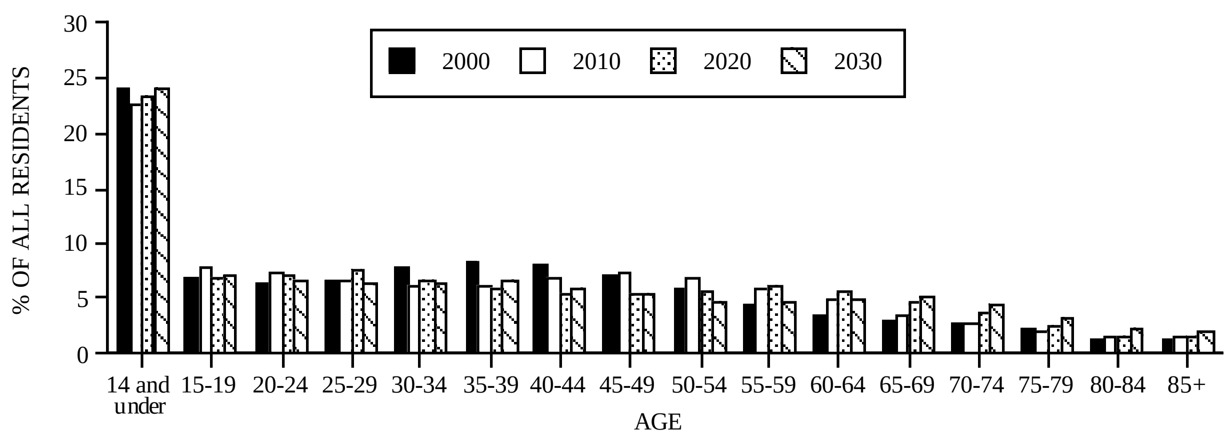
CALIFORNIA TRAFFIC DATA

California Driver Population

The relationship between age and driving behavior has interested highway safety researchers and administrators for many years. It is generally acknowledged that the greatest risk of accidents is among teenaged drivers. Although teenagers represent the greatest safety problem because of their exceptionally high crash liability, senior drivers are also at increased risk compared to those in the middle age range. The number and visibility of senior drivers' accidents can be expected to rise with growth in the older population (Williams & Carsten, 1989), increases in the percentage of older people who are licensed to drive (McKelvey & Stamatiadis, 1989), and higher mileage for older drivers (Federal Highway Administration [FHWA], 1999). According to researchers from the Insurance Institute for Highway Safety (Lyman, Ferguson, Braver, & Williams, 2002), by 2030 the number of involvements in police-reported motor vehicle crashes among senior drivers in the U.S. is expected to increase by almost 180%, while their fatal involvements may increase by over 150%. Yet these drivers—who will largely come from the baby-boom generation—will still be underrepresented in crashes relative to their number in the population, the authors stated.

Figure 1 shows actual (as of 2000) and projected (predicted) age distributions for the California population in the years 2000, 2010, 2020, and 2030 (California Department of Finance [DOF], 2000). Over the next 30 years the population percentage of seniors is expected to increase in California as elsewhere, and by 2030 almost 27% of the population is projected to be 55 or older, with 17% aged 65 or older. All of the baby boomers will be in that 17%, since the oldest members of the cohort will turn 84 in 2030 and the youngest members will turn 66.



Note. From California Department of Finance, 2000, *Population Projections by Race/Ethnicity for California*.

Figure 1. Age groups' actual and projected percentages of California population.

An increase in the proportion of older people living in suburban or rural areas, where distances to stores and other services are relatively great and public transportation is either inconvenient or unavailable, has increased the need among seniors for usable, affordable, convenient transport (Transportation Research Board [TRB], 1988). Closely linked to the convenience factor, for people of any age, is the greater independence from others' schedules that is afforded by driving oneself. The TRB publication noted that this has contributed to an increase in commuters driving alone in their vehicles, as opposed to carpooling, and also to the number of senior drivers on the road. It commented that:

> *Mobility is essential to the quality of life of older persons, and the automobile is the primary means of meeting that mobility need. More than 80 percent of trips by those 65 and over are made in automobiles today [i.e., 1988], and this percentage is increasing* (p. 3).

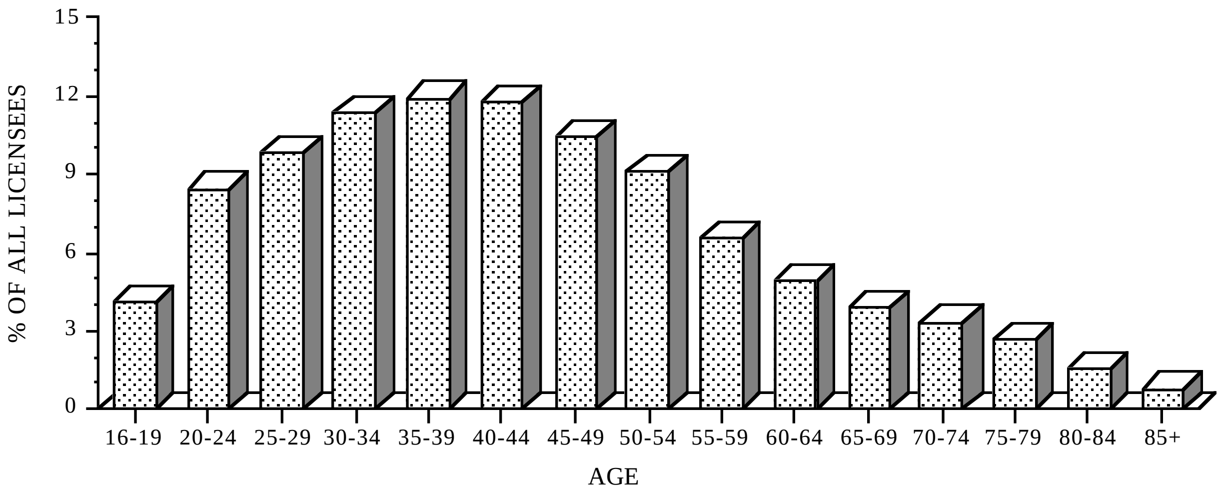
Table 1

Percentage of Licensed Drivers by Age and Sex

		Men		Women	
Age	Percent of all licensees	Percent of all male licensees	Percent of all licensees	Percent of all female licensees	Percent of all licensees
16	0.42	0.41	0.21	0.44	0.21
17	0.82	0.82	0.42	0.82	0.39
18	1.26	1.30	0.67	1.23	0.59
19	1.55	1.57	0.81	1.53	0.74
16-19	4.05	4.09	2.12	4.02	1.94
20-24	8.39	8.38	4.34	8.41	4.06
25-29	9.82	10.00	5.18	9.64	4.65
30-34	11.35	11.67	6.04	11.01	5.31
35-39	11.92	12.08	6.25	11.74	5.66
40-44	11.69	11.70	6.06	11.67	5.63
45-49	10.40	10.32	5.34	10.48	5.05
50-54	9.05	8.91	4.61	9.21	4.44
55-59	6.51	6.50	3.37	6.53	3.15
60-64	4.88	4.85	2.51	4.91	2.37
65-69	3.85	3.82	1.98	3.89	1.88
70-74	3.27	3.16	1.64	3.39	1.64
75-79	2.60	2.44	1.26	2.78	1.34
80-84	1.48	1.40	0.72	1.57	0.76
85 +	0.71	0.68	0.35	0.75	0.36
All ages	100.00	100.00	51.77	100.00	48.23

Note. Licensing data for 2000 are from California Department of Motor Vehicles, January 2001, *Age and Sex Report*, Sacramento, CA.

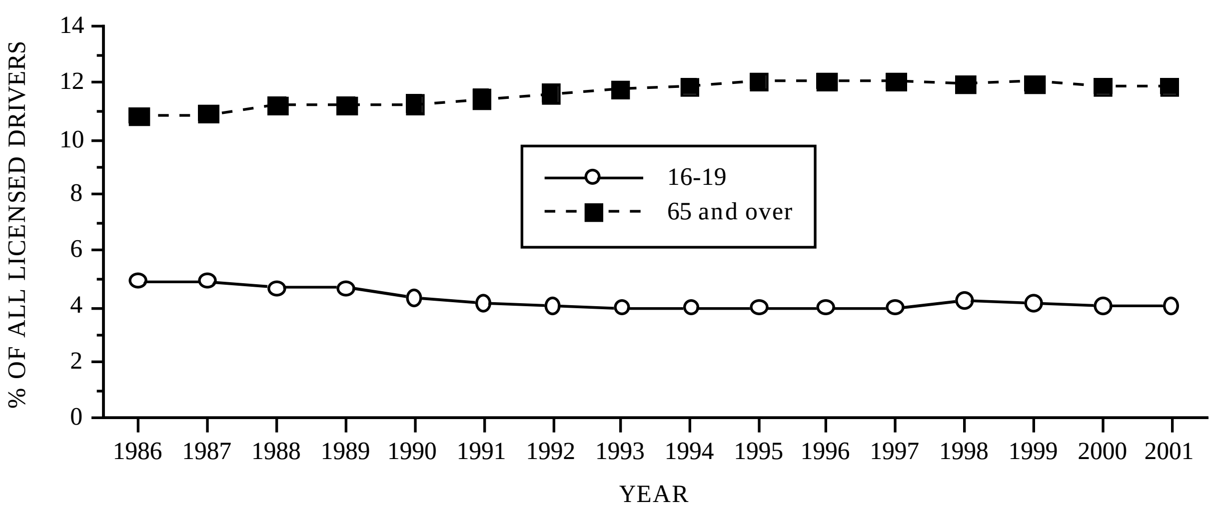
Figure 1 showed age groups' percentages of the population, not percentages of drivers. Table 1 gives, for the year 2000, the number of licensed drivers in each age group as a percent of all California licensed drivers. These data are plotted in Figure 2. They were derived from a randomly selected 10% sample of the driving records of all individuals holding California driver licenses (California Department of Motor Vehicles [DMV], 2001). (Records are also kept for people with only instruction permits, but they are not included in these counts.) Of drivers licensed in 2000, 4.1% were teenagers and 11.9% were seniors—that is, people aged at least 65.



Note. Licensing data for 2000 are from California Department of Motor Vehicles, January 2001, *Age and Sex Report*, Sacramento, CA.

Figure 2. Licensees in age group as a percentage of all California licensed drivers.

Figure 3 shows, by year, the volumes of teenaged and senior drivers as percentages of the total licensed driver population over the years 1986 through 2001. The data are from the database of driving records for all California licensed drivers (California Department of Motor Vehicles, 1986-2001). Between 1986 and 2001, seniors' share of the licensed driving population increased from 10.8% to 11.8% and teenagers' share decreased from 5.0% to 4.1%.



Note. Licensing data for 1986 through 2001 from California Department of Motor Vehicles, *DL Information Report*, Sacramento, CA.

Figure 3. Percentages over time of the total licensed driving population by year and age of driver.

Almost all licensing and incident involvement data presented below are for the year 2000. Table 2 and Figure 4 show licensure rates by age—the estimated percentage of California residents in each age group who held a driver license as of January 1, 2001; that is, during the year 2000. Population estimates are from California Department of Finance (2000). The licensing data, derived from counts of licenses in a 10% random sample of the driver record file in 2000, are from California Department of Motor Vehicles (January 2001). License rates may be somewhat inflated by the inclusion of out-of-state residents and members of the military holding California licenses; in fact two of the rates shown here are a little over 100%. Nevertheless, one can conclude broadly that an appreciably greater percentage of men than women are licensed within almost all age groups, and that from age 18 through somewhere in the eighties the majority of people hold driver licenses.

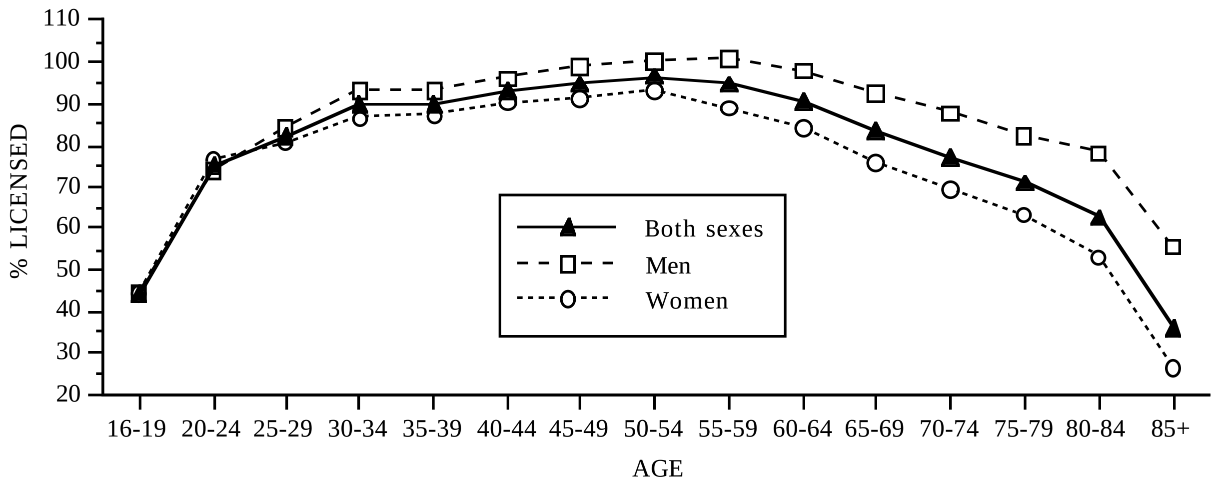
Table 2

Driver Licenses, California Residents, and Licensure Rate by Age and Sex

	Both sexes			Men			Women		
Age	Licenses[a] (thousands)	Residents[b] (thousands)	Licenses per 100 residents	Licenses (thousands)	Residents (thousands)	Licenses per 100 residents	Licenses (thousands)	Residents (thousands)	Licenses per 100 residents
16	90	483	18.67	45	250	17.89	46	233	19.52
17	174	494	35.19	90	258	34.91	84	237	35.50
18	269	490	54.95	143	255	56.11	126	235	53.69
19	331	495	66.92	173	259	66.99	158	236	66.83
16-19	864	1,962	44.06	451	1,021	44.16	413	941	43.94
20-24	1,788	2,381	75.09	924	1,246	74.18	864	1,136	76.10
25-29	2,093	2,544	82.29	1,103	1,311	84.10	990	1,232	80.36
30-34	2,418	2,686	90.05	1,288	1,382	93.14	1,131	1,303	86.78
35-39	2,539	2,815	90.19	1,333	1,430	93.17	1,206	1,384	87.11
40-44	2,490	2,671	93.23	1,290	1,342	96.14	1,199	1,328	90.29
45-49	2,215	2,332	95.01	1,139	1,153	98.75	1,077	1,179	91.35
50-54	1,929	2,000	96.46	983	981	100.23	946	1,019	92.84
55-59	1,388	1,467	94.60	717	711	100.87	671	756	88.71
60-64	1,040	1,147	90.67	535	546	97.97	505	601	84.03
65-69	821	985	83.41	421	457	92.25	400	528	75.75
70-74	697	903	77.16	348	398	87.55	349	505	68.98
75-79	555	779	71.20	269	328	82.10	286	452	63.29
80-84	316	503	62.84	154	197	78.19	162	306	52.92
85+	152	426	35.62	75	134	55.69	77	291	26.37
All ages	21,306	25,599	83.23	11,030	12,638	87.28	10,275	12,961	79.28

[a]Licensing data for 2000 are from California Department of Motor Vehicles, January 2001, *Age and Sex Report*, Sacramento, CA.

[b]Population data for 2000 are from California Department of Finance, *2000 Census of Population and Housing*, unpublished document, Sacramento, CA.



Note. Licensing data for 2000 are from California Department of Motor Vehicles, January 2001, *Age and Sex Report*, Sacramento, CA. Population data for 2000 are from California Department of Finance, *2000 Census of Population and Housing*, unpublished document, Sacramento, CA.

Figure 4. Percentage of California licensed drivers by age and sex.

Total Traffic Accidents and Citations

The information presented in the rest of this report describes group averages, ignoring any variation—and there is always variation—among the differing members of the group. The average value for a group on any variable, by itself, is actuarial information of the type an insurance company might use to control its losses over the long run, and tells very little if anything about a particular group member. This point is probably obvious, but the tendency to think of individuals belonging to a particular group as being at their group's average is strong, so the point is made at the outset. In almost all cases, determining which Californians should have the driving privilege is done through an individualized testing process rather than use of actuarial information; more will be said about that below.

Past studies in California—as elsewhere—have shown that age and gender are related to driver record (e.g., Gebers, Romanowicz, & McKenzie, 1993; Aizenberg & McKenzie, 1997; Gebers, 1999). For instance, teenagers and men tend as groups to show higher crash and citation rates than, respectively, non-teenagers and women. This sort of statement may lead to a question of how crashes and citations are defined. Motor vehicle crashes are those officially reported to DMV; an accident is not required to be reported if no death, injury, or damage to a person's property amounting to more than $750 has occurred. Citations, in this context, are traffic tickets. The count of citations includes convictions of traffic violations (usually through forfeiting bail, which does not require an appearance at court), failure of a driver who has not deposited bail to appear in court to answer the charge, failure of a driver to pay a fine assessed in connection with the charge, and dismissal of the charge on condition that the driver attend a court-approved program.

DMV maintains an ongoing 1% random sample of California licensed drivers for research purposes. Data from this sample for the years 1996 through 1998 were used to calculate annual accident and citation averages. These are shown in Tables 3 and 4 and Figures 5 and 6, and give a picture consistent with findings presented in earlier *Teen and Senior Drivers* reports. The tables and figures show each age/sex group's average yearly number of casualty plus non-casualty (that is, total) accident involvements—an involvement is counted for each driver involved in a crash—and average annual number of traffic citations. Both averages are given per 100 licensed drivers.

Some of the conclusions that can be drawn from Tables 3 and 4 and Figures 5 and 6 are the following:

- For each sex, the age group 16-19 shows the highest average annual crash and citation rates. The average annual crash rates for both young men and young women peak at age 16, their citation rates at age 18.
- The average annual crash rate for combined sexes declines through about age 69 and then increases, though it remains below the level for all ages combined (which is 5.18 per 100 drivers, shown in Table 3).
- The average annual citation rate for combined sexes decreases strongly with age.
- At all ages, average annual crash and citation rates for men exceed those for women.

Table 3

Average Annual Accident Involvements Per 100 Licensed Drivers by Age and Sex

Age	Both sexes (n = 194,948)	Men (n = 105,075)	Women (n = 89,873)
16	9.10	9.65	8.56
17	8.88	9.46	8.24
18	8.45	9.90	6.85
19	7.68	7.90	7.46
16-19	8.48	9.19	7.73
20-24	6.85	7.43	6.18
25-29	5.49	6.00	4.88
30-34	5.14	5.46	4.77
35-39	5.08	5.50	4.58
40-44	4.92	5.41	4.38
45-49	4.60	5.25	3.89
50-54	4.17	4.80	3.48
55-59	4.04	4.79	3.21
60-64	3.79	4.35	3.18
65-69	3.77	4.35	3.15
70-74	4.10	4.84	3.40
75-79	4.26	4.95	3.64
80-84	4.71	5.70	3.74
85+	5.16	5.92	4.31
All ages	5.18	5.73	4.56

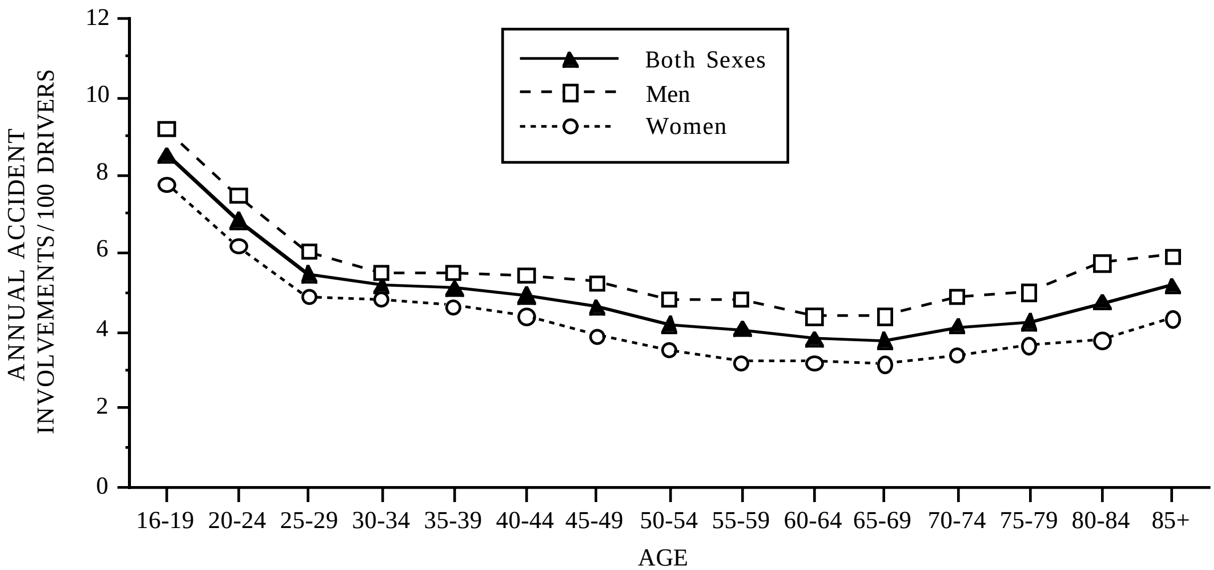
Note. Based on driver records of a 1% random sample of California licensed drivers. Annual averages (per 100 drivers) are based on accidents occurring during the years 1996 through 1998.

Table 4

Average Annual Traffic Citations Per 100 Licensed Drivers by Age and Sex

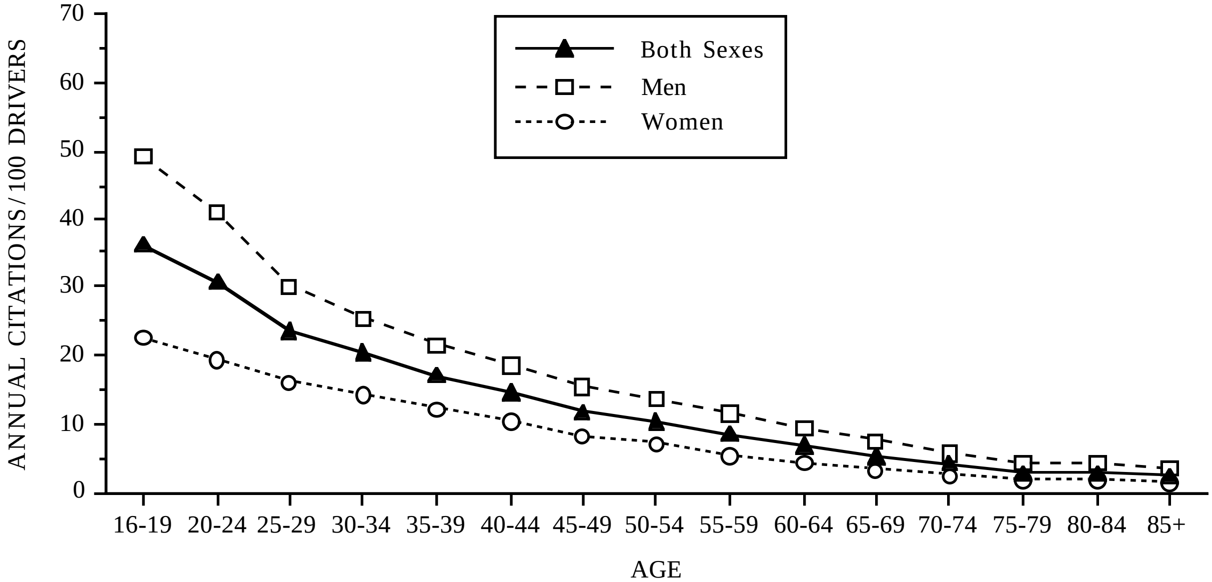
Age	Both sexes (n = 194,948)	Men (n = 105,075)	Women (n = 89,873)
16	31.00	42.83	19.54
17	36.56	47.87	23.91
18	38.90	53.43	22.96
19	37.54	50.99	23.29
16-19	36.31	49.25	22.54
20-24	30.93	41.01	19.34
25-29	23.72	30.29	15.95
30-34	20.24	25.31	14.31
35-39	17.20	21.65	12.08
40-44	14.56	18.45	10.25
45-49	11.89	15.30	8.23
50-54	10.35	13.44	6.97
55-59	8.54	11.45	5.33
60-64	6.74	9.11	4.13
65-69	5.32	7.42	3.11
70-74	4.02	5.80	2.34
75-79	2.79	4.20	1.52
80-84	2.86	4.19	1.56
85+	2.43	3.51	1.23
All ages	17.33	22.63	11.45

Note. Based on driver records of a 1% random sample of California licensed drivers. Annual averages (per 100 drivers) are based on the number of citations received during the years 1996 through 1998.



Note. Based on driver records of a 1% random sample of California licensed drivers. Annual averages are based on the number of accidents occurring during the years 1996 through 1998.

Figure 5. Average annual accident involvements per 100 licensed drivers by age and sex.



Note. Based on driver records of a 1% random sample of California licensed drivers. Annual averages are based on traffic citations received during the years 1996 through 1998.

Figure 6. Average annual traffic citations per 100 licensed drivers by age and sex.

The high average crash rate per year for young novice drivers justifies special efforts to make them safe members of the driving population, and these efforts are described below in <u>Crash Countermeasures for Teenaged Drivers</u>. Present-day senior drivers have a relatively low average annual crash rate, but this does not contradict the fact that driving performance eventually declines with age, though it may alleviate concerns that the group, as presently constituted, poses an unusually great threat to other road users. Senior drivers' underinvolvement in accidents despite a predictable average decline in driving skills caused by functional changes associated with aging and age-related disease (Janke, 1994b) indicates that most are aware, at least at some level, of their limitations and accordingly restrict the amount and conditions of their driving. For example, much research has shown that senior drivers tend to drive less than others, to avoid driving at night or in bad weather, and to forego driving when traffic is congested. In this sense, senior drivers as a group compensate for driving-related impairments, though any individual driver's compensation may or may not be adequate. Since the average accident rate based on 1996-1998 data began to rise, however gradually, around age 70, that may mark a point—at least for the present cohort of seniors—at which there begins to be a critical mass of drivers in the group whose impairments outstrip their compensatory powers, thus raising the group average (cf. Hennessy, 1995).

Traffic Accidents and Citations Adjusted for Mileage

The measures presented above are annual crash averages. Crash averages based on a fixed period of time may be used to indicate the average risk imposed by a particular group, collectively, on other road users, again collectively. That risk is a function of group members' physical and mental abilities, motivations, experience, and other factors. Measures like crash rate per year have been used in reports like the present one to compare different age, sex, or driver record groups in terms of the societal hazard they pose (that is, the threat they pose to other road users); they are also widely used by insurance companies in setting auto insurance premiums. But they do not provide a clear picture of crash risk (invariably to the driver and possibly to others) when that driver is actually on the road, however little that may be.

It is desirable to have a measure of this sort of personal risk as well as societal risk. This section of the report uses a common method of adjustment for mileage to compare age/sex groups on accident and citation rates per average distance traveled, rather than per time period. The measure is meant to adjust for a group's exposure to risk of crashes (or citations), because the greater the exposure (that is, the more and more challenging the driving), the greater the expected number of incidents. The adjustment is admittedly imperfect, because mileage is only a partial measure of exposure to risk. A perfect exposure measure would include additional variables to represent such things as the surrounding traffic environment, roadway type, lighting, and weather conditions. All these and more are factors that influence risk.

Studies have consistently found that the youngest and oldest drivers have, as groups, the highest mileage-adjusted accident and citation rates. Reports of some recent studies in California were authored by Gebers, Romanowicz, and McKenzie (1993) and Aizenberg and McKenzie (1997), and basic trends remain much the same. Typical trends are shown below in Table 5 and Figures 7 and 8, which give the expected accident and citation rates per 100,000 miles of driving. To find these, an annual average (based for this report on the 3 years 1996 through 1998) of incident counts was found for licensed drivers in the 1% random sample of California drivers mentioned above. This gave annual crash and citation rates. Then the most recent available mileage data were obtained from the Nationwide Personal Transportation Survey (Federal Highway Administration, 1999), which is conducted periodically. Statistical curve smoothing of the 1995 NPTS data was done to derive a stable annual mileage estimate for each age group (see Appendix for detail).

Following that, and using accidents as an example, the average annual accident rate for each age/sex group—average accidents per driver within the group per year—was divided by average mileage per driver within that group per year (from the 1995 NPTS data for California). The "year" term cancels out of both numerator and denominator, leaving average accidents per mile. This is an extremely small number for any group; for example, the average accident rate per mile for men aged 45-49 is only .0000029. Therefore the figure was multiplied by 100,000 for all groups to show average accidents per driver per mile within each group, times the factor 100,000.

An alternative way of looking at the result is that it shows average accidents per driver within each age/sex group over a hypothetical 100,000 miles of driving. Driving 100,000 miles would take members of different age/sex groups, if they were driving the average number of miles for their group annually, different numbers of years to accomplish. How many years might it take, *on the average*, for a member of one of the various groups being considered here? Six or seven is a reasonable minimum, 20 a reasonable maximum. Smoothed data for California from the 1995 NPTS show that teenagers drove on the average about 8,500 miles a year; drivers in their twenties through forties had averages ranging from about 11,500 to 14,500 miles a year, and thereafter average annual mileage declined to a low point of slightly over 5,000 miles a year for people aged 85 or more. These data are for combined sexes; more detailed information appears in the Appendix.

Readers should be warned specifically that the accident involvement rate per 100,000 miles of .99 for teenagers and 1.00 for age 85 and over does not mean that just about everyone who is a teenager, and everyone who is very old, will inevitably crash. The teenager can be expected to mature and become a safer, more experienced driver; the very old person can be expected to stop driving, for whatever reason. Neither do these rates mean that if a group of teenagers, or one of very old people, *collectively* drives 100,000 miles in a year, then every individual in the group will have a crash. The rates are averages *per driver,* per 100,000 miles.

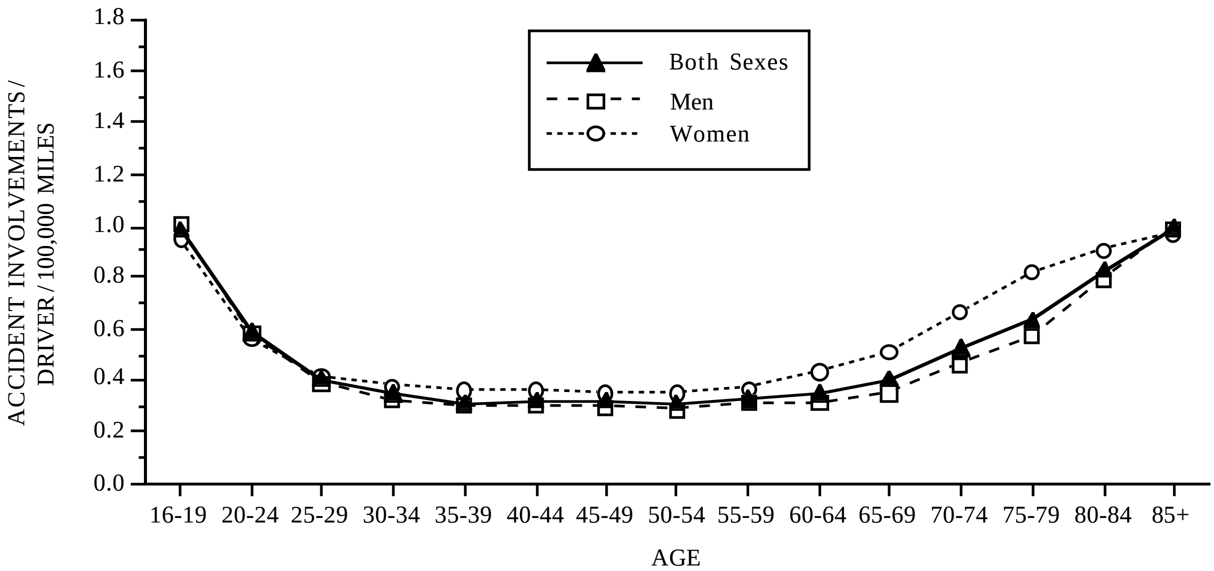
Below, Table 5 and Figures 7 and 8 show mileage-adjusted accident and citation rates.

Table 5

Average Accident Involvements and Traffic Citations per Driver per 100,000 Miles by Age and Sex

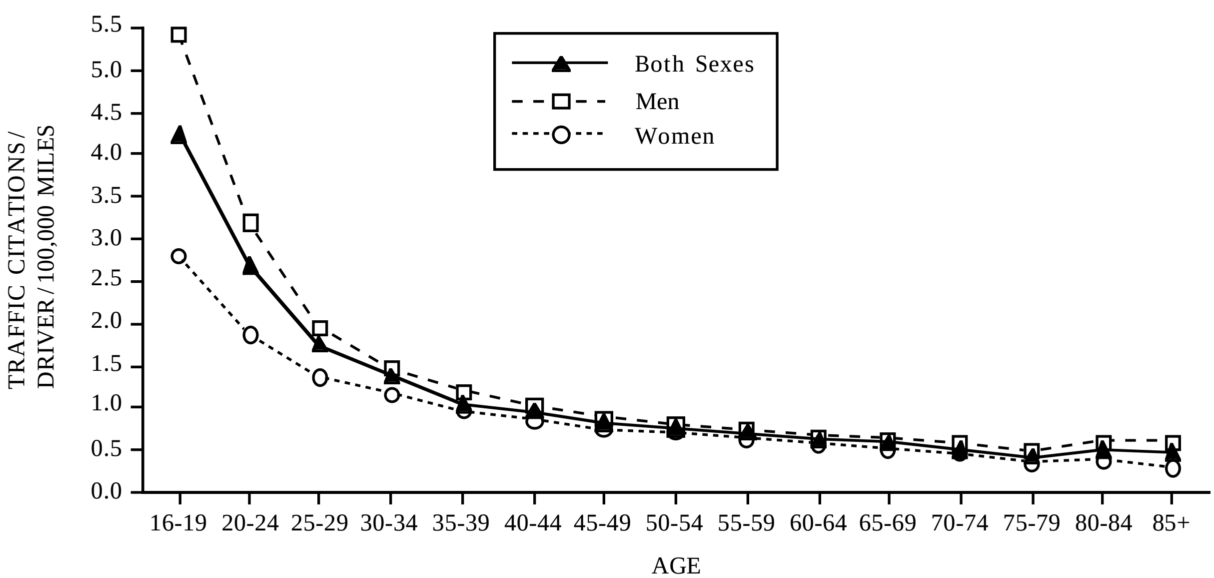
	Accidents			Citations		
Age	Both sexes	Men	Women	Both sexes	Men	Women
16-19	0.99	1.01	0.95	4.24	5.43	2.78
20-24	0.59	0.58	0.56	2.68	3.20	1.86
25-29	0.40	0.39	0.41	1.74	1.95	1.35
30-34	0.35	0.32	0.38	1.37	1.47	1.14
35-39	0.31	0.30	0.36	1.05	1.19	0.96
40-44	0.32	0.30	0.36	0.96	1.01	0.85
45-49	0.32	0.29	0.35	0.82	0.86	0.73
50-54	0.31	0.28	0.35	0.76	0.79	0.69
55-59	0.33	0.31	0.37	0.70	0.73	0.61
60-64	0.35	0.31	0.43	0.62	0.65	0.55
65-69	0.40	0.35	0.51	0.57	0.61	0.50
70-74	0.52	0.46	0.66	0.51	0.55	0.45
75-79	0.64	0.57	0.82	0.42	0.48	0.34
80-84	0.83	0.79	0.90	0.50	0.58	0.37
85 +	1.00	0.99	0.97	0.47	0.59	0.28
All ages	0.51	0.48	0.56	1.16	1.34	0.90

Note. Based on driver records of a 1% random sample of California licensed drivers. Averages based on accidents and citations occurring during the years 1996 through 1998. Mileage estimates are based on data from Federal Highway Administration, 1999, *Summary of Travel Trends: 1995 Nationwide Personal Transportation Survey*, Washington, D.C.: U.S. Department of Transportation.



Note. Based on 1% random sample of California licensed drivers. Annual averages are based on accidents occurring during the years 1996 through 1998. Annual mileage estimates are based on data from Federal Highway Administration, 1999, *Summary of Travel Trends: 1995 Nationwide Personal Transportation Survey*, Washington, D.C.: U.S. Department of Transportation.

Figure 7. Average accident involvements per driver per 100,000 miles by age and sex.



Note. Based on 1% random sample of California licensed drivers. Annual averages are based on citations occurring during years 1996 through 1998. Annual mileage estimates are based on data from Federal Highway Administration, 1999, *Summary of Travel Trends: 1995 Nationwide Personal Transportation Survey*, Washington, D.C.: U.S. Department of Transportation.

Figure 8. Average traffic citations per driver per 100,000 miles by age and sex.

Conclusions that can be drawn from the table and figures include the following:

- In agreement with other studies, the youngest and oldest drivers have the highest average mileage-adjusted accident rates. The curve in Figure 7 has often been described as "U-shaped."

- For both sexes, the average mileage-adjusted citation rate is highest for drivers aged 16-19, and diminishes with age. The rate for young men exceeds that for young women.

- The average mileage-adjusted accident rate for older women is considerably higher than the corresponding rate for older men. This may be in part a consequence, as discussed below, of women's much lower mileage (about half as great as men's, see Appendix) in the age range where the male-female disparity is most apparent; in part it may be due to recent widows or spouses of recently disabled men, who were not previously active drivers, joining the driving population. Related factors probably enter in as well; Stamatiadis and Deacon (1995), who used a different method of adjusting for exposure and found a similar result, discussed the relative lack of driving experience gained by present cohorts of older women—as compared to men—during their younger years.

There was a change in NPTS methodology for the 1995 survey; that change should be described because it may help to account for differences in detail between the data presented here and those presented in earlier research (e.g., Romanowicz & Gebers, 1990). According to the NPTS user guide on the Internet, reachable through www.fhwa.dot.gov, the 1995 survey at first showed per-driver declines in mileage compared to 1990 NPTS figures, not considered by the researchers a credible finding. It was discovered that in 1990 only 2% of the drivers had reported driving no miles during the year, while this rose to 9% in 1995. Confusingly, many of the 9% indicated elsewhere on the survey form that they actually did drive, either on their assigned "travel day," when they were to keep a diary of all trips, or as primary driver of one of their household vehicles for which mileage was reported. Therefore drivers who reported not driving, but paradoxically showed up elsewhere on the survey form as having driven, were moved from a "no miles" category to another, "miles not reported." After this change was made, only about 1.5% of all drivers remained in the "no miles" category, according to the user guide. The revised data (which were used for this report) showed slight mileage decreases for most age groups under 65, an increase starting at age 65 which became substantial for drivers 75 and above, and a sizable decline for teenagers. Teenagers' decrease in mileage would be expected to increase their accident rate per mile, and the reverse would be expected for older driver groups whose mileage increased. (The basis for expectations of a higher mileage-adjusted crash rate when mileage is less will be discussed below.)

The U-shaped curve in Figure 7, relating accidents per 100,000 miles to age, appears flatter than it was in earlier DMV reports. An increase in the mileage-adjusted accident rate for teenagers would tend to make the U steeper, everything else being equal, so any overall flattening of the U would seem to be a function of a lower mileage-adjusted accident rate for seniors than was seen in the past. That both of these effects did occur is readily seen when comparing Figure 7 in the present report to the equivalent

Figure 7 in Gebers, Romanowicz, and McKenzie (1993). Comparing Table 5 in their report to the equivalent Table 5 in the present report, one finds that, combining the sexes, the average number of accident involvements per 100,000 miles for teenagers was 0.84 in the 1993 publication, while in the present report their mileage-adjusted accident rate increased to 0.99. For seniors aged 85 and above the rate was 1.71 in the 1993 publication, decreasing to 1.00 in the present report. For seniors aged 80-84, the earlier rate was 1.03, while in the present data it is 0.83. The rate for middle-aged drivers is essentially unchanged. For example, for drivers aged 40-44 in the 1993 report it was 0.31, while in the present report it is 0.32.

If the very elderly are driving more now than they used to, it is possible that they are more fit than elderly people were in the past. This possibility is consistent with a higher contemporary level of public knowledge and interest in health and fitness issues, and improved medical management of chronic conditions. As group mileage rises, it is predictable that the group's rate of crashes per mile will fall. The empirical curve representing accidents as a function of miles rises very steeply at first, when mileage is low, and then levels off to a gradual increase as mileage becomes high. This makes accidents per mile misleading as a measure of crash risk (Janke, 1991)—if it is assumed, for example, that a group driving twice the number of miles on average should have twice the accident rate. Actually they will have less than that. Probably part of the reason for the empirical curve findings is that unfit groups tend to drive less and also to experience proportionately more crashes when they drive. But another part may be that groups with relatively low average mileage tend to accumulate more of their miles on congested city streets with two-way traffic, including pedestrians and non-motorized vehicles, and no restriction of access. High-mileage groups, on the other hand, typically accumulate a substantial proportion of their miles on divided multilane highways with no cross-traffic and limited access. At least after merging onto the highway has been accomplished, the driving task on these "freeways" is simpler (less exposure to risk), and the accident rate per mile is lower. Janke cited data from the California Business, Transportation and Housing Agency (1985) which indicated that there were 2.75 times as many accidents per mile driven on non-freeways as on freeways. Even if two groups are equally competent on the average, a group driving half the mileage of another would be expected to have more than half the rate of crashes per mile, simply because of their proportionally greater exposure to higher-risk driving conditions.

Fatal/Injury and Fatal Accidents

The heading refers to casualty accidents—that is, those involving someone's injury or death. "Fatal/injury" refers to the sum of fatal and nonfatal injury crashes. These are not as common as "property-damage-only" accidents, but because of their severity are much more likely to be investigated by police and reported to the DMV. Fatal and fatal/injury (F/I) crash rates are especially high for the group of drivers less than 25 years old, and in addition the average rate of involvement in fatal accidents is considerably elevated for the very aged when compared to middle-aged people, though not as high as for the young. A non-ability factor that magnifies older people's casualty rate is their vulnerability to dying from crash injuries that would be survivable by younger people (Evans, 1991); evidence for this, and its implications, will be discussed in the section Research on Senior Drivers.

Average F/I and fatal accident involvement rates per 1,000 licensed California drivers for each age/sex group during 2000 are shown in Table 6. California accident data for 2000 are from the California Highway Patrol (CHP). They are exhaustive, including not only crash involvements of California-licensed drivers within the state, but also involvements in California of unlicensed drivers and those holding out-of-state licenses. State licensing data for 2000 are from DMV.

Fatal crashes are much less common than crashes resulting in only nonfatal injuries. According to CHP, during 2000 there were 3,331 fatal collisions in California and 198,348 nonfatal injury collisions, almost 60 times as many (California Highway Patrol, 2001b). Table 6 shows that in 2000, combining sexes and ages, the driver involvement rate for F/I crashes was almost 73 times that for fatal crashes.

Table 6

Fatal/Injury and Fatal Accident Involvements per 1,000 Drivers by Age and Sex

	Fatal/injury			Fatal		
Age	Both sexes	Men	Women	Both sexes	Men	Women
16	61.43	66.95	56.01	0.71	0.83	0.59
17	46.24	48.62	43.69	0.41	0.60	0.21
18	45.38	50.38	39.71	0.65	0.82	0.46
19	37.83	42.59	32.60	0.52	0.66	0.37
16-19	44.33	48.68	39.60	0.56	0.71	0.39
20-24	28.23	32.12	24.07	0.40	0.59	0.20
25-29	20.57	23.12	17.73	0.27	0.40	0.12
30-34	17.25	19.09	15.16	0.21	0.30	0.11
35-39	16.24	17.84	14.47	0.21	0.30	0.11
40-44	14.75	16.36	13.01	0.20	0.29	0.11
45-49	13.54	15.34	11.63	0.18	0.25	0.10
50-54	12.17	14.28	9.97	0.17	0.26	0.08
55-59	11.27	13.01	9.41	0.15	0.21	0.09
60-64	10.63	12.64	8.50	0.15	0.23	0.08
65-69	9.83	11.78	7.77	0.13	0.16	0.10
70-74	9.64	11.55	7.74	0.19	0.26	0.12
75-79	10.00	11.89	8.23	0.22	0.31	0.13
80-84	10.16	12.00	8.40	0.23	0.34	0.14
85 +	12.14	14.59	9.77	0.36	0.54	0.20
All ages	16.76	18.98	14.38	0.23	0.33	0.12

Note. Accident data for 2000 are from California Highway Patrol, 2001, *2000 Annual Report of Fatal and Injury Motor Vehicle Traffic Accidents*, Sacramento, CA. Licensing data for 2000 are from California Department of Motor Vehicles, January 2001, *Age and Sex Report*, Sacramento, CA.

Table 7 gives indexes of relative involvement in F/I and fatal accidents, during 2000, for drivers grouped by age and sex. What is called a relative involvement index was calculated for each age/sex group by dividing the percent the group represented of *all drivers involved in F/I (or fatal) accidents* by the percent it represented of *all licensed drivers*. This type of index is general; it can be used for total accidents as well. It is meant to answer the question: Considering how large a group is, as a percent of the driving population, is the group overinvolved or underinvolved in crashes? The expected index for any group would be 1.00—if a group is 10% of the driving population, for instance, one would expect drivers in it to have 10% of the accident involvements, everything else being equal. If another age/sex group contained 4% of the drivers involved in F/I accidents but only 2% of all licensed drivers in California, its relative involvement index would be 2.0, indicating that the group had twice as many F/I crash involvements as expected. Similarly, a group that contained 2% of the drivers involved in F/I accidents but was 4% of the driving population would have had half as many casualty accident involvements as expected, with a relative involvement index of 0.5.

Some caution should be used in making quantitative inferences about California licensees based on the data of Table 7. That is because, as noted, out-of-state and unlicensed drivers involved in California accidents were included in CHP's data. Such drivers probably represent a relatively small part of the total group. But the distortion caused by this source of error could make the licensed members of a particular age group look more hazardous than they really are, if the group contains many people who are unlicensed (at least, unlicensed in California), but drive and experience accidents nonetheless. This may be particularly true of teenagers. Conversely, if members of an age group are licensed in California but do not actually drive, this would reduce the group's relative involvement rate. This may be especially likely in the case of nondriving seniors keeping their licenses for personal reasons only.

Table 7

Relative Involvement in Fatal/Injury and Fatal Accidents by Age and Sex

	Group as % of all licensed drivers[a]			Fatal/injury: Group as % of all involved drivers[b]			Fatal/injury: Relative involvement index[c]			Fatal: Group as % of all involved drivers			Fatal: Relative involvement index		
Age	Both sexes	Men	Women	Both sexes	Men	Women	Both sexes	Men	Women	Both sexes	Men	Women	Both sexes	Men	Women
16	0.42	0.21	0.21	1.55	0.84	0.71	3.67	3.99	3.34	1.30	0.75	0.55	3.08	3.59	2.57
17	0.82	0.42	0.39	2.25	1.22	1.03	2.76	2.90	2.61	1.47	1.10	0.37	1.80	2.61	0.93
18	1.26	0.67	0.59	3.42	2.02	1.40	2.71	3.01	2.37	3.56	2.38	1.18	2.82	3.55	1.99
19	1.55	0.81	0.74	3.51	2.07	1.44	2.26	2.54	1.94	3.50	2.32	1.18	2.25	2.85	1.60
16-19	4.06	2.12	1.94	10.73	6.15	4.59	2.65	2.90	2.36	9.84	6.56	3.28	2.42	3.10	1.69
20-24	8.39	4.34	4.06	14.14	8.31	5.83	1.68	1.92	1.44	14.75	11.16	3.59	1.76	2.57	0.88
25-29	9.82	5.18	4.65	12.06	7.14	4.92	1.23	1.38	1.06	11.31	8.96	2.34	1.15	1.73	0.50
30-34	11.35	6.04	5.31	11.68	6.88	4.80	1.03	1.14	0.90	10.49	7.94	2.55	0.92	1.31	0.48
35-39	11.92	6.25	5.66	11.55	6.66	4.89	0.97	1.06	0.86	10.98	8.23	2.75	0.92	1.32	0.49
40-44	11.69	6.06	5.63	10.28	5.91	4.37	0.88	0.98	0.78	10.12	7.52	2.61	0.87	1.24	0.46
45-49	10.40	5.34	5.05	8.40	4.89	3.51	0.81	0.92	0.69	8.01	5.76	2.24	0.77	1.08	0.44
50-54	9.05	4.61	4.44	6.57	3.93	2.64	0.73	0.85	0.59	6.84	5.30	1.55	0.76	1.15	0.35
55-59	6.51	3.37	3.15	4.38	2.61	1.77	0.67	0.78	0.56	4.38	3.10	1.28	0.67	0.92	0.41
60-64	4.88	2.51	2.37	3.10	1.89	1.20	0.63	0.75	0.51	3.26	2.49	0.77	0.67	0.99	0.33
65-69	3.85	1.98	1.88	2.26	1.39	0.87	0.59	0.70	0.46	2.20	1.41	0.79	0.57	0.71	0.42
70-74	3.27	1.64	1.64	1.88	1.13	0.76	0.58	0.69	0.46	2.73	1.85	0.88	0.83	1.13	0.54
75-79	2.60	1.26	1.34	1.55	0.90	0.66	0.60	0.71	0.49	2.46	1.69	0.77	0.95	1.34	0.58
80-84	1.48	0.72	0.76	0.90	0.52	0.38	0.61	0.72	0.50	1.51	1.06	0.45	1.02	1.46	0.59
85+	0.71	0.35	0.36	0.52	0.31	0.21	0.72	0.87	0.58	1.12	0.81	0.31	1.57	2.32	0.85
All ages	100.00	51.77	48.23	100.00	58.63	41.37	1.00	1.13	0.86	100.00	73.84	26.16	1.00	1.43	0.54

[a]Licensing data for 2000 are from California Department of Motor Vehicles, January 2001, *Age and Sex Report*, Sacramento, CA.

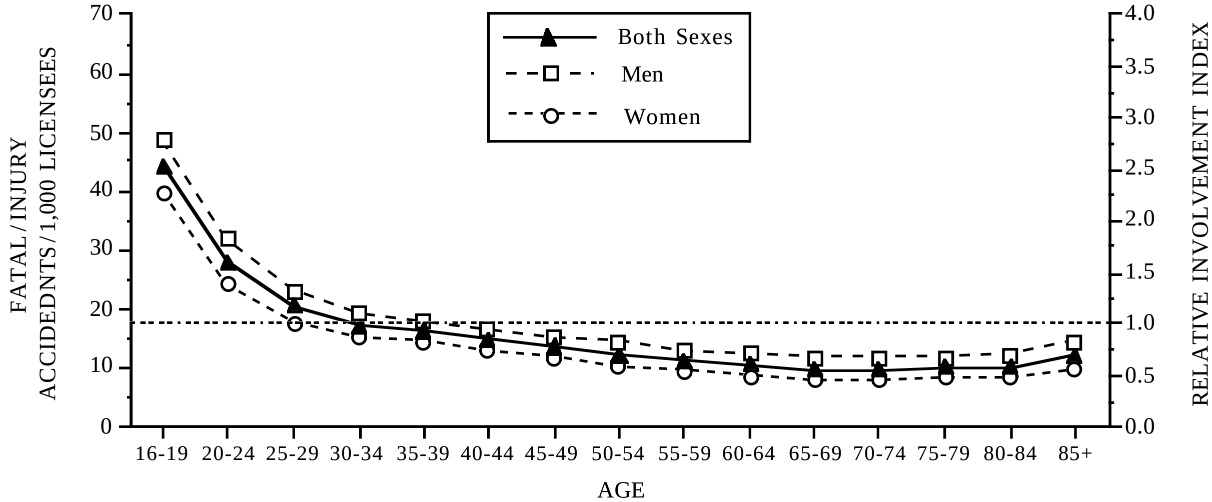
[b]Accident data for 2000 are from California Highway Patrol, 2001, *2000 Annual Report of Fatal and Injury Motor Vehicle Traffic Accidents*, Sacramento, CA.

[c]Relative involvement is the accident involvement for the age/sex group as a percent of such involvement for all drivers, divided by the percent of all licensed drivers represented by that group.

Table 7 shows relative involvement indexes at each age level for male and female drivers separately and combined. The indexes given for men and women separately reflect both age and sex differences—so that women, say, are compared to the driving population as a whole (all ages, both sexes), and not just to other women. As an example, the 1.06 fatal/injury relative involvement index for women aged 25-29 means that women in this age group have, on the average, a relative involvement in fatal/injury crashes that is 6% greater than the relative involvement index for all drivers, defined as 1.00. Relative involvement indexes can also be made sex-specific (with men compared only to men, for example) by dividing each age/sex group's index by the "all ages" index for that sex, shown at the bottom of the table. The “all ages” F/I index for men is 1.13, so a sex-specific F/I index for men aged 25-29 would be 1.38/1.13 = 1.22. This means that, for that age/sex group, the relative involvement in F/I crashes is 22% greater than it is for men in general.

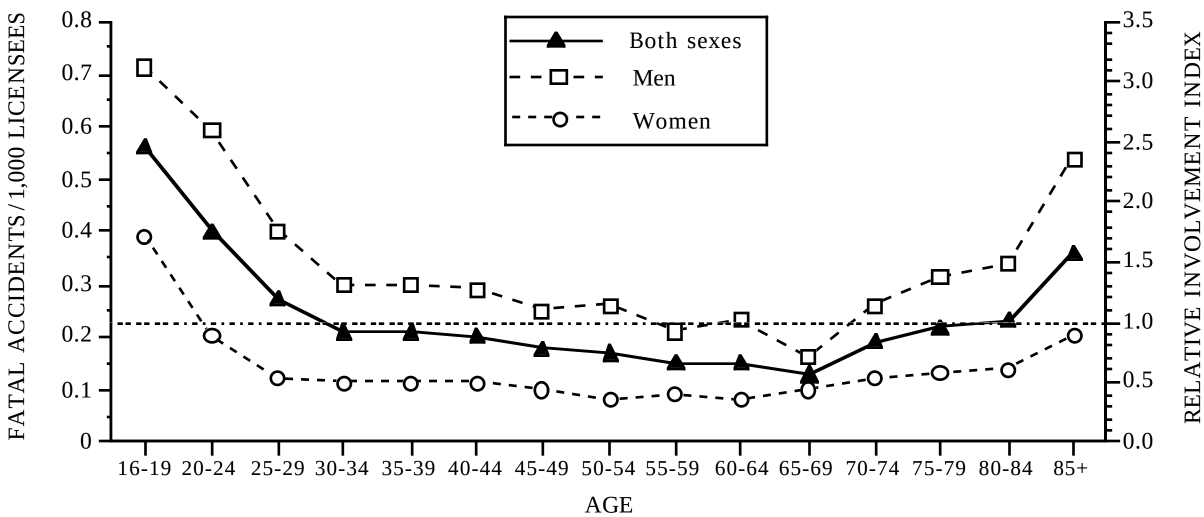
Given a measuring scale with a true zero point and equal intervals, relative information in the form of ratios (B is twice as heavy as C) can be inferred from scale readings (B weighs 8 lb and C weighs 4 lb). In a similar way, indexes of relative involvement for all age groups in a population can be inferred from the groups’ separate involvement rates (the number of involvements for people in an age group divided by the number of people in that age group) and the average involvement rate for the entire population (the total number of involvements for all age groups divided by the total number of people in the population). Here we are concerned with traffic accidents of licensed drivers in the driving population. Because relative involvement index is a different way of presenting information that is already implicit in involvement rate, both the relative involvement indexes and the average group involvement rates for different age groups can be shown on the same graph. The actual curves are identical; only the numbers on the Y axis will be different, because one measure is a group’s average rate of involvements per driver, and the other is a number that indicates a group’s share of involvements compared to its share of drivers.

The graphing procedure requires using two Y-axes and drawing a horizontal line across the graph at the level of the average population crash-involvement rate on one of the Y axes. In the graphs below it is the left axis. The intersection of this line and the other Y axis, the one on the right, represents a relative involvement index of 1.00. Fixing the position of 1.00 establishes a unit distance and defines the relative involvement scale. Figures 9 and 10 show the result for F/I and fatal accidents, respectively. As mentioned, in each figure the Y-axis on the left represents accident involvement rate and the one on the right represents relative involvement index. The data are taken directly from Tables 6 and 7.



Note. Accident data for 2000 are from California Highway Patrol, 2001, *2000 Annual Report of Fatal and Injury Motor Vehicle Traffic Accidents*, Sacramento, CA. Licensing data for 2000 are from California Department of Motor Vehicles, January 2001, *Age and Sex Report*, Sacramento, CA. The relative involvement index is the accident involvement for the age/sex group as a percent of such involvements for all drivers, divided by the percent of all licensed drivers represented by that group.

Figure 9. Fatal/injury accident involvement rate and relative involvement index by age and sex.



Note. Accident data for 2000 are from California Highway Patrol, 2001, *2000 Annual Report of Fatal and Injury Motor Vehicle Traffic Accidents*, Sacramento, CA. Licensing data for 2000 are from California Department of Motor Vehicles, January 2001, *Age and Sex Report*, Sacramento, CA. The relative involvement index is the accident involvement for the age/sex group as a percent of such involvements for all drivers, divided by the percent of all licensed drivers represented by that group.

Figure 10. Fatal accident involvement rate and relative involvement index by age and sex.

Tables 6 and 7, and Figures 9 and 10, indicate that:

- As a group, teenaged drivers have the highest average F/I and fatal accident involvement rates. Within that group, 16-year-olds are at highest risk.

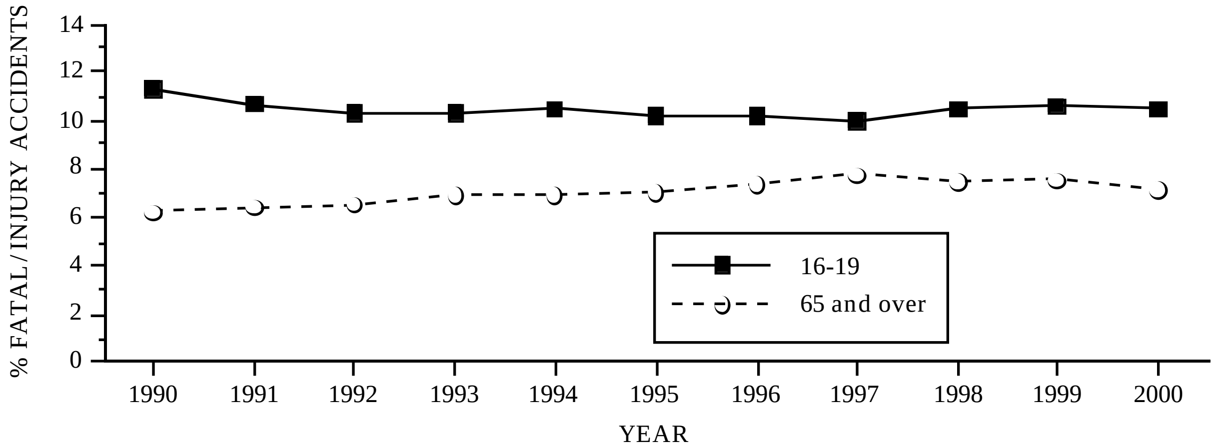
- As drivers age, their average involvement in F/I accidents decreases, reaching a low point at ages 70-74 and then rising slightly. The increase is by no means steep, despite seniors' greater physical and physiological vulnerability. However, vulnerability is a factor leading to an earlier increase in fatal accident involvement than is seen for F/I accident involvement; the increase in average fatal accident involvement begins after ages 65-69.

- Within each age group, average F/I and fatal accident involvement rates of male drivers exceed those of female drivers. This is despite the finding that "from about age 15 to age 45, the same physical insult is approximately 25% more likely to kill a female than a male of the same age" (Evans, 1991).

- With all ages combined, the average involvement rate of men in fatal/injury accidents is 1.3 times (30% greater than) that of women.

- With all ages combined, the average involvement rate of men in fatal accidents is 2.6 times (160% greater than) that of women.

Figure 11, below, shows for years 1990 through 2000 the percentage of F/I crashes in which teenaged or senior drivers were involved. Accident data are from CHP and disregard culpability for the accident; licensing data cover the same years and are from DMV. It is instructive to compare Figure 11 with the years 1990-2000 in Figure 3, which shows teenagers' and seniors' percentage shares of the licensed driver population. Figure 3 shows that licensed senior drivers had increased to about 12% by 2001 (essentially the same as for 2000), while licensed teenaged drivers had diminished to about 4% by 2001 (again, essentially the same as for 2000). Figure 11, picturing the groups' percentage shares of F/I accidents, shows for 2000 that teenagers (4% of licensees) were involved in about 10%, and seniors (12% of licensees) in about 7%, of F/I accidents. This indicates that the groups were over- and underinvolved, respectively, in casualty accidents.



Note. Accident data for 1990-2000 are from California Highway Patrol, 1991-2001, *1990-2000 Annual Report of Fatal and Injury Motor Vehicle Traffic Accidents*, Sacramento, CA. Licensing data for 1990-2000 are from California Department of Motor Vehicles, *DL Information Report*, Sacramento, CA.

Figure 11. Percentage of fatal/injury accidents by year and age of driver.

Fatal/Injury and Fatal Accidents Adjusted for Mileage

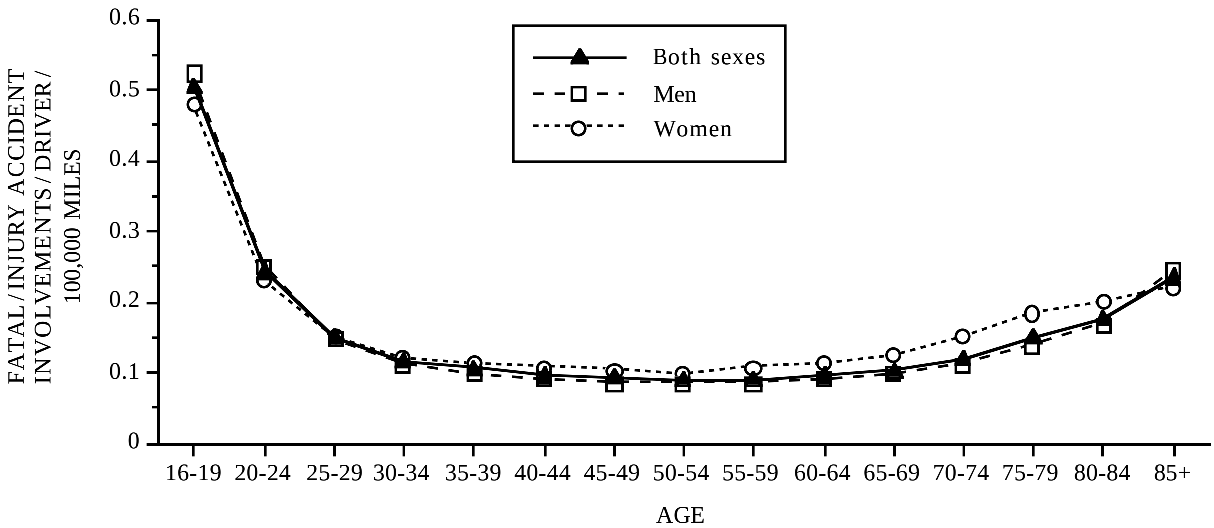
Table 8 and Figures 12 and 13 show the mileage-adjusted F/I and fatal accident involvements per driver per 100,000 miles (or simply the per-mile rates times 100,000) by age and sex. The mileage adjustments were obtained by applying the procedures previously described for total accidents to the casualty accident involvement rates in Table 6. The same interpretive cautions should be kept in mind.

Table 8

Mileage-Adjusted Fatal/Injury and Fatal Accidents by Age and Sex

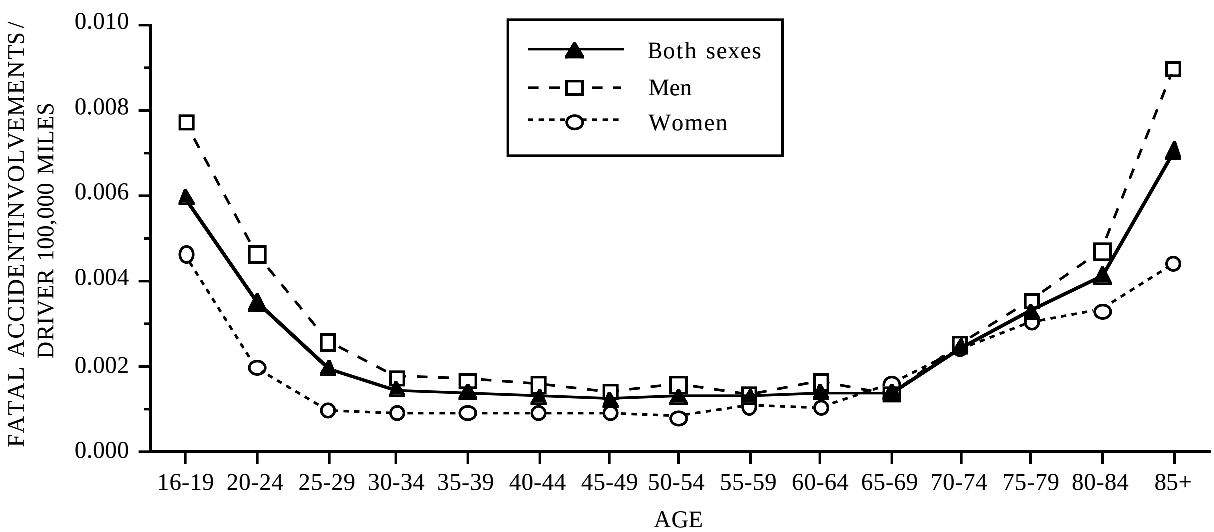
	Fatal/injury			Fatal		
Age	Both sexes	Men	Women	Both sexes	Men	Women
16-19	0.518	0.537	0.489	0.007	0.008	0.005
20-24	0.244	0.250	0.231	0.004	0.005	0.002
25-29	0.151	0.149	0.150	0.002	0.003	0.001
30-34	0.116	0.111	0.121	0.001	0.002	0.001
35-39	0.106	0.098	0.115	0.001	0.002	0.001
40-44	0.097	0.089	0.108	0.001	0.002	0.001
45-49	0.093	0.086	0.104	0.001	0.001	0.001
50-54	0.090	0.084	0.099	0.001	0.002	0.001
55-59	0.092	0.083	0.107	0.001	0.001	0.001
60-64	0.098	0.090	0.114	0.001	0.002	0.001
65-69	0.105	0.096	0.125	0.001	0.001	0.002
70-74	0.122	0.110	0.150	0.002	0.002	0.002
75-79	0.151	0.136	0.185	0.003	0.004	0.003
80-84	0.179	0.167	0.202	0.004	0.005	0.003
85 +	0.236	0.244	0.220	0.007	0.009	0.004
All ages	0.152	0.142	0.167	0.002	0.002	0.001

Note. Accident data for 2000 are from California Highway Patrol, 2001, *2000 Annual Report of Fatal and Injury Motor Vehicle Traffic Accidents*, Sacramento, CA. Licensing data for 2000 are from California Department of Motor Vehicles, January 2001, *Age and Sex Report*, Sacramento, CA. Mileage estimates are based on 1995 data from Federal Highway Administration, 1999, *Summary of Travel Trends: 1995 Nationwide Personal Transportation Survey*, Washington, D.C.: U.S. Department of Transportation.



Note. Accident data for 2000 are from California Highway Patrol, 2001, *2000 Annual Report of Fatal and Injury Motor Vehicle Traffic Accidents*, Sacramento, CA. Licensing data for 2000 are from California Department of Motor Vehicles, January 2001, *Age and Sex Report,* Sacramento, CA. Mileage estimates are based on 1995 data from Federal Highway Administration, 1999, *Summary of Travel Trends: 1995 Nationwide Personal Transportation Survey*, Washington, D.C.: U.S. Department of Transportation.

Figure 12. Fatal / injury accident involvement rate per driver per 100,000 miles by age and sex.



Note. Accident data for 2000 are from California Highway Patrol, 2001, *2000 Annual Report of Fatal and Injury Motor Vehicle Traffic Accidents*, Sacramento, CA. Licensing data for 2000 are from California Department of Motor Vehicles, January 2001, *Age and Sex Report*, Sacramento, CA. Mileage estimates are based on1995 data from Federal Highway Administration, 1999, *Summary of Travel Trends: 1995 Nationwide Personal Transportation Survey*, Washington, D.C.: U.S. Department of Transportation.

Figure 13. Fatal accident involvement rate per driver per 100,000 miles by age and sex.

The mileage-adjusted F/I and fatal accident rates show the following:

- As with total accidents, the youngest and oldest drivers have the highest mileage-adjusted F/I and fatal accident rates, compared to middle-aged drivers.

- For combined sexes, mileage-adjusted F/I accident rates decline from the teenage years through about age 54. Thereafter they rise gradually, the increase becoming relatively steep between age groups 80-84 and 85+. Nevertheless, the mileage-adjusted F/I crash rate for drivers aged 85 or more remains less than that for drivers through age 24.

- For combined sexes, mileage-adjusted fatal accident rates decline from the teenage years, reaching a low point that is sustained from ages 30-34 through ages 65-69. They rise after that, with the male rate at ages 85 and above exceeding, and that for combined sexes equaling, the rate for teenagers.

Had-Been-Drinking (HBD) Drivers in Fatal/Injury and Fatal Accidents

The HBD indicator is put on an accident report by the investigating officer to indicate that an involved driver has been drinking and is still under the influence of alcohol (with a blood alcohol level of .08% or more, or as determined by the officer from other evidence when blood alcohol is lower than .08%), had been drinking but is not under the influence of alcohol, or had been drinking but the degree of alcohol impairment is unknown by the officer. (The last possibility may arise, for example, if the driver is unconscious after the accident.) The term “HBD driver” will be used here to refer to a driver involved in an accident where some type of HBD indicator was put on the accident report because he or she had been drinking—and for brevity, the accidents of such drivers will sometimes be referred to here as “HBD accidents.” Table 9 presents the F/I and fatal accident involvement rates of HBD drivers during 2000 by age and sex, and Table 10 gives the corresponding relative involvement indexes for such drivers. Figures 14 and 15 show these data graphically for HBD F/I and HBD fatal crashes, respectively. As before, the Y-axis on the left represents involvement rate per 10,000 licensed drivers, and the Y-axis on the right represents relative involvement index. Data on HBD accidents taking place in 2000 are from California Highway Patrol (2001), and licensing data for 2000, which were used to obtain relative involvement index, are from California Department of Motor Vehicles (2001). A cautionary note is that, due to the small number of HBD fatal accident involvements for the youngest and oldest drivers, particularly the women in those groups, group involvement rates are unstable and may vary considerably from year to year.

Table 9

Had-Been-Drinking (HBD) Drivers in Fatal/Injury and Fatal Accidents Compared to All Drivers Involved in Casualty Accidents, and to All Licensed Drivers, by Age and Sex

	Number of accident-involved drivers			Number of accident-involved HBD drivers			% of accident-involved drivers identified as HBD			Accident-involved HBD drivers per 10,000 licensees		
Accident type Age	Both sexes	Men	Women	Both sexes	Men	Women	Both sexes	Men	Women	Both sexes	Men	Women
Fatal/injury												
16	5,544	2,994	2,550	146	111	35	2.63	3.71	1.37	16.18	24.82	7.69
17	8,041	4,372	3,669	220	182	38	2.74	4.16	1.04	12.65	20.24	4.53
18	12,218	7,204	5,014	468	389	79	3.83	5.40	1.58	17.38	27.20	6.26
19	12,523	7,382	5,141	641	535	106	5.12	7.25	2.06	19.36	30.86	6.72
16-19	38,326	21,952	16,374	1,475	1,217	258	3.85	5.54	1.58	17.06	26.99	6.24
20-24	50,476	29,675	20,801	3,959	3,304	655	7.84	11.13	3.15	22.14	35.76	7.58
25-29	43,063	25,504	17,559	2,944	2,500	444	6.84	9.80	2.53	14.07	22.67	4.48
30-34	41,718	24,578	17,140	2,455	1,959	496	5.88	7.97	2.89	10.15	15.21	4.39
35-39	41,228	23,780	17,448	2,382	1,826	556	5.78	7.68	3.19	9.38	13.70	4.61
40-44	36,714	21,115	15,599	1,997	1,500	497	5.44	7.10	3.19	8.02	11.62	4.14
45-49	29,988	17,469	12,519	1,391	1,085	306	4.64	6.21	2.44	6.28	9.53	2.84
50-54	23,474	14,043	9,431	937	771	166	3.99	5.49	1.76	4.86	7.84	1.75
55-59	15,646	9,332	6,314	532	425	107	3.40	4.55	1.69	3.83	5.92	1.60
60-64	11,053	6,763	4,290	342	271	71	3.09	4.01	1.66	3.29	5.07	1.41
65-69	8,071	4,966	3,105	200	158	42	2.48	3.18	1.35	2.44	3.75	1.05
70-74	6,722	4,025	2,697	170	143	27	2.53	3.55	1.00	2.44	4.10	0.77
75-79	5,551	3,198	2,353	89	72	17	1.60	2.25	0.72	1.60	2.68	0.59
80-84	3,210	1,852	1,358	37	31	6	1.15	1.67	0.44	1.17	2.01	0.37
85+	1,841	1,090	751	14	12	2	0.76	1.10	0.27	0.92	1.61	0.26
All ages	357,081	209,342	147,739	18,924	15,274	3,650	5.30	7.30	2.47	8.88	13.85	3.55
Fatal												
16	64	37	27	7	6	1	10.94	16.22	3.70	0.78	1.34	0.22
17	72	54	18	9	9	0	12.50	16.67	0.00	0.52	1.00	0.00
18	175	117	58	34	26	8	19.43	22.22	13.79	1.26	1.82	0.63
19	172	114	58	35	24	11	20.35	21.05	18.97	1.06	1.38	0.70
16-19	483	322	161	85	65	20	17.60	20.19	12.42	0.98	1.44	0.48
20-24	724	548	176	189	165	24	26.10	30.11	13.64	1.06	1.79	0.28
25-29	555	440	115	145	133	12	26.13	30.23	10.43	0.69	1.21	0.12
30-34	515	390	125	103	83	20	20.00	21.28	16.00	0.43	0.64	0.18
35-39	539	404	135	119	99	20	22.08	24.50	14.81	0.47	0.74	0.17
40-44	497	369	128	83	69	14	16.70	18.70	10.94	0.33	0.53	0.12
45-49	393	283	110	65	56	9	16.54	19.79	8.18	0.29	0.49	0.08
50-54	336	260	76	35	34	1	10.42	13.08	1.32	0.18	0.35	0.01
55-59	215	152	63	29	21	8	13.49	13.82	12.70	0.21	0.29	0.12
60-64	160	122	38	19	16	3	11.88	13.11	7.89	0.18	0.30	0.06
65-69	108	69	39	11	10	1	10.19	14.49	2.56	0.13	0.24	0.03
70-74	134	91	43	15	14	1	11.19	15.38	2.33	0.22	0.40	0.03
75-79	121	83	38	3	3	0	2.48	3.61	0.00	0.05	0.11	0.00
80-84	74	52	22	3	2	1	4.05	3.85	4.55	0.09	0.13	0.06
85+	55	40	15	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00
All ages	4,909	3,625	1,284	904	770	134	18.42	21.24	10.44	0.42	0.70	0.13

Note. Accident data for 2000 from California Highway Patrol, 2001, *2000 Annual Report of Fatal and Injury Motor Vehicle Traffic Accidents*, Sacramento, CA. Licensing data for 2000, used to compute percentages based on number of licensed drivers within age/sex group, from California Department of Motor Vehicles, January 2001, *Age and Sex Report*, Sacramento, CA.

Table 10

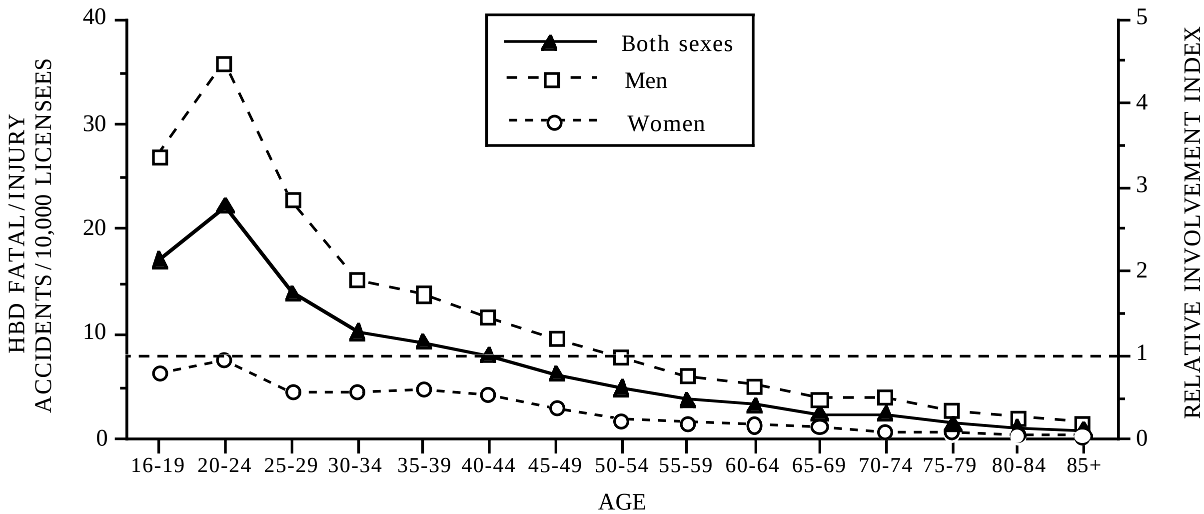
Relative Involvement in Had-Been-Drinking (HBD) Fatal/Injury and HBD Fatal Accidents by Age and Sex

	Group as % of all licensed drivers[a]			Fatal/injury: Group as % of all involved drivers[b]			Fatal/injury: Relative involvement index[c]			Fatal: Group as % of all involved drivers			Fatal: Relative involvement index		
Age	Both sexes	Men	Women	Both sexes	Men	Women	Both sexes	Men	Women	Both sexes	Men	Women	Both sexes	Men	Women
16	0.42	0.21	0.21	0.77	0.59	0.18	1.82	2.79	0.87	0.77	0.66	0.11	1.83	3.16	0.52
17	0.82	0.42	0.39	1.16	0.96	0.20	1.42	2.28	0.51	1.00	1.00	0.00	1.22	2.36	0.00
18	1.26	0.67	0.59	2.47	2.06	0.42	1.96	3.06	0.70	3.76	2.88	0.88	2.98	4.29	1.49
19	1.55	0.81	0.74	3.39	2.83	0.56	2.18	3.47	0.76	3.87	2.65	1.22	2.49	3.26	1.64
16-19	4.06	2.12	1.94	7.79	6.43	1.36	1.92	3.04	0.70	9.40	7.19	2.21	2.32	3.40	1.14
20-24	8.39	4.34	4.06	20.92	17.46	3.46	2.49	4.03	0.85	20.91	18.25	2.65	2.49	4.21	0.65
25-29	9.82	5.18	4.65	15.56	13.21	2.35	1.58	2.55	0.50	16.04	14.71	1.33	1.63	2.84	0.29
30-34	11.35	6.04	5.31	12.97	10.35	2.62	1.14	1.71	0.49	11.39	9.18	2.21	1.00	1.52	0.42
35-39	11.92	6.25	5.66	12.59	9.65	2.94	1.06	1.54	0.52	13.16	10.95	2.21	1.10	1.75	0.39
40-44	11.69	6.06	5.63	10.55	7.93	2.63	0.90	1.31	0.47	9.18	7.63	1.55	0.79	1.26	0.28
45-49	10.40	5.34	5.05	7.35	5.73	1.62	0.71	1.07	0.32	7.19	6.19	1.00	0.69	1.16	0.20
50-54	9.05	4.61	4.44	4.95	4.07	0.88	0.55	0.88	0.20	3.87	3.76	0.11	0.43	0.82	0.02
55-59	6.51	3.37	3.15	2.81	2.25	0.57	0.43	0.67	0.18	3.21	2.32	0.88	0.49	0.69	0.28
60-64	4.88	2.51	2.37	1.81	1.43	0.38	0.37	0.57	0.16	2.10	1.77	0.33	0.43	0.70	0.14
65-69	3.85	1.98	1.88	1.06	0.83	0.22	0.27	0.42	0.12	1.22	1.11	0.11	0.32	0.56	0.06
70-74	3.27	1.64	1.64	0.90	0.76	0.14	0.27	0.46	0.09	1.66	1.55	0.11	0.51	0.95	0.07
75-79	2.60	1.26	1.34	0.47	0.38	0.09	0.18	0.30	0.07	0.33	0.33	0.00	0.13	0.26	0.00
80-84	1.48	0.72	0.76	0.20	0.16	0.03	0.13	0.23	0.04	0.33	0.22	0.11	0.22	0.31	0.15
85+	0.71	0.35	0.36	0.07	0.06	0.01	0.10	0.18	0.03	0.00	0.00	0.00	0.00	0.00	0.00
All ages	100.00	51.77	48.23	100.00	80.71	19.29	1.00	1.56	0.40	100.00	85.18	14.82	1.00	1.65	0.31

[a]Licensing data for 2000 from California Department of Motor Vehicles, January 2001, *Age and Sex Report*, Sacramento, CA.

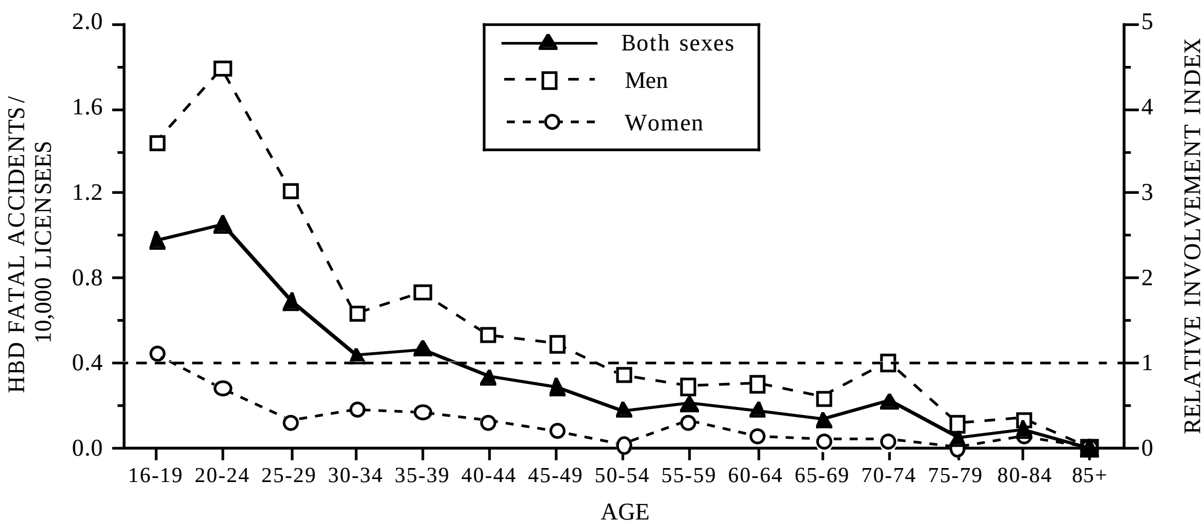
[b]Accident data for 2000 from California Highway Patrol, 2001, *2000 Annual Report of Fatal and Injury Motor Vehicle Traffic Accidents*, Sacramento, CA.

[c]Relative involvement is the accident involvement for the age/sex group as a percent of such involvement for all drivers, divided by the percent of all licensed drivers represented by that group.



Note. Accident data for 2000 are from California Highway Patrol, 2001, *2000 Annual Report of Fatal and Injury Motor Vehicle Traffic Accidents,* Sacramento, CA. Licensing data for 2000 are from California Department of Motor Vehicles, January 2001, *Age and Sex Report,* Sacramento, CA.

Figure 14. Had-been-drinking (HBD) fatal/injury accident involvement rate and relative involvement index by age and sex.



Note. Accident data for 2000 are from California Highway Patrol, 2001, *2000 Annual Report of Fatal and Injury Motor Vehicle Traffic Accidents*, Sacramento, CA. Licensing data for 2000 from California Department of Motor Vehicles, January 2001, *Age and Sex Report*, Sacramento, CA.

Figure 15. Had-been-drinking (HBD) fatal accident involvement rate and relative involvement index by age and sex.

Tables 9 and 10, and Figures 14 and 15, indicate that:

- Drivers aged 24 or younger are the age range most involved in HBD F/I and HBD fatal accidents. The high point of average HBD F/I crash involvement is reached at ages 20-24; thereafter involvement consistently goes down. (Buying or consuming alcoholic beverages does not become legal in California until age 21.)

- The decrease after ages 20-24 is not consistent for HBD fatal accidents, probably because of small numbers' leading to instability, as noted above. However, the high point for men and combined sexes still occurs at ages 20-24, with a marked downward trend after that.

- On the average, the oldest drivers (85+) are the group with the fewest HBD F/I and HBD fatal accident involvements.

- Within each age group, men's average HBD accident involvement substantially exceeds that of women, with the exception of HBD fatal crashes for drivers aged 85 or more, where the male and female rates are both zero.

- Within the group of teenaged drivers, the average involvement rate for young men in HBD F/I accidents is over 4 times that for young women (26.99 vs. 6.24).

- Within the group of teenaged drivers, the average involvement rate for young men in HBD fatal accidents is exactly 3 times that for young women (1.44 vs. 0.48).

Primary Collision Factors in Casualty Accidents

The primary collision factor in an accident is noted by the police officer on the accident report; this notation usually refers to an unlawful action taken by the driver "at fault"—that is, the driver considered by the investigating officer to be most responsible for the accident—or a condition the driver was in, like drunkenness, when the accident occurred. The idea is that without the primary collision factor the accident would have been much less likely to occur—and perhaps would not have occurred. Tables 11 and 12 present the number and percent within age/sex group, respectively, of F/I and fatal accidents during 2000 by primary collision factor and age and sex of the driver at fault.

Table 11

Number of Fatal/Injury and Fatal Accidents by Primary Collision Factor Within Age and Sex of Driver at Fault

Accident type Sex	Primary collision factor[a]	All ages	16-19	20-29	30-39	40-49	50-59	60-69	70-79	80 +
Fatal/injury										
Men	All factors	97,307	14,071	28,381	20,290	15,137	9,130	4,719	3,710	1,869
	Alcohol/drugs	12,183	1,008	4,650	3,016	2,055	946	323	155	30
	Unsafe speed	32,824	5,157	9,615	7,175	5,222	3,000	1,355	869	431
	Wrong side of road	2,503	499	659	476	364	241	116	100	48
	Passing/lane change	4,573	595	1,335	1,000	765	472	207	155	44
	Improper turn	10,311	1,985	2,991	1,852	1,491	916	492	407	177
	Right-of-way	16,885	2,455	4,125	2,989	2,385	1,714	1,206	1,237	774
	Signs/signals	7,817	1,154	2,318	1,470	1,059	747	485	393	191
	Other moving violations	8,154	940	2,151	1,858	1,451	861	414	327	152
	All others	2,057	278	537	454	345	233	121	67	22
Women	All factors	62,058	9,400	16,493	12,948	10,079	5,791	3,114	2,843	1,390
	Alcohol/drugs	2,941	199	832	856	714	226	80	30	4
	Unsafe speed	18,414	3,139	5,152	4,026	2,914	1,586	752	587	258
	Wrong side of road	1,326	231	315	248	208	137	66	74	47
	Passing/lane change	2,719	403	845	560	432	249	124	74	32
	Improper turn	7,926	1,489	2,367	1,482	1,170	631	332	308	147
	Right-of-way	16,086	2,371	3,798	3,057	2,509	1,628	1,043	1,076	604
	Signs/signals	6,018	752	1,479	1,237	982	633	374	399	162
	Other moving violations	5,519	673	1,418	1,241	956	590	281	248	112
	All others	1,109	143	287	241	194	111	62	47	24
Fatal										
Men	All factors	1,867	207	590	369	274	169	83	105	70
	Alcohol/drugs	714	65	290	166	110	46	19	15	3
	Unsafe speed	312	46	88	61	43	39	13	14	8
	Wrong side of road	137	20	40	25	14	10	9	10	9
	Passing/lane change	80	9	20	17	10	13	1	4	6
	Improper turn	286	37	78	51	46	28	15	21	10
	Right-of-way	124	7	17	11	23	9	7	24	26
	Signs/signals	99	13	28	15	13	9	8	8	5
	Other moving violations	69	4	15	18	10	9	5	5	3
	All others	46	6	14	5	5	6	6	4	0
Women	All factors	635	99	146	117	98	57	36	51	31
	Alcohol/drugs	149	19	42	43	27	13	2	2	1
	Unsafe speed	67	19	16	13	6	3	4	2	4
	Wrong side of road	44	5	11	6	7	7	1	4	3
	Passing/lane change	29	3	11	5	5	2	1	1	1
	Improper turn	156	31	42	21	31	12	8	9	2
	Right-of-way	89	8	10	8	9	8	13	18	15
	Signs/signals	49	6	9	8	4	6	4	8	4
	Other moving violations	40	4	5	11	9	5	2	3	1
	All others	12	4	0	2	0	1	1	4	0

Note. Unpublished data for 2000 are from California Highway Patrol's Statewide Integrated Traffic Records System (SWITRS), Sacramento, CA.

[a]The factor "other moving violations" consists of infractions for impeding traffic, following too closely, violating pedestrian right-of-way, starting/backing, improper driving, and falling asleep. The factor "all others" consists of the infractions pedestrian violation, hazardous parking, unsafe equipment, other hazards, and "not stated."

Table 12

Percentage of Fatal/Injury and Fatal Accidents by
Primary Collision Factor Within Age and Sex of Driver at Fault

Accident type Sex	Primary collision factor[a]	All ages	16-19	20-29	30-39	40-49	50-59	60-69	70-79	80+
Fatal/injury										
Men	All factors	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
	Alcohol/drugs	12.5	7.2	16.4	14.9	13.6	10.4	6.8	4.2	1.6
	Unsafe speed	33.7	36.6	33.9	35.4	34.5	32.9	28.7	23.4	23.1
	Wrong side of road	2.6	3.5	2.3	2.3	2.4	2.6	2.5	2.7	2.6
	Passing/lane change	4.7	4.2	4.7	4.9	5.1	5.2	4.4	4.2	2.4
	Improper turn	10.6	14.1	10.5	9.1	9.9	10.0	10.4	11.0	9.5
	Right-of-way	17.4	17.4	14.5	14.7	15.8	18.8	25.6	33.3	41.4
	Signs/signals	8.0	8.2	8.2	7.2	7.0	8.2	10.3	10.6	10.2
	Other moving violations	8.4	6.7	7.6	9.2	9.6	9.4	8.8	8.8	8.1
	All others	2.1	2.0	1.9	2.2	2.3	2.6	2.6	1.8	1.2
Women	All factors	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
	Alcohol/drugs	4.7	2.1	5.0	6.6	7.1	3.9	2.6	1.1	0.3
	Unsafe speed	29.7	33.4	31.2	31.1	28.9	27.4	24.1	20.6	18.6
	Wrong side of road	2.1	2.5	1.9	1.9	2.1	2.4	2.1	2.6	3.4
	Passing/lane change	4.4	4.3	5.1	4.3	4.3	4.3	4.0	2.6	2.3
	Improper turn	12.8	15.8	14.4	11.4	11.6	10.9	10.7	10.8	10.6
	Right-of-way	25.9	25.2	23.0	23.6	24.9	28.1	33.5	37.8	43.5
	Signs/signals	9.7	8.0	9.0	9.6	9.7	10.9	12.0	14.0	11.7
	Other moving violations	8.9	7.2	8.6	9.6	9.5	10.2	9.0	8.7	8.1
	All others	1.8	1.5	1.7	1.9	1.9	1.9	2.0	1.7	1.7
Fatal										
Men	All factors	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
	Alcohol/drugs	38.2	31.4	49.2	45.0	40.1	27.2	22.9	14.3	4.3
	Unsafe speed	16.7	22.2	14.9	16.5	15.7	23.1	15.7	13.3	11.4
	Wrong side of road	7.3	9.7	6.8	6.8	5.1	5.9	10.8	9.5	12.9
	Passing/lane change	4.3	4.3	3.4	4.6	3.6	7.7	1.2	3.8	8.6
	Improper turn	15.3	17.9	13.2	13.8	16.8	16.6	18.1	20.0	14.3
	Right-of-way	6.6	3.4	2.9	3.0	8.4	5.3	8.4	22.9	37.1
	Signs/signals	5.3	6.3	4.7	4.1	4.7	5.3	9.6	7.6	7.1
	Other moving violations	3.7	1.9	2.5	4.9	3.6	5.3	6.0	4.8	4.3
	All others	2.5	2.9	2.4	1.4	1.8	3.6	7.2	3.8	0.0
Women	All factors	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
	Alcohol/drugs	23.5	19.2	28.8	36.8	27.6	22.8	5.6	3.9	3.2
	Unsafe speed	10.6	19.2	11.0	11.1	6.1	5.3	11.1	3.9	12.9
	Wrong side of road	6.9	5.1	7.5	5.1	7.1	12.3	2.8	7.8	9.7
	Passing/lane change	4.6	3.0	7.5	4.3	5.1	3.5	2.8	2.0	3.2
	Improper turn	24.6	31.3	28.8	17.9	31.6	21.1	22.2	17.6	6.5
	Right-of-way	14.0	8.1	6.8	6.8	9.2	14.0	36.1	35.3	48.4
	Signs/signals	7.7	6.1	6.2	6.8	4.1	10.5	11.1	15.7	12.9
	Other moving violations	6.3	4.0	3.4	9.4	9.2	8.8	5.6	5.9	3.2
	All others	1.9	4.0	0.0	1.7	0.0	1.8	2.8	7.8	0.0

Note Unpublished data for 2000 are from California Highway Patrol's Statewide Integrated Traffic Records System (SWITRS), Sacramento, CA.

[a]The factor "other moving violations" consists of infractions for impeding traffic, following too closely, violating pedestrian right-of-way, starting/backing, improper driving, and falling asleep. The factor "all others" consists of the infractions pedestrian violation, hazardous parking, unsafe equipment, other hazards, and "not stated."

Table 12 shows that:

- Unsafe speed is most often the primary collision factor in F/I accidents for men of all ages combined, but its percentage contribution decreases as driver age increases. Violation of right-of-way becomes increasingly important in causing collisions, and becomes dominant for men aged 70 or more. This frequently involves crashing while trying to make a left turn, probably the most challenging maneuver for older drivers in general (Staplin & Lyles, 1992).

- Unsafe speed (which always refers here to driving too fast; driving too slowly would be cited as “impeding traffic” and is included in the “other” category) is most often the primary collision factor in F/I accidents for women of all ages combined, as well. Violation of right-of-way is a very close second, and its percentage contribution increases as driver age increases. It becomes dominant for women as early as age 50.

- For all ages combined, right-of-way violation accounts for 14% of the fatal crashes of female drivers but less than 7% of the fatal crashes of male drivers, for whom other causes are considerably more important. In order of relative importance, the most important causes of fatal accidents for women are improper turns, alcohol/drugs, and right-of-way violation, while for men the most important are alcohol/drugs, unsafe speed, and improper turns.

Next, Table 13 presents primary collision factor within age group for responsible casualty accidents in the form of percentages. In this way it is like Table 12, but Table 13 does not break out the results separately by sex. Figures 16 and 17 plot the percentages from Table 13.

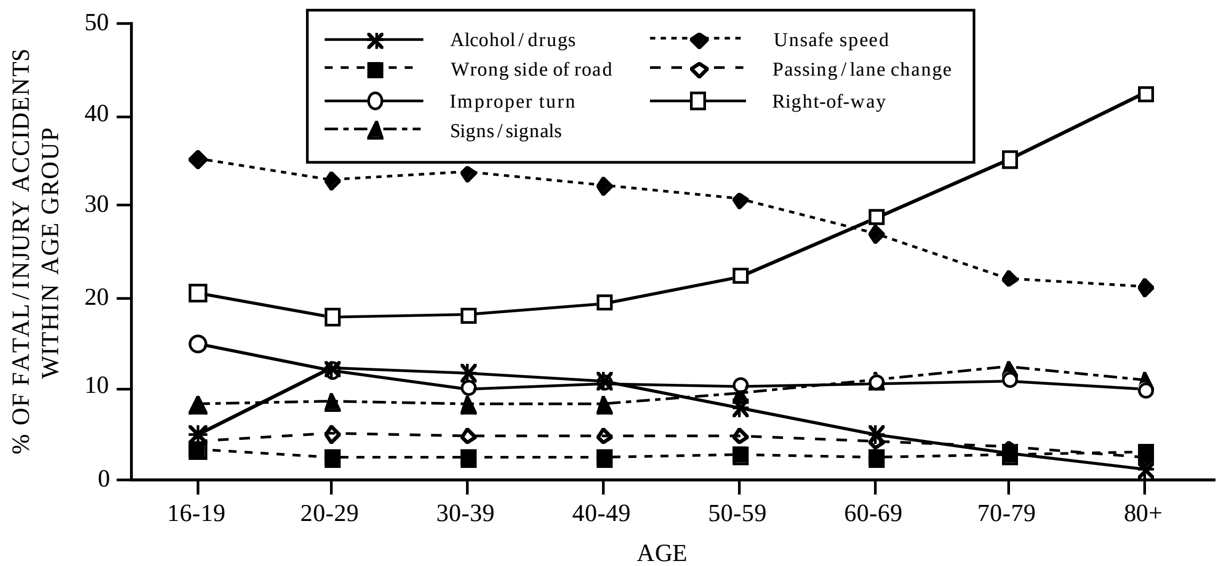
Table 13

Percentage of Fatal/Injury and Fatal Accidents for Combined Sexes by Primary Collision Factor Within Age of Driver at Fault

Accident type Primary collision factor[a]	All ages	16-19	20-29	30-39	40-49	50-59	60-69	70-79	80+
Fatal/injury									
All factors	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Alcohol/drugs	9.5	5.1	12.2	11.6	11.0	7.9	5.1	2.8	1.0
Unsafe speed	32.2	35.3	32.9	33.7	32.3	30.7	26.9	22.2	21.1
Wrong side of road	2.4	3.1	2.2	2.2	2.3	2.5	2.3	2.7	2.9
Passing/lane change	4.6	4.3	4.9	4.7	4.7	4.8	4.2	3.5	2.3
Improper turn	11.4	14.8	11.9	10.0	10.6	10.4	10.5	10.9	9.9
Right-of-way	20.7	20.6	17.7	18.2	19.4	22.4	28.7	35.3	42.3
Signs/signals	8.7	8.1	8.5	8.1	8.1	9.2	11.0	12.1	10.8
Other moving violations	8.6	6.9	8.0	9.3	9.5	9.7	8.9	8.8	8.1
All others	2.0	1.8	1.8	2.1	2.1	2.3	2.3	1.7	1.4
Fatal									
All factors	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Alcohol/drugs	34.5	27.5	45.1	43.0	36.8	26.1	17.6	10.9	4.0
Unsafe speed	15.1	21.2	14.1	15.2	13.2	18.6	14.3	10.3	11.9
Wrong side of road	7.2	8.2	6.9	6.4	5.6	7.5	8.4	9.0	11.9
Passing/lane change	4.4	3.9	4.2	4.5	4.0	6.6	1.7	3.2	6.9
Improper turn	17.7	22.2	16.3	14.8	20.7	17.7	19.3	19.2	11.9
Right-of-way	8.5	4.9	3.7	3.9	8.6	7.5	16.8	26.9	40.6
Signs/signals	5.9	6.2	5.0	4.7	4.6	6.6	10.1	10.3	8.9
Other moving violations	4.4	2.6	2.7	6.0	5.1	6.2	5.9	5.1	4.0
All others	2.3	3.3	1.9	1.4	1.3	3.1	5.9	5.1	0.0

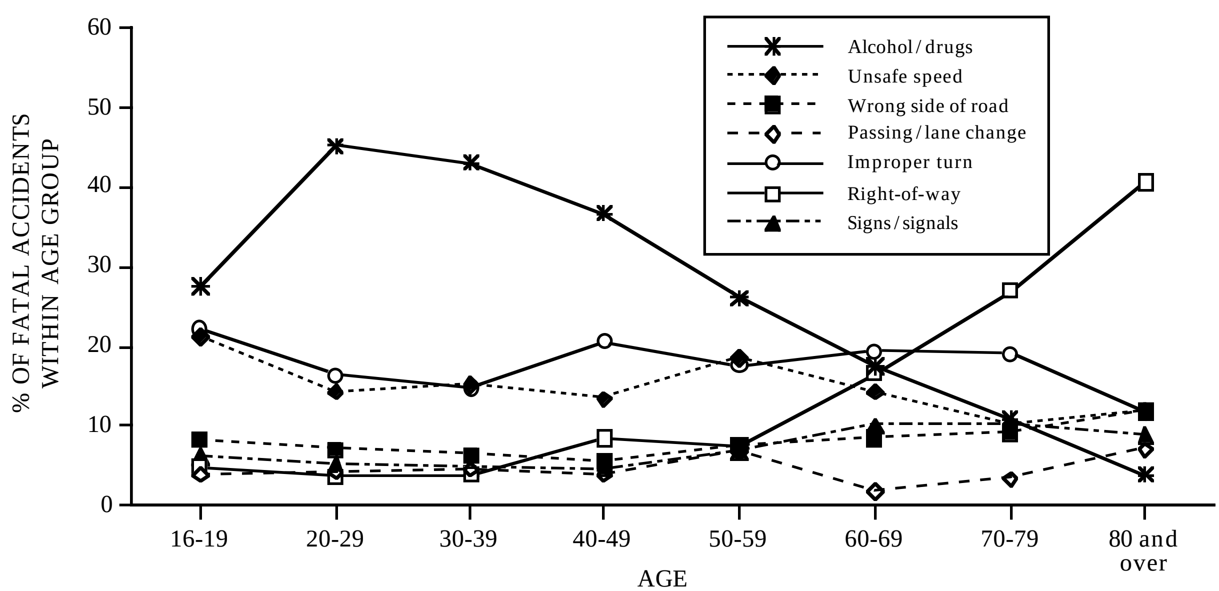
Note. Unpublished data for 2000 are from California Highway Patrol’s Statewide Integrated Traffic Records System (SWITRS), Sacramento, CA.

[a]The factor "other moving violations" consists of infractions for impeding traffic, following too closely, violating pedestrian right-of-way, starting/backing, improper driving, and falling asleep. The factor "all others" consists of the infractions pedestrian violation, hazardous parking, unsafe equipment, other hazards, and "not stated."



Note. Unpublished data for 2000 are from California Highway Patrol's Statewide Integrated Traffic Records System (SWITRS), Sacramento, CA. Percents within age group do not add to 100 because only the most common collision factors were considered.

Figure 16. Percentage of responsible fatal/injury accidents within age group by primary collision factor and age of driver at fault.



Note. Unpublished data for 2000 are from California Highway Patrol's Statewide Integrated Traffic Records System (SWITRS), Sacramento, CA. Percents within age group do not add to 100 because only the most common collision factors were considered.

Figure 17. Percentage of responsible fatal accidents within age group by primary collision factor and age of driver at fault.

The interpretation of Figures 16 and 17 may not immediately be evident. Within each age group, the percentages of that group's responsible F/I or fatal accidents attributable to the seven listed collision factors should add to approximately 90% when summed over all seven factors. (They will not add to 100% because of the exclusion of categories "other moving violations" and "all others," which make up roughly 10% of the total for many groups, especially when considering F/I collisions.) For example, within the age group 80 and above, right-of-way violations account for about 42% of group members' responsible F/I accidents; unsafe speed accounts for 21% (more precise values are shown in Table 13). This is 63% of the group's responsible casualty accidents, while the other types of collision factors or violations play smaller roles. For the age group 30-39, unsafe speed accounts for about 34% of group members' responsible F/I accidents, and right-of-way violation is the next-largest contributor at 18%. These two violation types account for a little more than half of the group's responsible casualty accidents.

Graphs similar to these have sometimes been wrongly interpreted. Therefore it may be useful to stress that, for instance, Figure 16 should not be interpreted as implying that 41% of all casualty accidents are due to the right-of-way violations of drivers aged 80 or more, or that 35% of all casualty accidents are due to the unsafe speed of drivers between 30 and 39. The Y-axis is not percent of total casualty accidents attributable to specified collision factors, nor is it percent of drivers in an age group who are at fault in casualty accidents. It is percent share *within age group* of each specified primary collision factor in directly leading to the responsible casualty accidents of that particular age group's members, and thus it indicates the relative importance of each collision factor within the age group. The same is true for the fatal accident causes shown in Figure 17.

For F/I accidents, the chief primary collision factors are unsafe speed and right-of-way violation. Table 13 and Figure 16 show that:

- Unsafe speed is the most important factor in drivers' F/I crashes when all ages are combined, and in particular for drivers under age 60. Although its importance diminishes with age, it accounts for over 20% of F/I accidents even at ages 80 and above.

- Right-of-way violation exceeds speed by a wide margin as the primary collision factor in F/I crashes of drivers aged 70 or more. Though relatively less important at younger ages, it remains important at all ages as a cause of F/I crashes.

For fatal accidents, the most important primary collision factors and age-related trends are somewhat different from those for F/I accidents. Table 13 and Figure 17 show that:

- For all ages combined and for drivers less than age 60, alcohol/drug use is the predominant cause of fatal accidents. Its importance peaks for the age group 20-29, but even for teenagers—who cannot drink legally—it accounts for over 27% of fatal crashes.

- As with F/I accidents, right-of-way violation is the most important primary collision factor in fatal accidents of drivers aged 70 or more. It first becomes important as a causal factor for drivers aged 60-69, though still exceeded percentagewise at that age by improper turn and alcohol/drugs.

Traffic Violation Patterns and Age

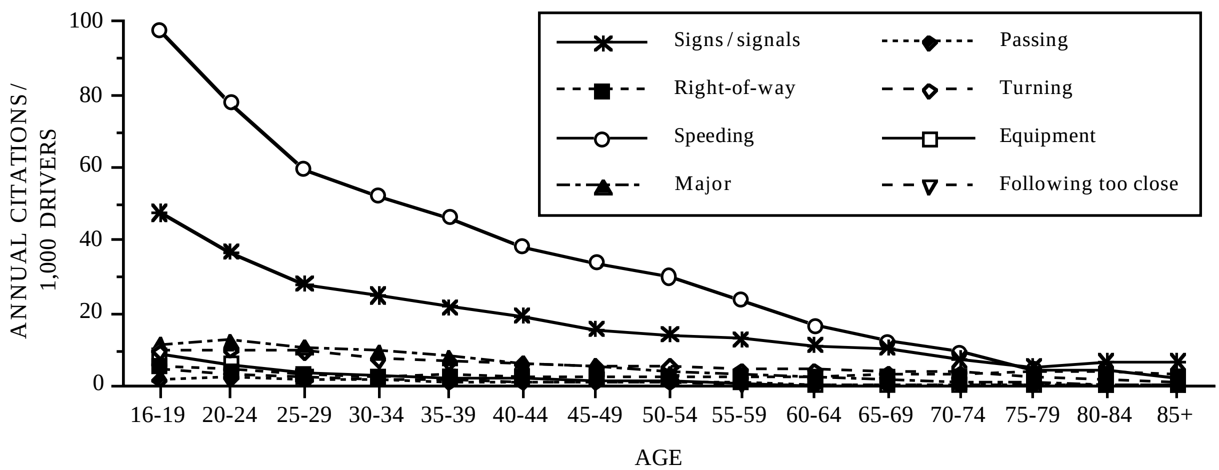
Abstracts of court records of conviction, and notices of citation dismissal contingent on completion of a court-approved program (usually a traffic violator school), are sent by the courts to DMV. These contain information on all violations recorded on traffic citations that arise from one traffic stop. (DMV's count of citations also includes failure of a driver who has not deposited bail to appear in court to answer the charge, and failure of a driver to pay a fine assessed in connection with the charge.) Dismissals in consideration of program attendance can be used for statistical purposes, but unless they become too frequent will not count against the driver in terms of assessing "negligent operator" demerit points or taking action against the license (which may be done based on the number of negligent operator points on the driver's record). Using DMV's citation data, Table 14 and Figure 18 show, by violation type and driver age, the citation rate per 1,000 drivers of selected violations occurring in California from 1996 through 1998. The information is not greatly different from that presented in terms of primary collision factors, since primary collision factors generally are, or imply, violations of traffic laws. But a salient difference is that when a primary collision factor is identified, there must first have been a crash.

Table 14

Average Annual Traffic Citations Per 1,000 Drivers by Violation Type and Driver Age

	Violation type								
Age	Signs/ signals	Passing	Right-of-way	Turning	Speeding	Equipment	Major	Following too close	Total
16-19	47.50	1.67	5.50	9.27	97.17	8.30	11.20	3.87	184.47
20-24	36.93	1.87	4.17	9.50	77.83	6.17	12.07	3.03	151.57
25-29	28.23	1.27	2.73	8.87	59.77	3.53	10.30	2.23	116.93
30-34	24.83	1.47	2.37	7.30	51.87	2.87	9.13	1.80	101.63
35-39	21.83	1.03	2.57	6.50	46.03	2.40	8.03	1.53	89.93
40-44	18.93	1.17	2.30	6.13	38.33	1.83	6.10	1.03	75.83
45-49	15.47	1.00	2.07	5.17	33.80	1.23	5.07	0.80	64.60
50-54	14.00	0.80	2.23	5.10	29.77	1.40	3.33	0.73	57.37
55-59	12.67	0.67	2.20	4.23	23.30	1.17	2.67	0.53	47.43
60-64	11.00	0.50	1.83	3.80	16.47	0.43	2.00	0.20	36.23
65-69	10.40	0.50	2.47	3.13	12.27	0.37	1.37	0.17	30.67
70-74	7.20	0.17	2.67	3.10	8.87	0.27	0.60	0.23	23.10
75-79	5.50	0.00	3.50	1.83	4.80	0.10	0.60	0.17	16.50
80-84	6.40	0.37	3.30	1.47	4.93	0.17	0.17	0.17	16.97
85 +	6.37	0.00	2.90	0.57	2.33	0.00	0.00	0.00	12.17
All ages	22.17	1.10	2.77	6.47	45.20	2.70	6.90	1.50	88.80

Note. Based on the driver records of a 1% random sample of licensed California drivers. Averages represent violations occurring during the years 1996 through 1998.



Note. Based on the driver records of a 1% random sample of licensed California drivers. Averages represent violations occurring during the years 1996 through 1998.

Figure 18. Average annual traffic citations per 1,000 drivers by violation type and driver age.

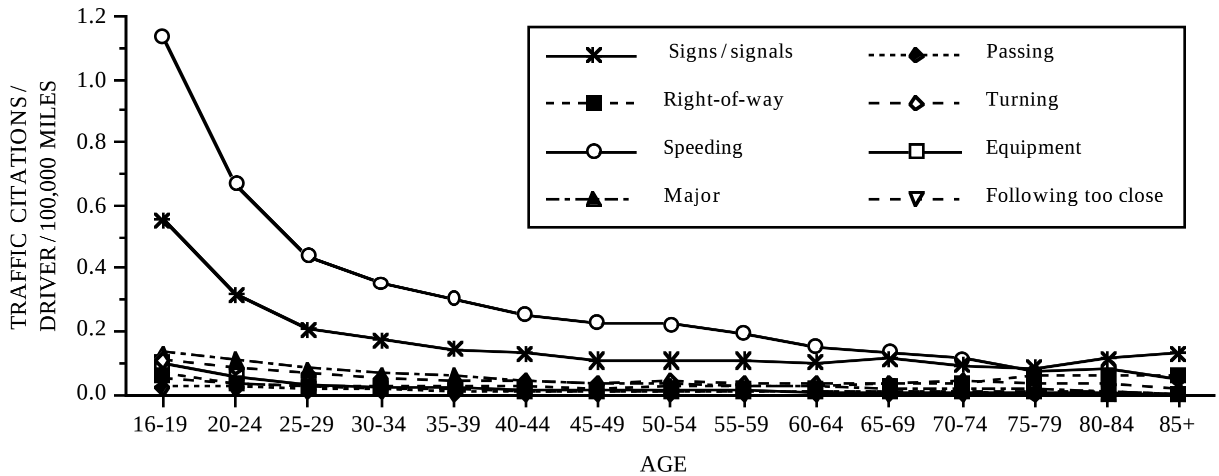
Table 15 and Figure 19 show, by age and violation type, the mileage-adjusted rate of traffic citations per driver per 100,000 miles (or citations per mile times 100,000). Previous remarks relating to the adjustment method still apply.

Table 15

Average Traffic Citations per Driver per 100,000 Miles

	Violation type							
Age	Signs / signals	Passing	Right-of-way	Turning	Speeding	Equipment	Major	Following too close
16-19	0.5548	0.0195	0.0642	0.1082	1.1349	0.0969	0.1308	0.0452
20-24	0.3194	0.0161	0.0360	0.0822	0.6732	0.0533	0.1044	0.0262
25-29	0.2074	0.0093	0.0201	0.0651	0.4391	0.0260	0.0757	0.0164
30-34	0.1676	0.0099	0.0160	0.0493	0.3500	0.0193	0.0616	0.0121
35-39	0.1426	0.0068	0.0168	0.0425	0.3008	0.0157	0.0525	0.0100
40-44	0.1247	0.0077	0.0152	0.0404	0.2525	0.0121	0.0402	0.0068
45-49	0.1063	0.0069	0.0142	0.0355	0.2323	0.0085	0.0348	0.0055
50-54	0.1034	0.0059	0.0165	0.0377	0.2198	0.0103	0.0246	0.0054
55-59	0.1034	0.0054	0.0180	0.0345	0.1901	0.0095	0.0218	0.0044
60-64	0.1018	0.0046	0.0170	0.0352	0.1523	0.0040	0.0185	0.0019
65-69	0.1116	0.0054	0.0265	0.0336	0.1317	0.0039	0.0147	0.0018
70-74	0.0912	0.0021	0.0338	0.0393	0.1124	0.0034	0.0079	0.0030
75-79	0.0828	0.0000	0.0527	0.0276	0.0723	0.0015	0.0090	0.0025
80-84	0.1125	0.0064	0.0580	0.0258	0.0867	0.0029	0.0029	0.0029
85 +	0.1239	0.0000	0.0565	0.0110	0.0454	0.0000	0.0000	0.0000
All ages	0.1636	0.0071	0.0308	0.0445	0.2929	0.0178	0.0400	0.0096

Note. Based on the driver records of a 1% random sample of licensed California drivers. Averages represent violations occurring during the years 1996 through 1998. Mileage estimates are based on data from Federal Highway Administration, 1999, *Summary of Travel Trends: 1995 Nationwide Personal Transportation Survey*, Washington, D.C.: U.S. Department of Transportation.



Note. Based on 1% random sample of California licensed drivers. Averages represent violations occurring during the years 1996 through 1998. Mileage estimates are based on data from Federal Highway Administration, 1999, *Summary of Travel Trends: 1995 Nationwide Personal Transportation Survey*, Washington, D.C.: U.S. Department of Transportation.

Figure 19. Average traffic citations per driver per 100,000 miles by violation type and driver age.

Table 16 presents each violation type as a percentage of total traffic citations issued to each age group. Therefore it is similar to the tables on primary collision factors, showing age differences in the pattern, rather than the number, of violations. In this way Table 16 essentially gives a profile of each age group's traffic citation experience, disregarding the age differences in overall citation rate pictured in Figure 6.

Table 16

Violation Type as a Percentage of Total Traffic Citations for Age Group by Driver Age

	Age														
Violation type	16-19	20-24	25-29	30-34	35-39	40-44	45-49	50-54	55-59	60-64	65-69	70-74	75-79	80-84	85+
Signs/signals	25.75	24.36	24.14	24.43	24.27	24.96	23.95	24.40	26.71	30.36	33.91	31.17	33.33	37.71	52.34
Passing	0.91	1.23	1.09	1.45	1.15	1.54	1.55	1.39	1.41	1.38	1.63	0.74	0.00	2.18	0.00
Right-of-way	2.98	2.75	2.33	2.33	2.86	3.03	3.20	3.89	4.64	5.05	8.05	11.56	21.21	19.45	23.83
Turning	5.03	6.27	7.59	7.18	7.23	8.08	8.00	8.89	8.92	10.49	10.21	13.42	11.09	8.66	4.68
Speeding	52.68	51.35	51.12	51.04	51.18	50.55	52.32	51.89	49.13	45.46	40.01	38.40	29.09	29.05	19.15
Equipment	4.50	4.07	3.02	2.82	2.67	2.41	1.90	2.44	2.47	1.19	1.21	1.17	0.61	1.00	0.00
Major	6.07	7.96	8.81	8.98	8.93	8.04	7.85	5.80	5.63	5.52	4.47	2.60	3.64	1.00	0.00
Following too close	2.10	2.00	1.91	1.77	1.70	1.36	1.24	1.27	1.12	0.55	0.55	1.00	1.03	1.00	0.00
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Note. Based on the driver records of a 1% random sample of California licensed drivers. Averages represent violations occurring during 1996-98. Percentages may not add to 100 due to rounding.

Readers may have noticed that there is no "miscellaneous violation" category in Table 16, and the eight violation types named add up to 100%. These are the types of violations tracked in departmental research involving the 1% random sample. That research is strongly concerned with the relationship between negligent operator point count and driver record, so the collection includes violations that carry different numbers of negligent operator points—2 points for major violations including drunk driving and hit-and-run, 1 point for most of the others listed, which are moving violations but not "majors," and 0 points for equipment violations.

The data in Table 16 are shown graphically in Figure 20.

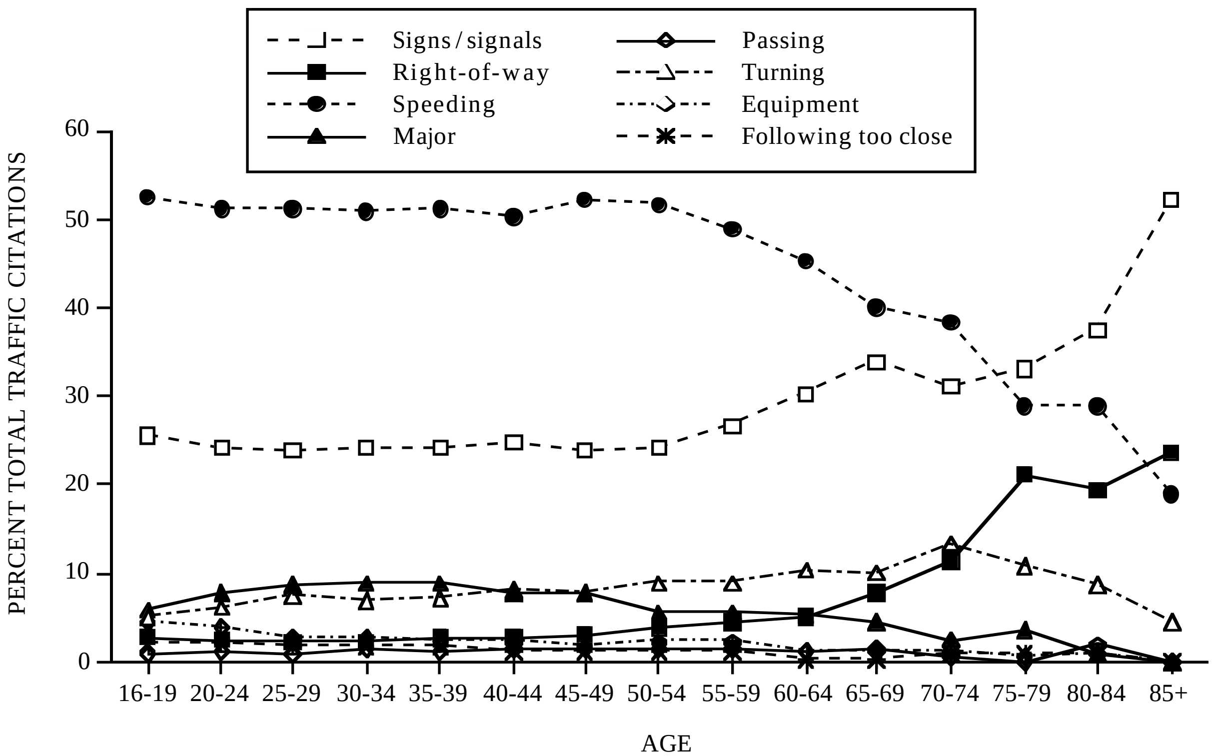


Figure 20. Violation type as a percentage of total traffic citations for age group by driver age.

The above tables and figures indicate that the average annual rates of specific types of cited violations, the average rates of these violations per 100,000 miles, and overall traffic violation patterns, are all related to driver age. The annual and mileage-adjusted rates shown in Tables 14 and 15, and Figures 18 and 19, indicate the following:

- Teenagers have the highest total citation rates annually, and seniors have the lowest. (This was also shown in Table 4 and Figure 6.)

- The average annual rate of unsafe speed citations is high for most age groups but highest among teenagers; it decreases as age increases and reaches a very low value for drivers aged 85 or more.

- Teenagers have the highest average annual rate of citations for disregarding signs/signals, and seniors have the lowest, though in the mileage-adjusted data there is an upswing for this type of violation after age 79.

- Average citation rates for major violations—driving under the influence of alcohol or drugs, hit and run, and reckless driving—are not high when compared with rates for speed and signs/signals violations. But they are highest for drivers under 25 and lowest for seniors.

- For ages 75 and above, signs/signals citations are the type most frequently issued—though, like other citations for this age group, they are not common. Next most frequent within the group are citations for unsafe speed.

Table 16, giving violation percentages within age group, shows the relative importance of specific cited violation types at different ages. Since the contributions of the various types add to 100% for each age group, the percentages (as discussed above) cannot be used to infer that one age group shows a higher rate of a particular type of violation than another. Nevertheless the patterns are interesting in themselves. Table 16 and Figure 20 show that:

- Speeding is unquestionably the dominant violation leading to citation for most age groups. Although its percentage contribution decreases as driver age increases, it is an important contributor for all groups.

- Signs/signals citations are the second most common type for most age groups, and become the dominant one for drivers aged 75 or more. They account for over half of the oldest (85+) group's citations.

- The relative importance of right-of-way violations is not great for drivers under age 75, but thereafter it remains fairly high. These violations are the second-highest generator of citations for the oldest (85+) group.

- Even at advanced ages, right-of-way violations are either overshadowed or closely rivaled by signs/signals violations and speeding. This is despite the important role of right-of-way violation as a primary collision factor in casualty accidents.

- Major violations like drunk driving, which constitute less than 9% of the citations within each age group, peak in their percentage contribution for drivers between 25 and 39. They are a negligible percentage of the total for drivers aged 75 or more.

Unsurprisingly, the above information on violation patterns will be seen as mostly consistent with the information on primary collision factors presented in Table 13. But the role of right-of-way violation is a particularly interesting discrepancy. This is not a large share of total citations but, as discussed above, it is the most important collision factor in responsible fatal accidents of drivers aged 70 or more and is important for all age groups as a cause of F/I crashes. Right-of-way violation also is a cause of responsible fatal accidents for women twice as often as for men. If it does not appear to be frequently cited, the reason may be that a citation for right-of-way violation is rarely issued unless the violation has caused an accident.

Arrests for Driving under the Influence of Alcohol/Drugs (DUI) and Hit-and-Run

Table 17 shows the relative involvement indexes for DUI and hit-and-run felony and misdemeanor arrests in 1991 by driver age; arrest data come from the California Department of Justice (DOJ; 1992). As mentioned in the preceding section, DUI and hit-and-run are both classified as major violations, counting for two negligent operator points on a driver's record as opposed to the single point assessed for most moving violations.

In California, neither purchase, possession, nor consumption of alcoholic beverages is legal until age 21. Therefore one might think that driving under the influence of alcohol would be negligible for teenagers. But a DUI conviction can be given on the basis of drug impairment alone, and even if there is no question of drugs, a minor can be convicted on a quasi-DUI charge (juvenile offense involving alcohol while driving, California Vehicle Code Section 23140) at a .05% blood alcohol level, considerably lower than the .08% level used for an adult. Unlike DUI, which is either a misdemeanor or a felony, the offense is considered an infraction, but conviction entails a 1-year license suspension. For simplicity, juvenile alcohol offenses while driving will generally be referred to in the following as DUI. Teenagers incur a substantial number of DUI convictions, and there is evidence that alcohol, in quantities above the legal limit for minors, is involved in most of them. Data for the year 2001 (Tashima & Helander, 2003) showed a blood alcohol concentration, or BAC, for approximately 6,000 convicted DUI offenders under age 21. The BACs of these offenders had an average value of 0.137%, 1.71 times higher than the 0.08% BAC level defining *per se* impairment (meaning that the BAC level *in itself* is sufficient evidence of impairment) for adults in California. It is 2.74 times higher than the 0.05% BAC level used for minors convicted of juvenile alcohol offenses. (The lower illegal BAC level for minors will be discussed more fully in the section Crash Countermeasures for Teenaged Drivers.) In fact, over 95% of these minors had BACs of 0.08% or above.

In addition to a possible conviction, there is a much more certain and immediate administrative penalty, driver license suspension, that follows arrest of adults (people aged 21 or more) with .08% of alcohol in their blood, and minors with .01% (California Vehicle Code Section 13353.2). A notice of "administrative per se" (APS) suspension is served at the time of arrest by the arresting officer; this notice contains the reason for and effective date of the suspension, along with other information. DMV subsequently determines what the facts of the case were, and takes the suspension if those facts are in order. DMV's determination of the facts, and its subsequent action, are civil matters, completely separate from the person's later conviction or acquittal on the DUI charge. Drivers who were arrested for DUI or hit-and-run, whether or not they were acquitted of the charge, appear in the data of Table 17 and Figure 21, below. Figure 21 plots, by age group, the relative involvement indexes from Table 17.

Table 17

Relative Involvement as Arrestee for Driving Under the Influence of Alcohol / Drugs (DUI) or Hit-and-Run by Age

Age	% of licensed drivers[b]	DUI[a]						Hit-and-run					
		Felony			Misdemeanor			Felony			Misdemeanor		
		Number[c]	%	Relative involve-ment index[d]	Number	%	Relative involve-ment index	Number	%	Relative involve-ment index	Number	%	Relative involve-ment index
16	0.42	38	0.64	1.51	464	0.25	0.58	72	3.60	8.51	369	4.91	11.60
17	0.82	52	0.88	1.07	993	0.53	0.65	60	3.00	3.68	268	3.57	4.37
18	1.26	135	2.28	1.80	3,302	1.76	1.39	99	4.95	3.92	401	5.34	4.22
19	1.55	180	3.04	1.95	4,878	2.59	1.67	84	4.20	2.71	389	5.18	3.33
16-19	4.06	405	6.83	1.68	9,637	5.12	1.26	315	15.77	3.89	1,427	19.00	4.68
20-24	8.39	1,089	18.37	2.19	36,118	19.20	2.29	430	21.52	2.56	1,368	18.21	2.17
25-29	9.82	882	14.88	1.51	31,813	16.92	1.72	292	14.61	1.49	836	11.13	1.13
30-39	23.27	1,559	26.29	1.13	51,258	27.26	1.17	349	17.47	0.75	1,249	16.63	0.71
40-49	22.08	998	16.83	0.76	32,804	17.44	0.79	189	9.46	0.43	677	9.01	0.41
50-59	15.57	393	6.63	0.43	12,258	6.52	0.42	56	2.80	0.18	309	4.11	0.26
60+	16.81	198	3.34	0.20	4,543	2.42	0.14	52	2.60	0.15	219	2.92	0.17
All ages	100.00	5,524	100.00	1.00	178,431	100.00	1.00	1,683	100.00	1.00	6,085	100.00	1.00

[a]Includes juvenile offenses involving alcohol; see text.

[b]Licensing data for 2000 are from California Department of Motor Vehicles, January 2001, *Age and Sex Report*, Sacramento, CA.

[c]Arrest data for 2000 are from California Department of Justice, 2001, *2000 Statewide Criminal Justice Profile*, Sacramento, CA.

[d]Relative involvement is arrest involvement in the age / sex group as a percent of such involvements for all drivers, divided by the percent of all licensed drivers represented by that group.

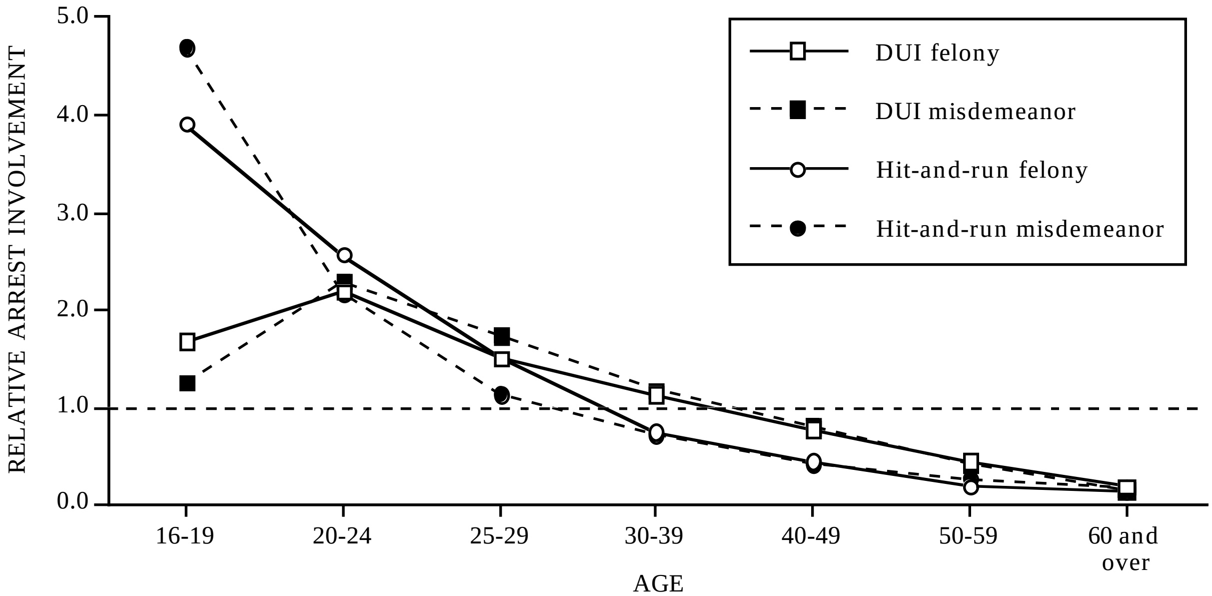
Table 17 shows that teenaged drivers as a group have a relative involvement index for DUI felony arrest—where there was a crash involving bodily injury—that is the second-highest among age groups, exceeded only by the index for drivers aged 20-24. For misdemeanor DUI arrest, the relative involvement index for teenagers as a group is the third-highest. The highest index for both types of DUI offense is for drivers aged 20-24. (Those who are 20 years old are, like teenagers, under the minimum legal drinking age and for conviction purposes need only have a BAC of 0.05%—for administrative suspension purposes a BAC of .01%—rather than 0.08%. Therefore this subgroup may be more similar to 19-year-olds than to drivers of an age to drink legally. However, both 19-year-olds and drivers aged 20-24 are relatively high-risk groups for DUI and DUI crashes.) Figure 21 displays the relative involvement indexes from Table 17.

Figure 21 shows graphically that:

- Relative involvement as an arrestee for DUI is relatively high for teenagers and highest at ages 20-24. It steadily declines thereafter, and the relative involvement of drivers aged 60 or more is close to zero.

- Teenagers have by far the highest relative involvement as arrestees for felony and misdemeanor hit-and-run. (This finding reflects alcohol-impaired behavior to some extent, because hit-and-run violations are frequently committed by drivers identified by the officer as HBD.)

- Hit-and-run arrest risk declines steeply with age. As with DUI, the relative hit-and-run arrest involvement of drivers aged 60 or more is close to zero.



Note. Arrest data for 2000 are from California Department of Justice, 2001, *2000 Statewide Criminal Justice Profile,* Sacramento, CA. Licensing data for 2000 are from Department of Motor Vehicles, January 2001, *Age and Sex Report,* Sacramento, CA. The relative involvement index is the arrest involvement for the age group as a percent of such involvement for all drivers, divided by the percent of all licensed drivers represented by that group.

Figure 21. Relative involvement as arrestee for driving under the influence of alcohol / drugs (DUI) or hit-and-run.

RESEARCH AND COUNTERMEASURES

Research on Teenaged Drivers

The high average crash rate for teenagers as a group, shown for example in Table 3, is due to a number of factors. In the early stages of learning these include a fundamental lack of driving skill, but evidence suggests that poor vehicle control skills account for only 10% of teenaged novice driver crashes; the remaining 90% are accounted for by factors like inexperience, immaturity, inaccurate risk perception, overestimation of driving skill, and risk-taking (Edwards, 2001). Research addressing factors that contribute to the young driver group's high crash rate is discussed in this section of the report. The following section will describe countermeasures used to reduce their risk.

<u>Hazard Perception, Risk Perception, and Risk-Taking</u>
Teenagers are generally quick to learn the basic vehicle handling skills and knowledge they need to drive. But it takes much longer, and requires more varied experience, for them to develop the higher-level skills of hazard perception and risk perception in the driving environment (Arnett, 2002; Deery, 1999; Hall & West, 1996). As it applies to driving, hazard perception depends upon perceptual and information-gathering skills, and involves properly identifying stimuli as potential threats. Risk perception involves

subjectively assessing the degree of threat posed by a hazard, and one's ability to deal with that threat (Deery, 1999).

Hazard perception. Mayhew and Simpson (1990, 1995) studied hazard perception in novice drivers who were not necessarily young. They found that novices in general tend to scan a smaller portion of the road, both in front and to the sides of their vehicle. Novices are also more likely to focus on individual details of the driving environment, and to respond to particular features of the situation independent of other information available to them (Benda & Hoyos, 1983; Milech, Glencross, & Hartley, 1989). For instance, they may always react the same way to another driver's waving them ahead, regardless of potential threat or the lack of it from other traffic. More experienced drivers tend to view the driving situation as a whole, and their reactions take into account the multiple factors involved in any particular driving situation. Young novices also tend not to be as skilled as more experienced drivers in rapidly detecting potentially hazardous traffic situations; despite characteristically short reaction times in most situations, they react slower to hazards pictured in driving simulations and may fail to detect these hazards altogether (Egberink, Lourens, & van der Molden, 1986; Summala, 1987).

Risk perception. Young drivers tend to underestimate the crash risk in hazardous situations and overestimate their ability to avoid the threats they identify (Deery, 1999; Finn & Bragg, 1986). For example, young males tend to underestimate the danger in high-risk driving situations that require fast reflexes or skilled vehicle handling, since they are confident in their abilities. They also rate higher-risk driving conditions, such as darkness and banked roadways, and dangerous driving behaviors, such as tailgating, speeding, and driving after drinking, as less risky than older drivers do (Matthews & Moran, 1986; Tränkle, Gelau, & Metker, 1990). Young male drivers consider themselves to be more skillful than either their age peers or older drivers, and less likely to be involved in a crash (Finn & Bragg, 1986; Matthews & Moran, 1986). Overconfidence of teenagers in their driving abilities may result from the fact that they tend to develop basic vehicle control skills quickly, and therefore conclude prematurely that they are highly skilled drivers (Brown, 1982). Higher crash rates may result because higher-level perceptual and judgmental skills are not adequately developed, yet overconfidence and an inclination to take risks (see below) result in teenagers' placing inappropriate demands on their driving abilities, given their inexperience (Brown, 1982; Deery, 1999).

Risk taking. As a result of immaturity, inexperience, and other factors, teenagers (especially males) tend to take more risks while driving. In fact, most evidence suggests that risk-taking is the most important factor underlying the high crash rate of teenaged drivers as a group (Williams, 2001). Young drivers are more likely to engage in risky behaviors like speeding, tailgating, running red lights, violating traffic signs and signals, making illegal turns, passing dangerously, failing to yield to pedestrians, not wearing seat belts, and driving after heavy drinking or marijuana use, all of which increase their crash risk (Irwin, 1996; Retting, Ulmer, & Williams, 1999; Williams & Ferguson, 2002; Wasielewski, 1984). Of the behaviors listed above, speeding, in particular, is strongly associated with youth (Williams & Ferguson, 2002). When young drivers crash, the types of crashes in which they are overinvolved also suggest risky driving. They include those involving a single vehicle (where its driver is almost always at fault) or those caused by driver error, intersection violations, speeding, following too closely, disobeying a traffic sign or signal, and passing dangerously (Kirk & Stamatiadis, 2001; McGwin & Brown, 1999; Williams, Preusser, Ulmer, & Weinstein, 1995). In addition, young drivers are more likely than other age groups to be judged at fault in serious head-on, rollover, and rear-end crashes—types of crashes that can result from poor judgment or reckless behavior (Richardson, Kim, Li, & Nitz, 1996).

Ample evidence suggests that the risky driving of teenagers may be part of a general risk-taking lifestyle (Gregersen & Berg, 1994; Swisher, 1988). For instance, teenagers who engage in risky activities outside the driving situation—for example, smoking, drug use, heavy drinking, and staying up late for whatever reason—tend to have a higher incidence of traffic crash involvement, *whether they are driving the vehicle or riding as a passenger* (Beirness, 1996; Beirness, Simpson, & Mayhew, 1992). This suggests that risky driving may be part of a more general pattern of risk-taking behavior (Swisher, 1988).

Inexperience, Immaturity, and Their Interaction

On the other hand, teenage driving behavior that looks like intentional risk-taking may not always be. It may be rather a result of young people's failure to appreciate the degree of risk in a situation (Arnett, 2002; Williams & Ferguson, 2002). In fact, the majority of evidence suggests that driving inexperience is the second most important factor, after risk-taking, making young drivers more likely to crash. Immaturity and inexperience can act together in causing accidents, as when young novice drivers take risks because of their immaturity, get into a hazardous situation, and then fail to avoid a crash because of their inexperience (Mayhew & Simpson, 1999; Williams & Ferguson, 2002). Immaturity and inexperience may also have different impacts on crash risk at different times in a teenager's driving career. There is evidence that crashes occurring earlier during licensure for novice drivers are due more to inexperience, whereas those that occur later are due more to risk-taking (Cooper, Pinili, & Chen, 1995; Harre, Brandt, & Dawe, 2000). These studies suggest that the effect of inexperience overshadows the effect of immaturity in causing teenagers' high crash risk in the first year of driving, while the effect of immaturity becomes the more important of the two later on, when they are somewhat older.

Some studies have tried more explicitly to disentangle the contributions of immaturity and inexperience in producing crashes. In the usual course of events, it is hard to separate the two factors. The most dangerous period of driving for teenagers is immediately after they have been licensed, particularly in the first month; that is also when they are youngest (most immature) and also most inexperienced (Mayhew, Simpson, & Pak, 2000; McCartt, Shabanova, & Leaf, 2003). Over a longer period of time, crash rates have been shown to decline with increasing age, and the increased driving experience and decreased immaturity that come with it, until old age is reached (Harrington, 1972; Mayhew, 2003; Mayhew & Simpson, 1999).

In an early DMV study that tried to disentangle the two, Ferdun, Peck, and Coppin (1967) analyzed the records of drivers aged 16 through 19. Experience was measured by total miles driven in life and months of licensure. Immaturity was measured indirectly by controlling all available variables which were related to age but not considered to indicate immaturity; any remaining relationship between age and driving record was attributed to immaturity. For males, as experience increased, violation rate increased, but experience was not related to crashes. As maturity (age) increased, crash rate decreased but violation rate still tended to increase, though not significantly. For females, as experience increased, violation rate again increased but crash rate decreased, while immaturity (age) was not related to either crashes or violations. The authors suggested that increasing experience may lead to increased confidence and therefore less compliance with traffic laws. Drivers with little experience lack confidence as well as defensive driving skills; they obey laws better, but lack the skill to avoid crashes as well as more experienced drivers do.

In a follow-up to the Ferdun et al. study, Harrington (1972) found that the average crash rate for males reached its peak in the second year of driving and then declined, while for females it declined from the first year on. Even though mileage increased across years, there was no corresponding increase in crashes. In contrast, the average traffic conviction rate rose "dramatically" for both sexes until the third year of driving, and then declined. Harrington concluded that young drivers learn a great deal about crash avoidance with increasing practice (experience), but seem to show little change in their attitudes toward the traffic laws until the fourth year of driving. The findings of both Ferdun et al. and Harrington suggest that immaturity is a stronger factor than inexperience in teenagers' violation rates and inexperience is a stronger factor than immaturity in their crashes. Immaturity cannot be discounted entirely as a factor in teenage crashes, however. Even among beginning drivers who all ranged in age between 18 and 20, the younger ones had higher crash rates in the first 6 to 18 months of driving than did the older ones (Laapotti, Keskinen, Hatakka, and Katila, 2001). All of these new drivers were inexperienced, but the crash rates of immature beginners were higher than those of more mature beginners.

Situations of Special Driving Risk for Teenagers

There are also situations in which teenagers have especially high risk. Although the teenaged group has average crash rates that are higher than those of most other age groups under most conditions, their crash rates are disproportionately high on weekends, at night, and when carrying passengers (Mayhew & Simpson, 1999; Williams, 2003). Some of these situations are discussed below.

Carrying passengers. When drivers (of any age) carry passengers, clearly more people are at risk of injury or death if a crash occurs. But over and above that, for teenagers the risk of being in a crash increases as well. Chen, Baker, Braver, and Li (1999, 2000) indicated that the fatality risk of drivers aged 16-17 is 3.6 times higher when they are transporting passengers than when they drive alone, and that the relative risk of a fatal crash increases as the number of passengers increases. When teenagers drive with three or more passengers, their crash risk is about 4 times greater than it is without passengers (Williams, 2003). Even for drivers as mature as 24, risk increases when passengers are carried. What is striking about this is that the relationship apparently does not hold for other age groups. For drivers aged 25-29 there is no increase in risk, while for drivers aged 30 and above there is decreased risk (Preusser, Ferguson, & Williams, 1998; Vollrath, Meilinger, & Kruger, 2002). Passengers who are age peers may encourage teenaged drivers to take more risks, and this may be especially true for young males riding with other young males (McKnight, 1996; Reagan & Mitsopouls, 2001).

Night driving. This is another especially risky situation for young drivers. Teenagers do not drive much at night; partly for that reason alone but more importantly for other reasons, their per-mile fatal crash risk is very high after 9:00 p.m. (Lin & Fearn, 2003; Williams & Preusser, 1997). The latter authors found that per-mile crash rates for teenaged drivers are 3 times higher after 9:00 p.m. than they are during the day. Williams (2003) expressed the opinion that the higher crash risk for teenagers at night may be because the task of driving is more difficult at night; they have had less experience driving at night than during the day; they are sleep-deprived, and/or because teenage recreational driving, which often involves alcohol, is more likely to occur at night. Overall, the highest crash rates for 16- to 19-year-old drivers occur when they carry passengers at night (Doherty, Andrey, & MacGregor, 1998).

Alcohol use. Driving under the influence of alcohol and/or drugs is a common cause of serious crashes, especially fatal ones (see Figure 17 for California data). The prevalence of alcohol involvement in crashes decreased dramatically during the 1980s (Mayhew, Brown, & Simpson, 1996, 1998). However, only marginal decreases were found in the early 1990s (Simpson, Mayhew, & Beirness, 1995), and alcohol and drug use remain important factors in the high crash risk of young drivers—including teenagers, as Figures 16 and 17 show.

Being below the legal drinking age in most states (including California), teenagers are less likely than some older age groups to drink and drive, and when tested by law enforcement are less likely to have high blood alcohol concentration (BAC) levels (Mayhew, Donelson, Beirness, & Simpson, 1986). But those who do drink and drive are at much greater risk of serious collisions than are older drivers with equal concentrations of alcohol in their blood; impairment and crash risk increase relatively faster for younger drivers than for older ones as BAC levels increase (Mayhew et al., 1986).

Figure 17 shows that, in California, driving under the influence of alcohol or drugs causes the highest percentage of fatal crashes for all driver ages below 60. Recent studies have found that 52% of the fatal crashes of young drivers aged 18 to 25 involved alcohol, with 82% of these young drivers having BAC levels greater than 0.08%, the legal limit in California and most other jurisdictions (Mayhew, Brown, & Simpson, 1996, 1998). The majority of teenagers' alcohol-related fatal and injury crashes occur during nighttime hours (9:00 p.m. to 6:00 a.m.) and on weekends (Mayhew & Simpson, 1999). The cumulative effect of lack of experience in drinking, lack of experience in driving, and lack of experience in doing these things together may increase their risk, although emerging research suggests that the relatively greater involvement of teenagers in alcohol-related crashes is due not to the group as a whole, or even a majority of it, but to an identifiable subset of teenagers who engage in a pattern of risk-taking behavior (Mayhew, Donelson, Beirness, & Simpson, 1986).

Other drugs. Although persons of all ages who are arrested for drug offenses pose an elevated traffic safety risk up to 2 years after their arrest (Marowitz, 1995), research on specific drugs and their effects on driving is less common than research on alcohol. Also, most studies have concentrated on marijuana. For example, Jessor (1987) found that marijuana use and other delinquent behaviors were associated with higher-risk driving. Ferguson and Horwood (2001) concluded that although marijuana use is associated with increased crash risk for young drivers, the relationship results more from a pattern of youth-related risky behavior than from the effects of marijuana use per se. Patton and Brown (2002) conducted a survey indicating that some teenagers believe it more acceptable to drive under the influence of marijuana than under the influence of alcohol. This suggested to them a need for additional education about the dangers of driving and drug use. The respective roles of marijuana use versus a general pattern of risk-taking in causing crashes have not been disentangled, and there has been little research on other drugs, but the suggestion made by Patton and Brown is an example of one kind of possible crash countermeasure for young drivers. Other possible countermeasures are discussed below.

Crash Countermeasures for Teenaged Drivers

Regardless of the reasons for the high crash and violation rates characteristic of young drivers as a group, it is the responsibility of states and other accountable jurisdictions to attempt to reduce their risk level. Different countermeasures that have been used for teenaged drivers include driver education and training, special licensing procedures for teens (here called modified licensing), curfew laws, driver improvement programs, and "zero-tolerance" (reduced BAC) alcohol laws.

Driver Education and Training

Driver education and training are commonly considered to have safety value for reducing teen crash and violation rates. But although it seems unquestionable that a novice must learn how to drive somehow, and preferably not by trial and error on the highway, the preponderance of scientific research in California and elsewhere does not support formal driver training's efficacy for teenagers (Peck, 1985; Mayhew & Simpson, 2002). It is true that one early California study (Dreyer & Janke, 1979) found a benefit of range training for high-school students. In it, driver training that included practice on an off-street driving range which simulated urban traffic conditions reduced students' crashes during the first year by a third, when the program incorporating range training was compared to standard driver training. Although these findings were promising, the sophisticated driving range used in the study was very costly, and the authors acknowledged that general use of such facilities might not be feasible. Moreover, a very thorough study in Georgia, considered to be definitive, failed to find any long-term beneficial effect, for the trainee group as a whole, of training programs that included range training as well as other types of driver training (Stock, Weaver, Ray, Brink, & Sadof, 1983). Overall, several comprehensive reviews of the relevant scientific literature have concluded that most evidence does not demonstrate a reduction in subsequent crashes and violations for students who complete formal driver training programs of any sort, when compared to students who lack such training (Mayhew & Simpson, 1996, 2002). In addition, formal training often leads to earlier and more widespread licensure of young drivers. When it occurs, this tends to increase their driving and, therefore, to cause excess crashes and violations that outweigh any potential safety benefits gained through the training. If driver education and training are to continue being offered, experts recommend that the courses (a) be redesigned to reduce risk-taking behavior by teaching teenagers how to make good decisions and be aware of risks, (b) include increased parent-supervised driving practice, (c) be integrated with modified teenager licensing programs (see below), and

(d) be multi-stage, with separate courses in the early learner and later transitional stages of licensing (Mayhew & Simpson, 1996, 2002; Williams & Mayhew, 2003).

Modified Driver Licensing

Modified driver licensing programs for novice drivers in various jurisdictions are designed to reduce novices' crash risk by requiring them to gain driving experience under conditions of reduced risk before achieving full licensure. (These programs are sometimes referred to as provisional or graduated licensing programs.) In the case of teenagers, this includes not only reducing their exposure to situations they lack sufficient experience to deal with, but also to situations in which their immaturity puts them at higher risk. Modified licensing programs usually apply to minor novice drivers (those below age 18), and consist of stages these teenagers must pass through before they are considered fully ready to hold regular licenses. For instance, there is a mandatory instruction-permit (IP) period during the first month to first year of driving. In the IP period there must be supervised practice behind the wheel before a transitional license can be granted, and restrictions are usually placed on the transitional license that prohibit driving at night and carrying young passengers. The initial license restrictions designed to keep risk at a lower level are phased out gradually, thus exposing young learner-drivers to higher-risk situations by degrees (Simpson, 2003). Simpson also noted that license control actions like warning letters and license suspensions are sometimes imposed at a lower violation or accident point level than the one used for regularly-licensed drivers. Evaluations in various jurisdictions of modified licensing programs or their separate components have generally found them to be associated with reductions in crashes that range from 4% to 60% (Ferguson, Leaf, Williams, & Preusser, 1996; McKnight, Hyle, & Albrecht, 1983; Preusser, Ferguson, & Williams, 1999). The results of a few such evaluations are described below.

- *California* - This state's first modified licensing program for novice drivers under age 18 was implemented in October 1983. It included a mandatory 1-month instruction period, a teen-parent practice guide, parent certification of behind-the-wheel practice, waiting periods before retaking knowledge or driving tests that were failed, and license control actions at lower violation or accident point counts for teenagers aged 15-17. Hagge and Marsh (1988) evaluated this program and found, when teenage rates were compared with those of drivers aged 24 and older, that the program was associated with 5.3% lower crash rates for 15- to 17-year-olds and 23% lower violation rates for 16-year-olds. The program also decreased the percentage of 16- and 17-year-olds licensed to drive and increased the time they held IPs, thus avoiding excess crashes which might have been caused by early licensure.

  Enhancements to the 1983 program were added by legislation and implemented in July 1998. These included a 1-year driving curfew between 12:00 a.m. and 5:00 a.m., increase of the mandatory IP period from 1 to 6 months; a requirement for parent certification of 50 hours of practice including 10 hours at night, and a restriction that forbade carrying passengers under age 20 for 6 months. Masten and Hagge (2003) evaluated this enhanced program. Based on an analysis of pre- and post-program monthly crash rates, they found no *overall* reduction in total crashes or fatal/injury crashes following program implementation. But their study did find that the program was associated with a 9.3% drop in total crashes, and a 9.6% drop in fatal/injury crashes, that involved drivers aged 15-17 and occurred during curfew hours midnight and 5:00 a.m. They also found that the program was associated with reductions of 6.8% in total crashes, and 13.9% in fatal/injury crashes, that involved drivers aged 15-17 and passengers under 20 years of age.

- *Nova Scotia* - In Canada, Nova Scotia's modified licensing program includes a 6-month IP period (3 months if the applicant completes a driver education course), a restriction barring the carrying of any passenger except an instructor, a restriction barring driving between 12:00 a.m. and 5:00 a.m., and a zero-tolerance alcohol provision for persons under age 21. An evaluation of the Nova Scotia program, comparing it to other jurisdictions that did not have a modified licensing program, suggested an average 24% reduction in per-person (within age group) crash rates for 16-year-olds during the first full year after the program, and an average 36% reduction during the program's second full year (Mayhew, Simpson, & Groseilliers, 1999; Mayhew, Simpson, Groseilliers, & Williams, 2001).

- *Michigan* - Michigan implemented a modified licensing program in 1997. It includes a 6-month IP period, 50 hours of supervised driving practice, and a restriction forbidding driving between 12:00 a.m. and 5:00 a.m. Initial results from an evaluation of the program indicated that it was associated with an average 24% per-person total crash reduction and 25% per-person injury crash reduction for 16-year-old drivers, compared to drivers over the age of 25 (Elliot & Shope, 2003; Shope, Molnar, Elliot, & Waller, 2001). Although the comparison between teenagers and adults did not rule out the possibility that results were due to the continuation of preexisting trends, a large (average 53%) drop in crashes of teenagers during the curfew hours of midnight to 4:59 a.m. strengthened, by its relative size, the evidence that at least some of teenagers' crash reduction was due to the program.

- *North Carolina* - This modified licensing program, also implemented in 1997, required all 15- to 17-year-old license applicants to hold an IP for a full year, an unusually long period. Additionally, teenagers in the program were prohibited from driving without supervision from 9:00 p.m. to 5:00 a.m. Initial evaluation results suggested average reductions for 16-year-old drivers in per-person total crashes (27%), fatal crashes (57%), injury crashes (28%), non-injury crashes (23%), nighttime crashes (43%), and daytime crashes (20%), when minors were compared to adults (Foss, Feaganes, & Rodgman, 2001). Again, the fact that the nighttime reduction was considerably larger than that for total or daytime crashes suggested that the program was at least partly responsible for reduced teenage crash rates.

Curfew Laws

As a component of modified driver licensing programs, night driving curfews appear effective in preventing teenage crashes at night (e.g., Foss et al., 2001; Shope et al., 2001; Ulmer, Preusser, Williams, Ferguson, & Farmer, 2000). Other studies have evaluated the effects of general curfews (i.e., curfews which are not components of a licensing program) on crash rates of teenagers. In their study of four states with general curfews, Preusser, Williams, Zador, and Blomberg (1984) found that crashes during curfew hours that involved 16-year-old drivers were 69% lower in Pennsylvania, 62% lower in New York, 40% lower in Maryland, and 25% lower in Louisiana than in comparison states without curfew laws. Their findings also suggested that longer curfew hours produce greater reductions in crashes, and that the start time of the curfew makes a difference. Showing the effect of start time, Foss and Evenson (1999) reviewed the research literature and found evidence of a fairly consistent 23-25% reduction in nighttime crash injury and fatality rates within jurisdictions having curfews that began before midnight. In contrast, they found no effect on crashes when the curfew began after midnight. The latter finding can be considered consistent with at least one study (Cooper, Pinili, & Chen, 1995) suggesting that the increased crash risk for first-year novice teenagers is higher in the early evening than after midnight while, in contrast, the risk is higher after midnight for second- and third-year young novice drivers. Other researchers have concluded that nighttime curfews should start by 11 p.m. at the latest in order to be truly effective (McKnight, 1986). (It may be worth pointing out that, of the modified licensing programs illustrated above, including California's, only North Carolina's begins before midnight.)

<u>Accelerated Post-Licensing Control Program</u>

Post-licensing control countermeasures—like warning letters, group driver improvement meetings, individual hearings, and license suspension or revocation—have been shown to be effective interventions for licensing agencies to use for reducing the crash and violation rates of licensed drivers in general (Masten & Peck, 2003). But there is some evidence that the traditional countermeasures used for adults are not as effective when used with younger drivers. For example, Jones (1997) compared the effectiveness of standard and "soft-sell" warning letters sent to drivers with a certain number of citations or crashes on their record. He found that both types of letters were effective for reducing crash risk in drivers over age 25, but significantly less effective for drivers younger than age 25.

Imposition of post-licensing control actions at an earlier violation/crash point level than that used for adults is characteristic of modified licensing programs for teenaged novice drivers. There is an intention to intervene before bad driving habits become ingrained. A few studies have evaluated the effect of this sort of accelerated driver improvement program on teenagers, using as a comparison group teenagers who received driver improvement actions at the greater point level applied to all other drivers. One of them, evaluating Oregon's modified licensing program (Jones, 1994), found no added benefit of accelerated driver improvement for teenagers when its results were compared to those of a delayed-intervention program like that used for adults. However, there is other evidence that teenaged recipients of accelerated control show a greater improvement in their crash and/or violation record than do teenagers for whom driver control actions are delayed. California's early modified-licensing program for teenaged novices (like the enhanced program) included accelerated license control actions. When their effect was compared to that of delayed intervention following the adult model, this aspect of the program proved significantly superior in reducing subsequent 2-year total crash and violation rates of teenagers. The finding was also true specifically for teens' fatal/injury crashes. Moreover, accelerated license control actions were increasingly more effective at higher point counts, when sanctions become more stringent (Hagge & Marsh, 1988).

<u>Alcohol Laws for Teenagers</u>

Many jurisdictions have implemented lower allowable BAC limits (sometimes called zero-tolerance laws) for teenagers, which for this purpose includes 20-year-olds. Breaking these laws by being caught anywhere with a measurable BAC (not necessarily while driving) usually results in driver license suspension or in an increase in the age at which the teenager can apply for a driver license (Preusser, 1996). Most evidence suggests that zero-tolerance laws and lower BAC levels for teenagers are effective in reducing their alcohol-related crashes (Hingson, Heeren, & Winter, 1995; Mayhew & Simpson, 1990, 1999). A review of six studies of lowered-BAC laws for young people found that all six, conducted in different jurisdictions, showed reductions in crashes associated with implementation of these laws (Zwerling & Jones, 1999). Estimates of the reductions in crashes and injuries ranged from 10% to 33%, with an average reduction of 20%. In general, the results suggested that where BAC laws were tougher, teen crash reductions were larger.

Research on Senior Drivers

Research on senior drivers has been conducted in at least two major ways. First, for many years there have been studies comparing the average performance of groups of varying ages on sensory, perceptual, motor, and cognitive tasks. The performance records being compared are collected during a single time period; if testing is done in 2002, for example, people who are young in 2002 are compared with people who are middle-aged and people who are old in that year. This method is called cross-sectional. When it is used, average scores for elderly people on most of the tasks studied are generally distinctly poorer than the averages for middle-aged or, particularly, young adult groups. Some of these findings will be presented here. There are also cross-sectional studies comparing the average performance of groups of varying age on specific driving outcome measures—generally crashes or road test performance. The findings for California have been presented above in tables and graphs, but results of studies in other jurisdictions will also be described in this section.

There is another major way to look at the effects of aging. That is to look at people not at the same point in time, like 2002, but to follow groups in time as their members age and see how their performance changes. Different birth-cohorts—for instance, people born in the same decade—may be found to have different average scores when they are compared with people of identical age when tested but born in a different decade. An example would be a comparison of fifty-somethings who were born in the 1940s and tested in 1999 with fifty-somethings who were born in the 1920s and tested in 1979. This sort of investigation uses what is called a longitudinal method; it is difficult to accomplish and not frequently done, but one study that used the method will be discussed briefly.

In the following presentation of disabilities associated with aging, it should be remembered that no one individual will show all the disabilities listed, nor will each person show particular aging-related effects at the same chronological age. What the following does show is that there is a strong tendency for a variety of impairments to become more common within a group of individuals as their aging progresses, so that average group performance tends to decline.

Common Visual Changes

Worsening vision is a major factor contributing to driving difficulty. Most of the sensory input required for driving is visual (Bailey & Sheedy, 1988). Numerous studies have determined that aging is associated with reduced peripheral vision, a need for more light in order to see, and increased difficulty in accommodation, or adjustment of the eyes' lenses for varying distances. Specifically, vision studies have found that:

- The relationship between static visual acuity and age, when the whole life span is considered (Pitts, 1982), takes the form of a curve. Average acuity is extremely poor at birth, improves to about 20/20 during the first year of life, remains relatively constant until about age 50, and then declines increasingly rapidly, with great variability in acuity at the older ages. Some usual physiological causes of the decline are reduction in pupil diameter, browning of the lens, and increased light-scattering by the ocular media—the glassy or watery material that fills the eyeball. Such changes result in greater sensitivity to glare—from, for instance, bright sunlight or vehicle headlights—and in lessened contrast sensitivity which, depending on its severity, can make detection of objects in fog or in low light extremely difficult. Other impairing factors arise from aging-related diseases, including cataracts, diabetic retinopathy, macular degeneration, and glaucoma.

- Additional practical consequences of common aging-related eye changes may be lessened ability to resolve visual detail, as in reading highway signs (Fozard, Wolf, Bell, McFarland, & Podolsky, 1977), and lessened adaptation to changes in light intensity (Kalish, 1982), as in entering or exiting poorly lighted tunnels (Winter, 1985).

- Peripheral vision tends to narrow with increasing age (Kalish, 1982); investigators have reported that the horizontal visual field typically drops from an average of 170 degrees for young adults to an average 140 degrees by age 50 (Retchin, Cox, Fox, & Irwin, 1988). In a much-cited study (Johnson & Keltner, 1983), it was found that drivers with severe visual field loss in both eyes (196 of the 10,000 volunteer driver license applicants studied, or almost 2%) had average accident and conviction rates twice as high as those of the general driving population.

- Perhaps even more important than sensory visual field, as it is commonly measured, is useful or functional field of view (Ball & Owsley, 1993). This can be described imprecisely as the extent of visual field that is available to a person who is focusing straight ahead to perform a visual task, as might be done in driving. If a driver is looking ahead trying, for instance, to gauge the intentions of the driver in front, can that driver simultaneously perceive the approach of a hazard from the side, warning him or her to direct attention there? As this capability gets into the areas of perception and cognition, which are discussed below, it is quite different from sensory visual field. In some sense, it requires attention to be divided between the central task and the periphery, and it is another function that tends to diminish with age and has been related to crash experience in older drivers. Owsley, Ball, Sloane, Roenker and Bruni (1991) measured what they saw as the three primary mechanisms underlying a restricted useful field of view: 1) reduced speed of processing visual information; 2) reduced ability to ignore irrelevant stimuli; and 3) reduced ability to divide attention. They found that, compared to other drivers, those with a severely restricted useful field of view had 3 to 4 times the general accident risk, and were 15 times more likely to be involved in an intersection accident.

- Hennessy (1995) investigated visual/perceptual tests as predictors of crashes in subjects of varying age. After statistical adjustment for sex, age within age group, and mileage, he found that such tests, including modules of the Useful Field of View test, showed crash-predictive value only for drivers aged 70 or more. Hennessy proposed an inadequate-compensation hypothesis to explain this result, positing that "vision-related driver record activity [crashes in this case] will generally be slight up to the ages when, on average, compensation is likely to be less than wholly adequate for <u>worsening</u> impairments of <u>multiple</u> visual abilities critical to safe driving" (p. 29; emphasis his).

For all these reasons, seniors often voluntarily limit or give up driving at night and, more generally, under conditions of reduced visibility (Planek, Condon, & Fowler, 1968). In a more recent study, investigators (Kosnik, Sekuler, & Kline, 1990) questioned elderly people about problems they encountered in performing routine visual tasks and found that most of them were conscious of, and admitted, their visual deficiencies. Additionally, study results showed that seniors who had recently given up driving reported more vision problems, on the average, than did persons of the same age who continued to drive.

<u>Common Perceptual/Cognitive Changes</u>
Driving, since it is a complex decision-making process, is influenced by many cognitive and perceptual factors. One touched on above is the functional or useful field of view. Aside from this, many studies have found that information processing tends to slow as people age, making it more difficult for some senior drivers to choose a course of action and react in a timely manner to hazardous driving situations. Some points from these studies are:

- Searching and scanning is of particular importance in driving, and the process tends to become markedly less efficient with aging (Staplin, Breton, Haimo, Farber, & Byrnes, 1987). In this study, older adults as a group were slower and made more errors than younger ones in finding target stimuli within an array of irrelevant stimuli. In driving, similar situations arise—for example, at non-protected intersections. It is as though there is interference from the many irrelevant stimuli that must be scanned in these search situations, and older people are particularly susceptible to it; such increased susceptibility to interference was cited in a review by Layton (1975).

- Divided attention is required for the processing of multiple stimuli where more than one stimulus is relevant. It has been mentioned before in connection with the useful field of view. Staplin et al. (1987) noted that complex divided-attention tasks, unlike simple ones, show average deficits beginning for groups of subjects in middle or old age. The ability to divide attention is necessary in driving situations where, for instance, a driver may recognize that one stimulus, the traffic light, has turned green for him, but at the same time another stimulus, a red-light runner, is approaching too fast to stop.

- In assessing driving performance with an interactive computer video, Schiff and Oldak (1993) found very little overall difference between age groups in response time when reacting to an event that was expected to happen, but drivers over 65 years of age generally required significantly more time to respond when the event was unexpected.

Effect of Medical Conditions

In addition to the usual normative changes of advancing age, elderly people are much more likely to incur medical problems that increase their accident risk or, if severe enough, influence them to stop driving. Examples are dementia, cardiovascular disease, diabetes, stroke, syncopal episodes, Parkinson's disease, and ailments that primarily affect flexibility, including arthritis and bursitis. Also, medications prescribed for some health problems can themselves have an adverse effect on driving ability, since the medication without undesirable side effects scarcely exists. Recent reviews of what is known about the effect of medical impairments on driving include Dobbs (2002) and Janke (2001a); these do not focus on the elderly alone. Dobbs' review, in particular, is exceptionally comprehensive. Some additional findings on medical conditions and driving that do have a primary focus on the elderly include the following:

- Cooper, Tallman, Tuokko, and Beattie (1993) found in Canada that elderly drivers with dementia were involved in over twice as many crashes, and were more often judged to be at fault, than drivers of similar age without dementia. Additionally, the vast majority of dementia patients involved in accidents continued to drive, and over one third of these had at least one more accident. A more recent study by Lundberg, Hakamies-Blomqvist, Almkvist, and Johansson (1998) found that measurements of cognitive deficits too mild to be called dementia discriminated among three groups—older drivers suspended for crash involvement, crash-free older drivers suspended for moving violations, and older non-suspended drivers with clean driving records (controls). (The study was conducted in Sweden, where all drivers guilty of police-reported moving traffic violations are given a temporary license suspension.) The crash group performed statistically significantly worse than controls on cognitive tests, indicating that the finding was extremely unlikely to be due to chance. This suggested to the authors the importance of cognitive decrements short of dementia in causing crashes of older drivers.

- Stewart, Moore, Marks, May, and Hale (1993) found that a brief loss of vision, macular degeneration (deterioration of central vision and color perception), stroke, Parkinsonism, and eye problems caused by declining general health were significantly related to cessation of driving. They also found that irregular heartbeat, cold feet or legs, bursitis, and protein in the urine (a common sign of renal disease) were significantly associated with accident involvement for those who continued to drive.

- On driving tests, elderly drivers on average performed worse on maneuvers, vehicle handling, safe driving practices, observing, and "driver processing" (that is, gap selection, lane changing, and speed control), when compared to drivers who were younger (Shaffron, Ostrow, & McPherson, 1991). The authors felt that such differences in performance are due in large part to loss of joint and skeletal flexibility, particularly in the shoulders, torso, and neck. In a later study, they also found that many elderly drivers can improve their shoulder flexibility and trunk rotation through exercise (Ostrow, Shaffron, & McPherson, 1992).

Older Driver Safety

The findings above constitute a litany of potential problems lying in wait for aging people who want to drive safely as long as they can. Seniors are largely aware of such problems, and tend to compensate for them by driving less, avoiding driving situations that have become too challenging, like darkness or inclement weather, and in many other ways (e.g., Evans, 1993). Thus most avoid crashing, and the average crash rate per year for California seniors is relatively low (Table 3). That is a finding not limited to this state; Cerrelli (1994), cited by Foley, Heimovitz, Guralnik, and Brock (2002), pointed out that while older drivers nationally have on average about a threefold increased risk of crashing per mile driven, seniors drive markedly less than middle-aged drivers, making their average *annual* risk for crashing equivalent to the latter group's.

Others have found that older drivers as a group do not pose a disproportionate threat to others on the road (e.g., Evans, 2000). Evans studied the risks older drivers face themselves as compared to the threats they pose to other road users, and concluded that renewing the license of a 70-year-old male driver for an additional year poses, on average, 40% less threat to other road users than similarly renewing the license of a 40-year-old male driver. And as Li, Braver, and Chen (2003) wrote, "Much of the public concern about older drivers has to do with perceptions that older drivers are imperiling not only themselves but other people. This concern is not substantiated by this study, which found that crash over-involvement was a minor problem except among the oldest drivers" (p. 234). Their paper, and an earlier one by Dellinger, Langlois, and Li (2002), illustrate a method used previously by Li (e.g., Li & Baker, 1996), in which an overall rate is broken down into separate components for analysis. Dellinger et al. studied U.S. drivers aged 55 or more who were involved in fatal crashes during 1990 or 1995, and divided the rate of fatal crash involvements in the two separate years into three components that could be explored separately. The components were risk of dying given a crash (greater for the very elderly), mileage-adjusted crash rate, and estimated annual mileage per driver. The overall fatal crash involvement rate was conceptualized as being the product of all three. Dellinger et al. found that the relative contributions of annual mileage and mileage-adjusted crash rate to the fatal crash rate were greater than the contribution of risk of dying given a crash, though that risk went up steeply after age 74. Considering the role of annual mileage, mileage was greater in 1995 than in 1990 for all age groups studied, and the mileage-adjusted crash rate for 1995 as compared to 1990 was correspondingly less. Additionally, in 1995 the mileage-adjusted crash rate started to rise only after age 74, in contrast to a 1990 increase that began after age 64.

Li, Braver, and Chen (2003), from whom the quotation above was taken, reported on another application of the method. Noting the high death rates per vehicle-mile of travel (VMT) experienced by the oldest drivers, they asked whether the rates were more attributable to high rates of crashes per VMT or to high rates of driver deaths per crash. No measure of individual exposure was used; instead, driver deaths per VMT were expressed as the product of driver deaths per crash and drivers involved in crashes per VMT. Thus the question of interest was: Are older driver deaths influenced more strongly by their greater musculoskeletal fragility and lesser physiologic reserve, or by overinvolvement in crashes? It should be noted that fatal crashes in which a driver did not die, but someone else did, were not part of their study. (Such crashes *had* been part of the study by Dellinger et al., making interpretation of the crash death rate difficult.)

In the study by Li et al., driver death rates per VMT among both genders were higher for the youngest and oldest age groups than for mid-age drivers, a familiar U-shaped curve. For both men and women, these rates were relatively high below age 30; they were lowest between ages 30 and 59, and started rising appreciably around age 70. They rose sharply after age 74, and were especially high for drivers aged 80 or more.

The fragility indicator, driver deaths per crash, was at its lowest point for teenage males; at its second-lowest point for teenage females. Drivers aged 30-59, grouped together, had fairly low fragility. Fragility started to increase steadily at age 60 for both sexes, with a steep increase beginning at age 80. At ages 80 and above, in fact, the rate of driver deaths per crash was about 5 times the rate at ages 30-59.

The crash overinvolvement indicator, the average rate per VMT of drivers involved in crashes, was highest among teenagers—at least 4 times as high as the rate for drivers aged 30-59. The risk of crash involvement as a function of distance traveled reached a low point at ages 65-69, then increased at ages 70-74 and continued to rise with age, reaching a high point, for drivers aged 80 or more, of about 3 times the rate at ages 30-59.

The relative contributions of fragility and excess crash involvement per VMT in crash deaths of groups of drivers differentiated only by age were the issues of primary interest to Li et al. Within the senior group, people aged 80 or more were on average the most fragile, but also on average the most crash-involved. Among older drivers overall, the authors concluded, fragility—which increased as early as ages 60-64—explained higher proportions of deaths per VMT than crash over-involvement did. In contrast, among drivers younger than 30, an age range when average fragility is at its lowest point, driver death rates per VMT were due almost entirely to excess crash involvement.

As mentioned above, another method of exploring age-group risk is longitudinal analysis, used for example by Evans (1993). In contrast with the more common cross-sectional analyses, in which groups of varying ages are compared at the same point in time, longitudinal analyses follow the same individuals over time as they age. Evans used data on fatal crashes from the years 1975-1990, monitoring the data for birth-cohorts of drivers as they aged over the 16-year period. The youngest cohort was born during 1967-1971; the oldest during 1892-1896. A striking finding was that, when crash rates were inspected for male drivers of the same age but from different birth cohorts, the more recently born drivers clearly and systematically had lower rates. (Data from men were emphasized because the amount and type of driving by women were judged to be still changing rapidly in the period studied.) Evans stated that there is every reason to expect similar ongoing declines in crash fatality rates, due to changes in the many factors that contribute to traffic safety—changes in roadways, vehicles, legislation, enforcement, education, and social norms, among others. These can all be considered crash countermeasures, and a few countermeasures specific to elderly drivers will be discussed below.

Crash Countermeasures for Older Drivers

It was mentioned above that, although many older drivers have impairments that challenge their ability to drive safely, the majority are able to limit their accident risk to a reasonable value by driving more cautiously and by limiting the amount and conditions of their driving. Nevertheless, it cannot be assumed that every elderly person is aware of his or her limitations, knows how to compensate for them in the most effective way, and does so consistently. (The assumption may be especially suspect in the case of cognitively impaired individuals.) If not circumvented by compensatory techniques or removed by treatment (as cataracts, for example, can be), non-trivial limitations can be expected to increase accident risk. Considering this, and the projected great increase in numbers of elderly drivers, policymakers have created proposals for, administrators have implemented, and researchers have evaluated, accident countermeasure programs targeting senior drivers.

Education and Training

- McKnight, Simone, and Weidman (1982) evaluated a training program for older drivers in four states, including California. The program content included such topics as rules of the road, adverse driving conditions, common hazards, older driver characteristics and accident experience, and physical conditions that relate to driving performance (e.g., vision, hearing, reaction time, and medication effects). The program increased knowledge of safe driving practices, traffic rules and regulations, hazardous driving situations, and the effects of aging on driving. But no significant differences in accident and violation rates were found between the training and control groups, so the countermeasure was not shown to be effective.

- In 1987 California initiated a “mature driver improvement program” (MDIP) that allows drivers aged 55 and above to update their driving-related knowledge by completing a classroom driver improvement course. The incentive for participation is automobile insurance premium reduction. The law establishing the program also called for yearly comparisons of the records of drivers who had completed the course and drivers who had not. A series of annual studies submitted to the Legislature (summarized by Janke, 1994a) showed no consistent evidence that the program had reduced accidents, although it did reduce citations among course graduates. The program continues to the present time, but DMV is no longer required to report its results.

- Vision diseases are a specific and very common form of medical impairment in older drivers. Owsley, Stalvey, and Phillips (2003) studied 365 older drivers who were licensed but visually impaired and crash-involved during the preceding year. They were randomly assigned to an educational intervention group or an eye-care-only group acting as a control. The goal of the educational curriculum was to help drivers realize how their impairment might affect their driving and what they could do about it, in terms of avoiding overly challenging driving situations. On a test after 6 months had gone by, drivers in the education group were more likely than controls to acknowledge that their vision was not excellent and reported a higher frequency of self-regulation, which included such practices as making three right turns to avoid a left turn. They also reported driving less, on the average, than controls. Future research, the authors wrote, will study crashes of the two groups in the years following the educational intervention. It should be noted that some of the material taught in the educational treatment was probably similar to that taught in the Mature Driver Improvement Program, which did not reduce crashes. But evidence suggested that one of the unforeseen results of the MDIP may have been an increase in driving leading to increased exposure to risk, and that apparently was not the case here. Also, specific practical techniques like “3 rights make a left” may not be taught in the MDIP.

- Since the best predictor of future traffic accidents and convictions is a person’s past driving record, a current DMV outreach effort is underway, aimed toward drivers aged 70 or more who have had recent (within the past 18 months) crash or violation activity on their records. (These drivers have not accumulated enough points for DMV to classify them as negligent operators and impose sanctions.) Since the consequences of accidents can be so grave for frailer senior drivers, and since their recent traffic incidents might be influenced by declines in health and foreshadow even more serious declines, it was felt that early intervention could be of particular value. Further, education and positive reinforcement seemed appropriate and more likely than threat of punishment to succeed in promoting safer driving. Shara Lynn Kelsey is the principal investigator in this effort.

  A federal grant was obtained through the Office of Traffic Safety to assess the feasibility, acceptance, and benefits of such an outreach. A sample of some 17,000 drivers aged 70 or older with recent incidents on record, and therefore above-average risk of future crashes (Gebers & Peck, 1992) was randomly divided into three groups. One got a letter from the DMV Director; one a letter and a list of resources for elder assistance and information; and the third received both of these, plus a number of elder-targeted pamphlets on vision, drugs (prescription, over-the-counter, herbal supplements, and their potential interactions), bodily flexibility, compensation for age-related declines, defensive driving, and so on. All three groups received a quiz/questionnaire to assess their safety-related knowledge and driving habits; also included was a short assessment of their attitudes toward DMV.

  The materials, some written by the principal investigator and some prepared by NHTSA and the AAA Foundation of Traffic Safety, were mailed out in January of 2003. There was an over-all questionnaire return rate of 54%. Results from the pilot testing revealed a surprising figure: 43% of the respondents owned a computer with Internet access. In another finding, the increased average annual mileage for senior drivers, noted above, was supported by questionnaire results. A number of the respondents not only claimed to drive cars and trucks, but to pilot airplanes as well. It will be interesting to see if analysis of the final data pool confirms these early results. This analysis will compare the relative knowledge of the groups, compile their comments, and follow their driving records for a year subsequent to the mailings. A cost/benefit analysis will be prepared, and the final report is due at the end of 2004.

  A related educational effort being carried out by the same principal investigator is developing a senior web site, which will branch from DMV’s Internet home page. The intent is to collect information on senior issues in one place for ease of access and use by seniors and those concerned with them. Included will be web pages on driver licensing, alternative transportation choices, health, and safety, as well as a How-To section instructing users how to navigate the web and use searches.

Earlier Post-Licensing Intervention

- Gebers and Peck (1992) introduced the idea of an age-mediated "negligent-operator" point system for elderly drivers with recent incidents on their driving records. The negligent-operator program as it presently exists in California assigns points to traffic convictions and at-fault accidents. When a driver of any age has accumulated a certain number of points in a certain period of time, there are sanctions which may be as benign as a warning letter or as severe as license suspension or revocation. Gebers and Peck plotted the expected number of crashes in a subsequent 3-year period against the total number of points accumulated in the preceding 3 years for drivers aged 60-69, 70 and above, and of any age. They found that at the lower point levels older-driver groups had crash risk equal to or less than that of the all-ages group, but around the 3-point level and above there was a steeper increase in the expected crash average for drivers 70 and above than for the other two groups. A similar trend was seen for drivers aged 60-69 who had more than 5 points in a 3-year period. Concerned that points on an older driver's record, which are fairly rare events, may be early warning signs of the onset of some driving-related impairment, the authors suggested that negligent operator interventions be invoked at a lower point level for older people than for younger ones, so long as the initial interventions were not punitive. An educational brochure or self-assessment guide was suggested to make the driver aware of typical problems associated with aging, and encourage him or her to assess possibilities for remediation or self-restriction. An educational intervention applied to drivers 70 or more with recent incidents on record, currently under study, is described above.

Medical Review and Restrictions on the License

License restrictions are by no means new, and in fact a restriction to driving only while wearing corrective lenses is very common. But DMV (and other jurisdictions) can also restrict the licenses of drivers with impairments that are not as readily corrected to driving only at particular times of the day, on particular routes, and the like. The rationale behind use of these less common restrictions is that, even for drivers chronically so impaired that their risk of having a crash in unrestricted driving is much higher than average, risk will be greatly reduced if their trips are few, short, and made under conditions that do not unduly challenge their limitations.

- Malfetti and Winter (1990) proposed guidelines for a conditional license for selected elderly drivers that would be similar to a restricted license ("you can drive only under certain conditions"), and would be adapted to the driver's mode of living, driving needs, and driving ability. The system would allow impaired seniors to operate a motor vehicle only under conditions that would not exceed their abilities, and would identify and treat high-risk drivers without penalizing safe drivers of the same age. Some of the ideas from Malfetti and Winter are planned to be applied to California's 3-tier assessment program, currently being evaluated in the field. That program is described below.

- Popkin, Stewart, and Lacey (1983) examined the impact of an initial medical review on the subsequent driving records of individuals, most commonly elderly, identified as having medical impairments. The results indicated that persons in most of the impairment groups (cardiovascular diseases, diabetes/endocrine illnesses, vision impairments, and mental problems) were at significantly lower accident risk following the medical review. In another study, the general effect of restricting the licenses of drivers with medical impairments was investigated in Saskatchewan, Canada by Marshall, Spasoff, Nair, and van Walraven (2002), though they did not look at the influence of specific restrictions or specific medical diagnoses. Saskatchewan Government Insurance, which provides insurance coverage to all drivers in the province, delivers a program that issues restricted licenses to people with medical impairments that may affect their driving ability. Restrictions include both driving restrictions (for example, may drive only during daylight hours) and/or licensing restrictions (for example, periodic eye examinations are required for licensure). The authors compared drivers with and without restrictions of either type. After adjustment for demographic variables, the group of drivers with any restriction had a significantly higher average crash rate than the group without restrictions, though the increases themselves were significantly lower than those associated with being male or living in an urban area. In contrast, restricted license holders had a significantly lower average traffic violation rate than the group of drivers without restrictions. Saskatchewan has one item of information that California lacks—the date on which a restriction was imposed. So in a second analysis, Marshall et al. compared average rates of crashes and traffic violations before and after driving restrictions (not licensing restrictions) were imposed. In all instances, average rates decreased following imposition of restriction(s). This led to a conclusion that restricted licensing programs like that used in Saskatchewan appear to be effective.

- California law specifies that patients with conditions that can cause recurrent lapses of consciousness, or with dementia, must be reported by physicians; these reports (which are confidential) go through the local health office to DMV. In addition, physicians, law enforcement officers, family members, and others can report drivers who may be unsafe directly to DMV. Those reported, either by law or otherwise, are commonly elderly. A full medical evaluation is generally obtained, and on the basis of this evaluation, interaction with the driver, and results from a law, vision, and/or road test administered to him or her, the department decides what the status of the driver's license should be. Sometimes the impairment is so severe that the license must be withdrawn. But for lesser degrees of impairment, where the person is judged to be able to drive safely within certain limits, those limits (restrictions) are placed on the license, as noted above. Perhaps an important point to make here is that DMV's decision to retest a driver, and DMV's decision with regard to a reexamined driver's license status, are made purely on the basis of such factors as medical review and driving performance, not on the basis of a non-individualized attribute like age.

Enhanced Renewal Testing

- As a countermeasure to older drivers' accidents, many states practice age-based renewal testing. Different tests may be given to applicants above a certain age, or their license term—the time between successive tests—may be shortened. Some states administer road tests to drivers at or above a particular age, and in others, including California, the practice has been proposed though not adopted. Lange and McKnight (1996) compared the per-driver crash rates of senior drivers in two populous states (Illinois and Indiana) that administered age-based road tests starting at age 75 with corresponding rates in two demographically similar states (Ohio and Michigan) that did not have age-based testing. Accidents per licensed driver during 1991-1992 were obtained by age group for the four states, and drivers aged 70 through 74 were compared to drivers aged 75 or more in terms of crash experience. Lange and McKnight found that the states with age-based road testing had significantly fewer elderly driver accidents, and estimated that about 366 accidents may have been prevented each year in the two states combined. This suggested a question—did the testing process remove high-risk older drivers from the driving population, or did it discourage driving by older people in general? The investigators looked at single-vehicle accidents to answer this question, finding that the *proportion* of this type of accident (where the driver can be assumed to be at fault) was increased significantly in the road-testing states. This did not support the idea that testing was removing high-risk older drivers from the road; rather the main effect of the testing seemed to be consistent with less driving for older drivers in general, not just unsafe older drivers. Summing up, the investigators stated that "No matter at what age testing is mandated, it is too late for some and too early for others. An alternative is to confine testing to those within the older age group who give some evidence of age-related declines in their ability to drive safely" (page 87).

- Kelsey, Janke, Peck, and Ratz (1985) found that clean-record drivers aged 70 or older who were offered a 2-year license extension by mail, thereby avoiding all renewal tests, had significantly *fewer* accidents (and citations) than did a comparison group of similarly clean-record age peers who were required to go to DMV field offices and take these tests. At the very least, this finding indicated no adverse effect, over the short term, of omitting renewal testing for elderly drivers, given the tests then current. (Considerations other than driving performance led to the subsequent placing of an age ceiling of 69 on eligibility for license extension [or renewal by mail, RBM] in California. RBM became valid for a 4-year license term, with the possibility of a second 4 years, and at the time of writing is valid for a 5-year license term, again with the possibility of a second one.) The fact that delaying renewal testing for 2 years seemed if anything to improve older people's driving records suggests that the renewal tests used at that time may not have been adequate. Requiring license applicants to take adequate renewal tests (especially, perhaps, vision tests) should be safety-enhancing, and work is progressing in the development and evaluation of an improved testing system, described immediately below.

- A countermeasure that should especially benefit the elderly, but does not target them as a special group, is an experimental assessment system being studied by California DMV. It is a "tiered" system containing three levels of tests and is called here, for brevity, the 3-tier. A conditional licensing system similar to the one proposed by Malfetti and Winter (1990) will be developed to accompany the assessment system, which is currently under study in four DMV field offices after more limited pilot studies conducted and reported by Janke (2001b). In the 3-tier system, tests are administered to renewal applicants who renew in one of the field offices (this group includes all applicants who are above age 69 when their license expires, but is not limited to them). They are also administered to drivers of any age, called referrals, who are reported to DMV—by doctors, police, family members, or others—and referred to a field office for road testing, because of evidence that they may not be able to drive safely. Two aims of the project are to see whether renewal applicants have acquired some physical or mental condition which should be evaluated on a road test, and to determine whether such a condition has progressed to the point where it would be too hazardous to take the driver out on the road. (Referrals, unless too hazardous to test, are always road tested.) In the current study, whose principal investigator is David Hennessy, each driver chosen to be a subject takes all tests. In actual practice, though, the system would work differently, with most people taking only the tests on the first tier. This first tier includes California's standard knowledge and visual acuity (Snellen) tests, supplemented by a brief cognitive screening exercise and unobtrusive observations by DMV staff for impairment. Also included on the first tier is a visual contrast sensitivity test; adequate contrast sensitivity is needed, for instance, to distinguish objects in fog or in low light. As the system is envisioned, if the first tier is passed, the license is renewed. If the tier is failed, the driver may be given a referral for medical or vision assessment and best correction of his or her condition. Second-tier examination is required if correction of a problem discovered on the first tier is not adequate; this consists presently of two computerized tests of information-processing ability, together with a driving habits survey. If performance is good, the license is renewed, possibly with restriction(s); if poor, there may be additional medical referrals and, afterward, either a road test—the third tier—or the determination that the driver is too unsafe to test on the road. This last possibility would imply withdrawal of the driving privilege. For others, the road test might or might not show that the driver could compensate adequately for his or her impairments. If the 3-tier becomes operational, it will be joined, as mentioned above, by a conditional licensing system in which appropriate restrictions would be identified through test performance. Use of license restrictions for referrals was discussed in a preceding section, but by far their most common application is to drivers who are not referrals, most commonly those who need corrective lenses to drive. The possibilities and effectiveness of license restrictions as applied to both referrals and non-referrals have not yet been adequately studied.

<u>Task Force on Older Adult Transportation</u>

A comprehensive approach to traffic safety for senior drivers, passengers, and pedestrians was initiated by a two-year Task Force on Older Adults and Traffic Safety. The task force gathered together 36 representatives from governmental agencies at the federal, state, and local levels, as well as universities and senior advocacy groups. Its goal was to develop a strategic framework of recommendations for action as a first step in a coordinated statewide effort to improve traffic safety for older Californians. Seven broad recommendations emerged, and all will involve preparatory research before ultimate implementation. The seven are:

1. developing a statewide system for the prevention of traffic-related injuries among older adults;
2. developing more effective driver assessment and licensing practices within DMV;
3. improving older adult risk identification and risk reduction practices;
4. improving the ability of health care and service providers to assess patients' or clients' traffic safety risks and minimize the impact of their health impairments on safe mobility;

5. establishing, through research, roadway infrastructure and land use practices that promote safety;
6. developing safer motor vehicle design; and
7. expanding the research and knowledge base for older adult traffic safety in ways that are not clearly subsumed under any of the above.

Most countermeasures discussed above have aimed at the behavior of the driver (although the task force list goes beyond that). But it should also be recognized that the human-factor problems of aging may have solutions that are primarily technological rather than behavioral. Since all drivers, regardless of age, sometimes function well below an optimal level of mental alertness and physical efficiency, it can be expected that technological advances designed to counteract the impairments of aging will make the driving task easier and safer for all drivers (Malfetti, 1985; Janke, 1994b).

<u>Roadway and Vehicle Factors</u>

- Improvements in the driving environment, such as better lighting and clearer, more strategically placed signs and signals, would go a long way toward making the roads safer for elderly drivers, according to Allen (1985). Lyman, Ferguson, Braver, and Williams (2002) recommended protected left-turn lanes and left-turn signals at intersections; these would be expected to reduce older drivers' documented (e.g., by Staplin & Lyles, 1992) problems in such situations. The emphasis should be on the word "protected," since a similar kind of traffic control, protected/permissive left turns (PPLT), can confuse drivers of any age, as Noyce and Kacir (2002) demonstrated. The problem is based on PPLT standards published in the Manual on Uniform Traffic Control Devices, Millennium Edition (Federal Highway Administration, 2000). Standards for PPLT signal phasing—which provides for a protected phase, in which left turns are made freely while opposing traffic is stopped, and a permissive phase, in which left-turners must yield to opposing traffic and make their turn only when it is clear—call for two signals to be illuminated simultaneously in the same signal face. For example, a separate signal face for the left-turn lane must simultaneously show both a green arrow and a red ball during the protected phase. Noyce and Kacir demonstrated driver confusion on the meaning of such signaling, conducting a large simulator study that presented left-turn scenarios with different traffic signal displays from the point of view of a driver in an exclusive left-turn lane. Subjects chose the most appropriate action in each scenario from among four possibilities: go; yield, wait for a gap; stop, then wait for a gap; and stop. All age groups did worse when a green arrow and red ball were shown simultaneously on the same signal face, but elderly people were particularly affected.

- A Highway Safety Forum sponsored by the National Safety Council in 1989 resulted in recommendations to enhance vehicle controls and displays, and perhaps tailor vehicles—"corrective cars"—especially to a "typical" senior's response characteristics (Rogers, 1989). Also recommended were larger sizes of letters on signs and redundant use of traffic signs for drivers with memory impairment (Michael, 1989). Redundancy in signage might aid distracted drivers of any age as well.

- Lyman et al. (2002) also addressed improvement of vehicle crashworthiness. They suggested depowered airbags and force-limiting seatbelts to give better protection to the fragile bodies of older vehicle occupants and reduce their injuries and deaths if a crash should occur. Li et al. (2003) gave specific examples of the sort of thing that might be developed. Modifications to seat belts that would better distribute the restraining forces include making belts wider or inflatable, or giving them four points of attachment to the vehicle instead of three. Also, according to Li et al., crash forces could be reduced if the crush zones of passenger vehicles were lengthened in conjunction with reducing the stiffness of vehicle front ends. They cautioned that any potential changes to vehicles or restraint systems need thorough testing, and would also need to be acceptable to vehicle owners. Such modifications, though, would protect not only drivers but their passengers. Fragile drivers and passengers would benefit from enhanced protection, and it will be remembered that Li et al. found that fragility explained more of older drivers' high death rate per distance traveled than excessive crash involvement did, and that increased physical fragility begins at an age (60-64) when crash involvement per mile is still low. Stevens and Dellinger (2002) also pointed out that fatal injuries represent only a small part of the overall injury burden. Motor vehicle crashes among older adults cause more than 200,000 non-fatal injuries each year, they wrote, and the greatest impact of such injuries is on morbidity, chronic disability, and decreased quality of life.

Evans (1991) wrote in his book, *Traffic Safety and the Driver*, that he expected the risk level of drivers in general to decline in response to positive changes in factors contributing to traffic safety. In addition to improved roadway and vehicle design he mentioned legislation, law enforcement, education, social norms, and medical and emergency care. He also speculated that additional improvements in highway safety will come from health-enhancing behavioral changes regarding hygiene, diet, exercise, and avoidance of alcohol and tobacco.

Care must sometimes be taken, though, in characterizing a particular change as positive. Noland (2003), analyzing the effect of roadway (infrastructure) upgrades on traffic fatalities and injuries, pointed out that such upgrades as increasing the number and width of lanes have been commonly assumed to be safety measures. It is true that roadway upgrades have increased, and fatalities per mile have decreased, in the U.S. over the last 30-40 years. But he warned that drawing a conclusion that the first causes the second ignores behavioral reactions to safety "improvements" that may affect fatality reduction goals adversely. For instance, increasing the number of lanes may result in some drivers' traveling at high speeds or dodging abruptly from lane to lane. In his empirical investigation, Noland analyzed data for all 50 states over the 14 years 1984-1997. The results suggested that "changes in highway infrastructure that have occurred between 1984 and 1997 have not reduced traffic fatalities and injuries and have even had the effect of increasing total fatalities and injuries" (p. 610). However, in controlling for other variables, Noland found that demographic changes in age cohorts (fewer young and more elderly), increased seat-belt use, reduced alcohol consumption, and advances in medical technology have accounted for a large share of overall reductions in traffic fatalities.

The aging of the population had a large effect in reducing both fatalities and injuries. As Noland stated, increasing the percentage of the population between 15 and 24 years of age increases these outcomes, since drivers in that age group are well known for being involved in more crashes. "However, increases in the percent of the population over age 75 leads [sic] to fewer fatalities and injuries, which is a surprising result" (p. 607). Noland's study results do not, of course, imply that there is no safety payoff in trying to improve roadways and devices associated with their use. Aside from the type of upgrades he studied, other infrastructure changes like increasing shoulder widths or separating lanes with medians, and improvements in signage, signals, and lighting, might be expected to benefit all—perhaps especially senior—drivers.

REFERENCES

Aizenberg, R., & McKenzie, D. M. (1997). *Teen and senior drivers* (Report No. 168). Pasadena: Beverly Foundation and Sacramento: California Department of Motor Vehicles.

Allen, M. J. (1985). Vision of the elderly driver: Implications for vehicle and highway design and for driver testing. In J. Malfetti (Ed.), *Drivers 55+: Proceedings of the Older Driver Colloquium* (pp. 1-7). Orlando, FL.

Arnett, J. J. (2002). Developmental sources of crash risk in young drivers. *Injury Prevention, 8*(Suppl. II), ii17-ii23.

Bailey, I. L., & Sheedy, J. E. (1988). Vision screening for driver licensure. *Transportation in an aging society: Improving mobility and safety for elderly persons*, *2*(Special Report No. 28), pp. 294-324. Washington, D.C.: Transportation Research Board.

Ball, K., & Owsley, C. (1993). The useful field of view test: A new technique for evaluating age-related declines in visual function. *Journal of the American Optometric Association*, *64*, 71-79.

Beirness, D. J. (1996). The relationship between lifestyle factors and collisions involving young drivers. In H. Simpson (Ed.), *New to the road: Reducing the risks for young motorists. Proceedings of the First Annual International Symposium of the Youth Enhancement Service*, pp. 71-77. Los Angeles: University of California.

Beirness, D. J., Simpson, H. M., & Mayhew, D. R. (1992). *Diagnostic Assessment of Problem Drivers: I. Review of Factors Associated with Risky and Problem Driving* (Report No. TP-11549). Ottawa, Ontario: The Traffic Injury Research Foundation of Canada.

Benda, H. V., & Hoyos, C. G. (1983). Estimating hazards in traffic situations. *Accident Analysis and Prevention, 15*, 1-10.

Brown, I. D. (1982). Exposure and experience are a confounded nuisance in research on driver behavior. *Accident Analysis and Prevention, 14*, 345-352.

California Business, Transportation and Housing Agency. (1985). *1984 accident data on California state highways (road miles, travel, accidents, accident rates)*. Sacramento, CA: Department of Transportation, Division of Traffic Engineering.

California Department of Finance. (2000). *Population projections for California and its counties, 1990-2040*. (Report 93 P-1, State Census Data Center). Sacramento: Author.

California Department of Justice. (1992). *1991 statewide criminal justice profile.* Sacramento: Author.

California Department of Motor Vehicles. (1986-2001). *DL information, county, age, & sex*. Sacramento: Author.

California Department of Motor Vehicles. (2001). *Age and sex report*. Sacramento: Author.

California Highway Patrol. (2001a). *1990-2000 annual reports of fatal and injury motor vehicle traffic accidents* (11 volumes). Sacramento: Author.

California Highway Patrol. (2001b). *2000 annual reports of fatal and injury motor vehicle traffic accidents* (11 volumes). Sacramento: Author.

Cerrelli, E. (1994). Crash data and rates for age-sex groups of drivers, 1994. Washington, D.C.: National Center for Statistics and Analyses, National Highway Traffic Safety Administration. *Research Notes, 1995.*

Chen, L., Baker, S. P., Braver, E. R., Li, G. (1999). *The potential benefits of restrictions on the transport of teenage passengers by teenage drivers*. Arlington, VA: Insurance Institute for Highway Safety.

Chen, L., Baker, S. P., Braver, E. R., Li, G. (2000). Carrying passengers as a risk factor for crashes fatal to 16- and 17-year-old drivers. *Journal of the American Medical Association*, *283*, 1578-1582.

Cooper, P. J., Pinili, M., & Chen, W. (1995). An examination of the crash involvement rates of novice drivers aged 16 to 55. *Accident Analysis and Prevention*, *27*, 89-104.

Cooper, P. J., Tallman, K., Tuokko, H., & Beattie, B. L. (1993). Vehicle crash involvement and cognitive deficit in elderly drivers. *Journal of Safety Research, 24,* 9-17.

Deery, H. A. (1999). Hazard and risk perception among young novice drivers. *Journal of Safety Research, 30*, 225-236.

Dellinger, A. M., Langlois, J. A., & Li, G. (2002). Fatal crashes among older drivers: Decomposition of rates into contributing factors. *American Journal of Epidemiology*, *155*(3), 234-241.

Dobbs, B. M. (2002). *Medical conditions and driving: Current knowledge*. University of Alberta, Edmonton, Canada.

Doherty, S. T., Andrey, J. C., & MacGregor, C. (1998). The situational risks of young drivers: The influence of passengers, time of day and day of week on accident rates. *Accident Analysis and Prevention*, *30*, 45-52.

Dreyer, D. R., & Janke, M. K. (1979). The effects of range vs. non-range driver training on the accident and conviction frequencies of young drivers. *Accident Analysis and Prevention*, *11*, 179-198.

Edwards, M. (2001). Standards for novice driver education and licensing. *In Driver Education at the Crossroads, Proceedings from the Committee on Operator Education and Regulation* (Report No. E-C024), Transportation Research Circular. Washington, D.C.: Transportation Research Board.

Egberink, H. O., Lourens, P. F., & van der Molden, H. H. (1986). Driving strategies among younger and older drivers when encountering children. *Accident Analysis and Prevention*, *18*, 315-324.

Elliot, M. R., & Shope, J. T. (2003). Use of a Bayesian changepoint model to estimate effects of graduated licensing program. *Journal of Data Science*, *1*, 43-63.

Evans, L. (1991). *Traffic safety and the driver*. New York: Van Nostrand Reinhold.

Evans, L. (1993). How safe were today's elderly drivers when they were younger? *American Journal of Epidemiology*, *137*(7), 769-775.

Evans, L. (2000). Risks older drivers face themselves and threats they pose to other road users. *International Journal of Epidemiology, 29*, 315-322.

Federal Highway Administration. (1991). *Highway statistics*. Washington, D.C.: U.S. Department of Transportation.

Federal Highway Administration. (1999). *Summary of travel trends: 1995 Nationwide Personal Transportation Survey*. Washington, D.C.: U.S. Department of Transportation.

Federal Highway Administration. (2000). *Manual on uniform traffic control devices, Millennium edition*. Washington, D.C.: U.S. Department of Transportation.

Ferdun, G. S, Peck, R. C., & Coppin, R. S. (1967). The teen-aged driver: An evaluation of age, experience, driving exposure and driver training as they related to driving record. *Highway Research Record, 163*, 31-53.

Ferguson, S. A., Leaf, W. A., Williams, A. F., & Preusser, D. F. (1996). Differences in young driver crash involvement in states with varying licensure practices. *Accident Analysis and Prevention, 28*, 171-180.

Fergusson, D. M., & Horwood, L. J. (2001). Cannabis use and traffic accidents in a birth cohort of young adults. *Accident Analysis and Prevention, 33*, 703-711.

Finn, P., & Bragg, B. W. E. (1986). Perception of the risk of an accident by young and elderly drivers. *Accident Analysis and Prevention*, *18*(4), 289-298.

Foley, D. J., Heimovitz, K. H., Guralnik, J. M., & Brock, D. B. (2002). Driving life expectancy of persons aged 70 years and older in the United States. *American Journal of Public Health*, *92*(8), 1284-1289.

Foss, R. D., & Evenson, K. R. (1999). Effectiveness of graduated driver licensing in reducing motor vehicle crashes. *American Journal of Preventative Medicine, 16*, 47-56.

Foss, R. D., Feaganes, J. R., & Rodgman, E. A. (2001). Initial effects of graduated driver licensing on 16-year-old driver crashes in North Carolina. *Journal of the American Medical Association*, *286*(13), 1588-1592.

Fozard, J. L., Wolf, E., Bell, B., McFarland, R. A., & Podolsky, S. (1977). Visual perception and communication. In J. E. Birren, & K. W. Schaie (Eds.), *Handbook of the psychology of aging* (pp. 497-534). New York: Van Nostrand Reinhold Co.

Gebers, M. A. (1999). *Strategies for estimating driver accident risk in relation to California's negligent-operator point system* (Report No. 183). Sacramento: California Department of Motor Vehicles.

Gebers, M. A., & Peck, R. C. (1992). The identification of high-risk elderly drivers through age-mediated point systems. *Journal of Safety Research, 23*, 81-93.

Gebers, M. A., Romanowicz, P. A., & McKenzie, D. M. (1993). *Teen and senior drivers* (Report No. 141). Sacramento: California Department of Motor Vehicles.

Gregersen, N. P., & Berg, H. Y. (1994). Lifestyle and accidents among young drivers. *Accident Analysis and Prevention, 26*, 297-303.

Hagge, R. A., & Marsh, W. C. (1988). *The traffic safety impact of provisional licensing* (Report No. 116). Sacramento: California Department of Motor Vehicles.

Hall, J., & West, R. (1996). The role of formal instruction and informal practice in learning to drive. *Ergonomics, 39*, 693-706.

Harre, N., Brandt, T., & Dawe, M. (2000). The development of risky driving in adolescence. *Journal of Safety Research, 31*, 185-194.

Harrington, D. M. (1972). The young driver follow-up study: An evaluation of the role of human factors in the first four years of driving. *Accident Analysis and Prevention, 4*, 191-240.

Hennessy, D. F. (1995). *Vision testing of renewal applicants: Crashes predicted when compensation for impairment is inadequate* (Report No. 152). Sacramento: California Department of Motor Vehicles.

Hingson, R., Heeren, T., & Winter, M. (1995). Lower legal blood alcohol limits for young drivers. *Public Health Report, 109*, 738-744.

Irwin, C. (1996). Adolescent development and driving: Does driving differ from other health damaging behaviors. In H. Simpson (Ed.), *New to the Road: Reducing the Risks for Young Motorists. Proceedings of the First Annual International Symposium of the Youth Enhancement Service*, pp. 51-70. Los Angeles, CA: University of California.

Janke, M. K. (1991). Accidents, mileage, and the exaggeration of risk. *Accident Analysis and Prevention*, *23*(2-3), 183-188.

Janke, M. K. (1994a). Mature driver improvement program in California. *Transportation Research Record, 1438*, 77-83.

Janke, M. K. (1994b). *Age-related disabilities that may impair driving and their assessment* (Report No. 156). Sacramento: California Department of Motor Vehicles.

Janke, M. K. (2001a). *Medical conditions and other factors in driver risk* (Report No. 190). Sacramento: California Department of Motor Vehicles.

Janke, M. K. (2001b). Assessing older drivers: Two studies. *Journal of Safety Research, 32*, 43-74.

Jessor, R. (1987). Risky driving and adolescent problem behaviour: An extension of problem-behaviour theory. *Alcohol, Drugs, and Driving, 3*, 1-11.

Johnson, C. A., & Keltner, J. L. (1983). Incidence of visual field loss in 20,000 eyes and its relationship to driving performance. *Archives of Ophthalmology, 101*, 371-375.

Jones, B. (1994). The effectiveness of provisional licensing in Oregon: An analysis of traffic safety benefits. *Journal of Safety Research, 25*, 33-46.

Jones, B. (1997). Age differences in response to high and low-threat driver improvement warning letters. *Journal of Safety Research, 28*, 15-28.

Kalish, R. A. (1982). *Late adulthood: Perspective on human development* (2nd ed.). Monterey, CA: Brooks/Cole.

Kelsey, S. L., Janke, M. K., Peck, R. C., & Ratz, M. (1985). *License extensions for clean-record drivers: A four-year follow-up* (Report No. 93). Sacramento: California Department of Motor Vehicles.

Kirk, A., & Stamatiadis, N. (2001). Crash rates and traffic maneuvers of younger drivers. *Transportation Research Record, 1779*, 68-74.

Kosnik, W. D., Sekuler, R., & Kline, D. W. (1990). Self-reported visual problems of elderly drivers. *Human Factors, 32*(5), 597-608.

Laapotti, S., Keskinen, E., Hatakka, M., & Katila, A. (2001). Novice drivers' accidents and violations—A failure on higher or lower hierarchical levels of driving behavior. *Accident Analysis and Prevention, 33*, 759-769.

Lange, J. E., & McKnight, A. J. (1996). Age-based road test policy evaluation. *Transportation Research Record, 1550*.

Layton, B. (1975). Perceptual noise and aging. *Psychological Bulletin, 82*, 875-883.

Li, G., Braver, E. R., & Chen, L.-H. (2003). Fragility versus excessive crash involvement as determinants of high death rates per vehicle-mile of travel among older drivers. *Accident Analysis and Prevention*, *35*, 227-235.

Li, T., & Baker, S. P. (1996). Exploring the male-female discrepancy in death rates from bicycling injury: The decomposition method. *Accident Analysis and Prevention*, *28*, 537-540.

Lin, M. L., & Fearn, K. T. (2003). The provisional license: Nighttime and passenger restrictions—a literature review. *Journal of Safety Research, 34,* 51-61.

Lundberg, C., Hakamies-Blomqvist, L., Almkvist, O., & Johansson, K. (1998). Impairments of some cognitive functions are common in crash-involved older drivers. *Accident Analysis and Prevention*, *30*(3), 371-377.

Lyman, S., Ferguson, S. A., Braver, E. R., & Williams, A. F. (2002). Older driver involvements in police reported crashes and fatal crashes: Trends and projections. *Injury Prevention*, *8*, 116-120.

Malfetti, J. L. (Ed.). (1985). *Drivers 55+: Proceedings of the elderly driver colloquium*. Orlando, FL.

Malfetti, J. L., & Winter, D. J. (1990). *A graded license for special elderly drivers: Premise and guidelines*. Washington, D.C.: AAA Foundation for Traffic Safety.

Marowitz, L. A. (1995). The relationship between drug arrests and driving risk. *Alcohol, Drugs and Driving*, *11*(1), 1-22.

Marshall, S. C., Spasoff, R., Nair, R., & van Walraven, C. (2002). *Canadian Medical Association Journal*, *167*(7).

Masten, S. V., & Hagge, R. A. (2003). *Evaluation of California's Graduated Driver Licensing Program* (Report No. 205). Sacramento: California Department of Motor Vehicles.

Masten, S. V., & Peck, R. C. (2003). *Problem driver remediation: A meta-analysis of the driver improvement literature*. Arlington, VA: Insurance Institute for Highway Safety.

Matthews, M. L., & Moran, A. R. (1986). Age differences in male drivers' perception of accident risk: The role of perceived driving ability. *Accident Analysis and Prevention*, *18*(4), 299-313.

Mayhew, D. R. (2003). The learner's permit. *Journal of Safety Research, 34,* 35-43.

Mayhew, D. R., Brown, S. W., & Simpson, H. M. (1996). *Alcohol use among drivers and pedestrians fatally injured in motor vehicle accidents: Canada, 1994.* Ottawa: Traffic Injury Research Foundation of Canada, Transport Canada: Road Safety and Motor Vehicle Regulation.

Mayhew, D. R., Brown, S. W., & Simpson, H. M. (1998). *Alcohol use among drivers and pedestrians fatally injured in motor vehicle accidents: Canada, 1996*. Ottawa: Traffic Injury Research Foundation of Canada, Transport Canada: Road Safety and Motor Vehicle Regulation.

Mayhew, D. R., Donelson, A. C., Beirness, D. J., & Simpson, H. M. (1986). Youth, alcohol, and relative risk of crash involvement. *Accident Analysis and Prevention*, *18*(4), 273-287.

Mayhew, D. R., & Simpson, H. M. (1990). *New to the road. Young drivers and novice drivers: Similar problems and solutions*? Ottawa, Ontario: Traffic Injury Research Foundation.

Mayhew, D. R., & Simpson, H. M. (1995). *The role of driving experience: Implications for training and licensing of new drivers*. Ottawa, Ontario: Traffic Injury Research Foundation.

Mayhew, D. R., & Simpson, H. M. (1996). *Effectiveness and Role of Driver Education and Training in a Graduated Licensing System*. Ottawa, Ontario: Traffic Injury Research Foundation.

Mayhew, D. R., & Simpson, H. M. (1999). *Youth and road crashes: Reducing the risks from inexperience, immaturity and alcohol.* Ottawa, Ontario: Traffic Injury Research Foundation.

Mayhew, D. R., & Simpson, H. M. (2002). The safety value of driver education and training. *Injury Prevention, 8*(Supp.II), ii3-ii8.

Mayhew, D. R., Simpson, H. M., & Groseilliers, M. (1999). *Impact of the graduated driver licensing program in Nova Scotia.* Ottawa, Ontario: Traffic Injury Research Foundation.

Mayhew, D. R., Simpson, H. M., Groseilliers, M., & Williams, A. F. (2001). Impact of the graduated driver licensing program in Nova Scotia. *Journal of Crash Prevention and Injury Control, 2*(3), 179-192.

Mayhew, D. R., Simpson, H. M., & Pak, A. (2000). *Changes in collision rates among novice drivers during the first months of driving.* Arlington, VA: Insurance Institute for Highway Safety.

McCartt, A. T., Shabanova, V. I., & Leaf, W. A. (2003). Driving experience, crashes, and traffic citations of teenage beginning drivers. *Accident Analysis and Prevention, 35,* 311-320.

McGwin, G. Jr., & Brown, D. B. (1999). Characteristics of traffic crashes among young, middle-aged, and older drivers. *Accident Analysis and Prevention, 31*, 181-198.

McKelvey, F. X., & Stamatiadis, N. (1989). *Highway accident patterns in Michigan related to elderly drivers* (Paper No. 88-0374). East Lansing, Michigan: Michigan State University, Department of Civil and Environmental Engineering.

McKnight, A J. (1986). Safety effects of provisional driver licensing programs. *Provisional Licensing Programs for Young Drivers, Topical Papers by Licensing Experts*, Washington, D.C.: U.S. Department of Transportation.

McKnight, A. J. (1996). Causes of the problem: The role of experience-related factors in the collisions of young drivers. In H. Simpson (Ed.), *New to the Road: Reducing the Risks for Young Motorists. Proceedings of the First Annual International Symposium of the Youth Enhancement Service*, pp. 35-40. Los Angeles, CA: University of California.

McKnight, A. J., Hyle, P., & Albrecht, L. (1983). *Youth license control demonstration project* (Report No. DOT HS-806 616). Washington, D.C.: National Highway Traffic Safety Administration.

McKnight, A. J., Simone, G. A., & Weidman, J. R. (1982). *Elderly driver retraining* (Report No. DOT HS-806 336). Alexandria, VA: National Public Service Research Institute.

Michael, H. L. (1989). Roadway environment and elderly drivers. In *Commitment to action: Conclusions and recommendations of the Highway Safety Forum on older drivers and pedestrians and younger drivers, Linthicum, Maryland.* Chicago, IL: National Safety Council.

Milech, D., Glencross, D., & Hartley, L. (1989). *Skill acquisition by young drivers: Perceiving, interpreting and responding to the driving environment* (Report No. MR4). Canberra, Australia: Federal Office of Road Safety.

Noland, R. B. (2003). Traffic fatalities and injuries: The effect of changes in infrastructure and other trends. *Accident Analysis and Prevention, 35*(4), 599-611.

Noyce, D. A., & Kacir, K. C. (2002). Drivers' understanding of simultaneous traffic signal indications in protected left-turns. Paper presented at the 81st Annual Meeting, Transportation Research Board, January 13-17, 2002, Washington, D.C.

Ostrow, A., Shaffron, P., & McPherson, K. (1992). The effects of a joint rate-of-motion physical fitness training program on the automobile driving skill of elderly adults. *Journal of Safety Research*, *23*, 207-219.

Owsley, C., Ball, K., Sloane, M. E., Roenker, D. L., & Bruni, J. R. (1991). Visual/cognitive correlates of vehicle accidents in elderly drivers. *Psychology and Aging*, *6*, 403-415.

Owsley, C., Stalvey, B. T., Phillips, J. M. (2003). The efficacy of an educational intervention in promoting self-regulation among high-risk older drivers. *Accident Analysis and Prevention, 35*(3), 393-400.

Patton, D., & Brown, D. (2002). Driving drink, driving high: A comparison of student attitudes towards driving while drunk versus driving while high on cannabis. Poster Session. *Proceedings of the 16th Annual Conference on Alcohol, Drugs, and Traffic Safety*, T-2002. Montreal, Canada.

Peck, R. C. (1985). The role of youth in traffic accidents: A review of past and current California data. In H. Moskowitz (Ed.), *Alcohol, Drugs and Driving: Abstracts and reviews*, *1*(1-2), 45-68.

Pitts, D. G. (1982) Visual acuity as a function of age. Journal of the *American Optometric Association*, *53*, 117-124.

Planek, T., Condon, M., & Fowler, R. (1968). *An investigation of the problems and opinions of aged drivers* (Report No. 5/68). Chicago: National Safety Council.

Popkin, C. L., Stewart, J. R., & Lacey, J. H. (1983). An examination of the driving performance of medically evaluated drivers. *Proceedings of the Twenty-Seventh Conference of the American Association for Automotive Medicine* (pp. 263-274). San Antonio, TX: American Association for Automotive Medicine.

Preusser, D. F. (1996). Initial licenses for young drivers. *In Graduated Licensing: Past Experiences and Future Status, Proceedings from the Committee on Operator Education and Regulation* (Report No. 458), Transportation Research Circular. Washington, D.C.: Transportation Research Board.

Preusser, D. F., Ferguson, S. A., & Williams, A. F. (1998). The effect of teenage passengers on the fatal crash risk of teenage drivers. *Accident Analysis and Prevention, 30*, 217-222.

Preusser, D. F., Ferguson, S. A., & Williams, A. F. (1999). The effect of Learner's permit requirements in Tennessee. *Journal of Safety Research*, *30*, 211-217.

Preusser, D. F., Williams, A. F., Zador, P. L., & Blomberg, R. D. (1984). The effect of curfew laws on motor vehicle crashes. *Law and Policy*, *6*(1), 115-128.

Reagan, M. A., & Mitsopouls, E. (2001). *Understanding passenger influences on driver behaviour: Implications for road safety and recommendations for countermeasure development.* Clayton: Monash University Accident Center.

Retchin, S. M., Cox, J., Fox, M., & Irwin, L. (1988). Performance-based measurements among elderly drivers and nondrivers. *Journal of the American Geriatric Society, 36,* 813-819.

Retting, R. A., Ulmer, R. G., & Williams, A. F. (1999). Prevalence and characteristics of red light running crashes in the United States. *Accident Analysis and Prevention, 31,* 687-694.

Richardson, J., Kim, K., Li, L., & Nitz, L. (1996). Patterns of motor vehicle crash involvement by driver age and sex in Hawaii. *Journal of Safety Research, 27,* 117-125.

Rogers, R. (1989). Vehicle design and elderly drivers. In *Commitment to action: Conclusions and recommendations of the Highway Safety Forum on older drivers and pedestrians and younger drivers, Linthicum, Maryland.* Chicago, IL: National Safety Council.

Romanowicz, P. A., & Gebers, M. A. (1990). *Teen and senior drivers* (Report No. 126). Sacramento: California Department of Motor Vehicles.

Schiff, W., & Oldak, R. (1993). *Functional screening of elderly drivers using interactive computer-video scenarios.* Washington, D.C.: AAA Foundation for Traffic Safety.

Shaffron, P., Ostrow, A., & McPherson, K. (1991). Older driver performance and joint flexibility. *Journal of Traffic Safety Education, 39*(2), 10-15.

Shope, J. T., Molnar, L. J., Elliot, M. R., & Waller, P. F. (2001). Graduated driver licensing in Michigan: Early impact on motor vehicle crashes among 16-year-old drivers. *Journal of the American Medical Association, 286*(13), 1598-1599.

Simpson, H. M. (2003). The evolution and effectiveness of graduated licensing. *Journal of Safety Research, 34,* 25-34.

Simpson, H. M., Mayhew, D. R., & Beirness, D. J. (1995). The decline of drinking-driving fatalities in Canada: A decade of progress come to an end? In: *Proceedings of the 13th International Conference on Alcohol, Drugs and Traffic Safety, Volume 1.* Eds. C.N. Kloeden and A.J. McLean, pp. 508-512. Adelaide, South Australia: University of Adelaide, NHMRC Road Accident Research Unit.

Stamatiadis, N., & Deacon, J. A. (1995). Trends in highway safety: Effects of an aging population on accident propensity. *Accident Analysis and Prevention, 27*(4), 443-459.

Staplin, L., Breton, M. E., Haimo, S. F., Farber, E. I., & Byrnes, A. M. (1987). *Age-related diminished capabilities and driver performance.* Task A Report, USDOT/FHWA Contract No. DTFH61-86-C-00044. Malvern, PA: KETRON, Inc.

Staplin, L., & Lyles, R. W. (1992). Age differences in motion perception and specific traffic maneuver problems. *Transportation Research Record, 1325,* 23-33.

Stevens, J. A., & Dellinger, A. M. (2002). Motor vehicle and fall related deaths among older Americans 1990-98: sex, race, and ethnic disparities. *Injury Prevention, 8,* 272-275.

Stewart, R. B., Moore, M. T., Marks, R. G., May, F. E., & Hale, W. E. (1993). *Driving cessation and accidents in the elderly: An analysis of symptoms, diseases, cognitive dysfunction and medications.* Washington, D.C.: AAA Foundation for Traffic Safety.

Stock, J. R., Weaver, J. K., Ray, H. W., Brink, J. R., & Sadof, M. G. (1983). *Evaluation of safe performance secondary school driver education curriculum demonstration project* (Report No. DOT HS-806 568). Washington, D.C.: National Highway Traffic Safety Administration.

Summala, H. (1987). Young driver accidents: Risk taking or failure of skill. *Alcohol, Drugs and Driving, 4*, 205-219.

Swisher, J. D. (1988). Problem-behavior theory and driving risk. *Alcohol, Drugs, and Driving, 4*, 205-219.

Tashima, H. N., & Helander, C. J. (2003). *Annual report of the California DUI management information system. Annual report to the Legislature of the State of California* (Report No. 198). Sacramento: California Department of Motor Vehicles.

Tränkle, U., Gelau, C., & Metker, T. (1990). Risk perception and age-specific accidents of young drivers. *Accident Analysis and Prevention, 22*(2), 119-125.

Transportation Research Board, National Research Council. (1988). *Transportation in an aging society: Improving mobility and safety for elderly drivers, 1*(Special Report 218). Washington, D.C.: Author.

Ulmer, R. G., Preusser, D. F., Williams, A. F., Ferguson, S. A., & Farmer, C. M. (2000). Effect of Florida's graduated licensing program on the crash rate of teenage drivers. *Accident Analysis and Prevention, 32*, 527-532.

Vollrath, M., Meilinger, T., & Kruger H. P. (2002). How the presence of passengers influences the risk of collision with another vehicle. *Accident Analysis and Prevention, 34*, 649-654.

Wasielewski, P. (1984). Speed as a measure of driver risk: Observed speeds versus driver and vehicle characteristics. *Accident Analysis and Prevention, 16*, 89-103.

Williams, A. F. (2001). Safety needs of drivers: Lifestyle factors. *In Driver Education at the Crossroads, Proceedings from the Committee on Operator Education and Regulation* (Report No. E-C024), Transportation Research Circular. Washington, D.C.: Transportation Research Board.

Williams, A. F. (2003). Teenage drivers: Patterns of risk. *Journal of Safety Research, 34*, 5-15.

Williams, A. F., & Carsten, O. (1989). Driver age and crash involvement. *American Journal of Public Health, 79*, 326-327.

Williams, A. F., & Ferguson, S. A. (2002). Rationale for graduated licensing and risks it should address. *Injury Prevention, 8(Supplement II)*, ii9-ii16.

Williams, A. F., & Preusser, D. F. (1997). Night driving restrictions for youthful drivers: A literature review and commentary. *Journal of Public Health Policy, 18*(3), 334-345.

Williams, A. F., Preusser, D. F., Ulmer, R. G., & Weinstein, H. B. (1995). Characteristics of fatal crashes of 16-year-old-drivers: Implications for licensure policies. *Journal of Public Health Policy, 16*, 347-360.

Williams, A. F., & Mayhew, D. R. (2003). *Graduated licensing: A blueprint for North America*. Arlington, VA: Insurance Institute for Highway Safety.

Winter, D. (1985). Learning and motivational characteristics of elderly people pertaining to traffic safety. In J. Malfetti (Ed.), *Drivers 55+: Proceedings of the Older Driver Colloquium* (pp. 77-86). Orlando, FL.

Zwerling, C., & Jones, M. P. (1999). Evaluation of the effectiveness of low blood alcohol concentration laws for younger drivers. *American Journal of Preventive Medicine, 16*, 76-80.

APPENDIX

Statistical Curve Smoothing of the 1995 Nationwide Personal Transportation Study Mileage Data for California

The mileage estimates utilized in this report are based on California data (N = 2,416) from the Nationwide Personal Transportation Survey (NPTS) conducted by the Federal Highway Administration (1999). An examination of the mileage rates by age and gender indicated that the data, for both sexes separately as well as combined, could be best described as reflecting a cubic polynomial trend.

A cubic trend describes a relationship in which there are two "bends" in the data. Therefore, it was decided to apply curvilinear regression models to these data in order to obtain "smoothed" mileage estimates for each age and sex group. The advantage of this approach over using the raw age group means is that the estimates tend to be more accurate and stable. The results of the curve fitting statistical tests indicate that the cubic curve provided a statistically significantly ($p < .05$) better fit to the mileage data than did either a quadratic equation or a linear equation.

The following polynomial regression models or equations were applied to the NPTS California group mileage rates to obtain the predicted mileage rate for each group. The estimated rates are displayed in the attached Table A1. The attached Figure A1 illustrates the actual and modeled mileage rates for both sexes.

Estimated mileage for both sexes = $4{,}497.79 + 4{,}633.87(X) – 588.64(X^2) + 18.84(X^3)$

Estimated mileage for men = $4{,}109.14 + 5{,}587.21(X) - 650.63(X^2) + 19.09(X^3)$

Estimated mileage for women = $4{,}823.83 + 3{,}812.11(X) – 552.32(X^2) + 19.75(X^3)$

In the above equations, X is an integer representing a specific age group (identified on the horizontal axis on Figure A1). X^2 and X^3 are the values of X raised to the 2^{nd} and 3^{rd} powers, respectively. For example, the estimated mileage rate for both sexes in the 6^{th} age group (drivers aged 40-44) is computed as follows:

$4{,}497.79 + 4{,}633.87(6) - 588.64(36) + 18.84(216) = 15{,}179$ miles

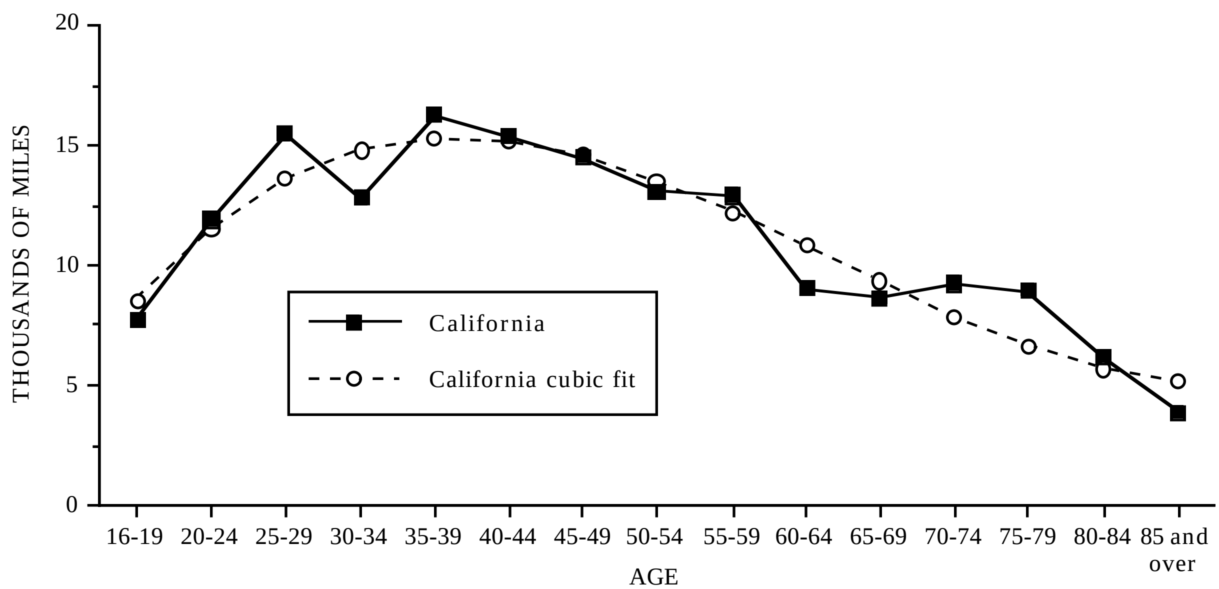
As noted in the 1995 NPTS Summary of Travel Trends (Federal Highway Administration, 1999), the observed data for the national sample showed modest increases of generally less than 10% for most age/gender groups. However, the main exception was the 16-19 year-old group, in which miles driven declined between 1990 and 1995. NPTS documentation suggested that the decline may be due to delayed licensing laws and/or higher auto insurance premiums. Nevertheless, a number of reviewers questioned this decline in teenage driving. The driving reported by this group on their assigned travel day was reviewed and also showed a slight decline, but there was still concern on the part of NPTS staff that this was a survey effect and, therefore, not a real decline. NPTS staff analyzed a number of other survey attributes, including the degree of proxy reporting by teenagers in 1990 and 1995 and whether they were a primary driver of a household vehicle. Nothing conclusive was found. Therefore, the NPTS documentation warns that use of the data on 16-19 year olds should be made with caution. We echo the warning for the smoothed California mileage data employed in the present report.

Table A1

Estimated Average Annual Mileage by Age and Sex

Age	Mileage		
	Both sexes	Male	Female
16-19	8,562	9,065	8,098
20-24	11,562	12,834	10,398
25-29	13,610	15,531	11,827
30-34	14,821	17,270	12,504
35-39	15,306	18,166	12,549
40-44	15,179	18,334	12,081
45-49	14,553	17,888	11,219
50-54	13,541	16,942	10,082
55-59	12,255	15,612	8,789
60-64	10,810	14,012	7,460
65-69	9,317	12,256	6,214
70-74	7,891	10,459	5,170
75-79	6,643	8,735	4,447
80-84	5,688	7,200	4,165
85 and over	5,137	5,967	4,442

Note. Mileage estimates are based on data from Federal Highway Administration, 1999, *Summary of Travel Trends: 1995 Nationwide Personal Transportation Survey*. Washington, D.C.: U.S. Department of Transportation.



Note. Mileage estimates are based on data from Federal Highway Administration, 1999, *Summary of Travel Trends: 1995 Nationwide Personal Transportation Survey*. Washington, D.C.: U.S. Department of Transportation.

Figure A1. Average annual miles by driver age.