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EFFECTIVENESS OF LAP SEAT BELTS
AND THE ENERGY ABSORBING STEERING SYSTEM
IN THE REDUCTION OF INJURIES

by
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ABSTRACT

This study deals with the effect of seat belts and energy absorbing steering systems in reducing injuries sustained by drivers of crash-involved passenger cars. Data was extracted from a pool of accident reports from vehicles involved in crashes in North Carolina in 1966 and 1968.

The data was divided into four mutually exclusive groups determined by usage of seat belt (yes or no) and presence of the energy absorbing steering system (yes or no). By comparing driver injury between groups the effect of the two devices was discernable.

Significant reductions associated with the energy absorbing steering system were recorded for medium speed frontal impact and medium speed car-ran-off-road accidents. The magnitude of the reduction was about 30%. For the seat belt reductions were observed in these situations as well as many others. The largest reductions were for high speed accidents, and the overall reduction is estimated at 43%. In contrast to previous studies, seat belts provided significant benefit in front impact situations.

The benefits provided by the two devices were independent of one another, and therefore were additive.

As expected, the reductions in injury were greater for the serious injury grouping than the any injury grouping.

INTRODUCTION

The injury-reducing benefits of seat belts, which have been available in cars for several years, have been amply documented.[1,2] This benefit presumably is widely conceded, although belt use remains low even today.

Another safety device, energy absorbing steering systems, was introduced on 1967 model passenger cars produced by American Motors, Chrysler, and General Motors. Beginning with 1968 models, Ford passenger cars also had such a device, and since that time manufacturers have introduced modifications designed to further improve the injury reducing characteristics of the system.

The energy absorbing steering system (EA system) is designed to function when a frontal impact occurs and the driver is thrown against the wheel. If the driver is belted he is likely to pivot over the belt and strike the wheel. If he is not belted he is likely to slide straight forward in an upright position and hit the wheel. This poses the question as to whether the way in which the driver strikes the steering wheel affects the injury level.

This study attempts to discern the effects of seat belts (SB) and energy absorbing steering systems in reducing injuries sustained by drivers of crash-involved passenger cars.

The data base consists of police-reported accidents that occurred in North Carolina in 1966 and 1968. *All* reporting police agencies, including the State Highway Patrol, city police and others, provided data for the study. Accident reports submitted by the police are public documents under North Carolina law, and nearly all police agencies use the standard form specified by the North Carolina Department of Motor Vehicles.

Reporting is widespread, and there are no known "holes" in the reporting system in the sense of sizeable cities not reporting, etc. The quality of reporting varies over the range that one expects in this kind of data. Some reports are very poor while others are quite good. A report is submitted if someone is injured or killed or if property damage exceeds $100.[3]

METHOD

To examine the effects of seat belts and energy absorbing systems in reducing driver injury, classifiable passenger car accidents were divided into four groups as follows:

Group	Driver Using Belt	Car Equipped With EA Steering System
1	no	no
2	no	yes
3	yes	no
4	yes	yes

---

[1] B. Tourin and J.W. Garrett, *Safety Belt Effectiveness in Rural California Automobile Accidents,* Automotive Crash Injury Research of Cornell University (Now Cornell Aeronautical Laboratory, Inc., of Buffalo, New York), 1960.

[2] B.J. Campbell, *Seat Belts and Injury Reduction in 1967 North Carolina Automobile Accidents,* University of North Carolina Highway Safety Research Center, December 1968.

[3] The law was changed in the summer of 1971, raising the threshold to $200, but does not apply to data in this study.

By comparing injuries in these four groups over a variety of accident situations, effects of the devices are discernable. In order to keep the effects of other vehicle-related variables as constant as possible over the four groups, the non-EA group was limited to the three model years prior to the introduction of the EA steering system.

Study Variables

The variables in this study include the following items drawn from the officers' report.

1. Reported driver seat belt use: yes or no

2. Energy absorbing steering system (drawn from make and model of car): yes or no

3. Estimated speed of car just prior to impact: 0-29 mph; 30-49 mph; 50^{+} mph.

4. Site of impact on car: front
   right side
   left side
   rear
   unspecified

5. Type of accident: car ran off roadway
   car hit fixed object
   car hit other object
   car hit other car
   car collided with truck
   cars in crash with 3 or more vehicles
   others

6. Injury to driver: none
   "c" (minor)
   "b" (intermediate)
   "a" (serious)
   "k" (killed)

Appendix 1 describes these variables in more detail.

Data Analysis

Due to limited data it was not possible to consider variables 3, 4 and 5 simultaneously. Hence, single variable analyses were performed with speed as a factor, then with site of impact as a factor and finally with accident type as a factor. Because of the large data base in the front impact and car-ran-off-roadway situations, it was possible to analyze each of these with speed as a factor.

The data were examined using a program for analyzing categorical (discrete) data by linear models techniques. The linear model was fit using logits (i.e. log [Prob. (serious injury) / Prob. (no serious injury)]). The statistical procedures are detailed in Appendix 3.

RESULTS

The data were examined for two injury categories: fatal and serious vs. *any* injury. For both seat belts and the energy absorbing steering system, the greatest injury reductions were found in the serious and fatal injury category. As expected, the energy absorbing system was most effective in reducing driver injuries sustained in frontal impacts at medium speeds of 30-49 mph. In contrast to the previous seat belt studies, our data showed a 27 percent reduction in serious and fatal injury reduction for frontal impacts when the driver was belted. Moreover, the combined benefit of seat belts and energy absorbing steering systems appears to be additive at all speeds.

While there is no reason to expect the EA system to be associated with significant benefits except in frontal impacts, it is known from previous studies that benefits from seat belts are manifested in a variety of accident circumstances. In fact, the present study shows a 43 percent reduction in serious injury summing over all kinds of crashes![4]

Serious and Fatal Injury

The serious injury category consists of an "A" or a fatal injury as indicated on the accident report. An "A" injury denotes the presence of a bleeding wound, distorted member(s), or any condition that requires that the victim be carried from the scene of the accident. (All injury categories are defined in Appendix 1, item 6.)

The value of a safety device is more appropriately determined by measuring reduction in serious injury as opposed to any injury. If a device is to be of benefit in reducing injury, it is more likely to reduce a large proportion of serious injuries than mild injuries. While it is important to reduce all injuries it is more so to reduce serious injuries.

Frontal impacts. The data for frontal impacts includes 8,822 such accidents that fall among three speed categories.

a. Medium speed. In the medium speed category (30-49 mph.), 3,809 frontal impacts were reported and analyzed. The proportions of the 3,809 drivers sustaining serious and fatal injuries are:

1.	no belt	no EA system	8.3% [5]	(2,195)
2.	no belt	yes EA system	5.8%	(985)
3.	yes belt	no EA system	6.1%	(353)
4.	yes belt	yes EA system	4.2%	(276)

---

[4] The overall reduction of 43 percent is a weighted average of the individual reductions for low, medium, high and unspecified speed. Since the effect of SB were about the same for EA present and EA absent, the individual reductions for each speed group (40.0%, 33.9%, 49.0%, 58.7% respectively) were averages of the reductions in Table 1 (or Figure 1) for SB with EA and for SB without EA. The weights for each speed are obtained by dividing the number of vehicles with SB at that speed (with EASS and W/O EASS) by the total number of vehicles with SB. Note that this overall reduction has been obtained taking speed into account; a similar reduction could be obtained for point of impact, etc.

[5] These proportions are calculated proportions—calculated from the statistical model. They are not necessarily the exact *obtained* proportion (though they are close in all cases). The calculated proportion gives a better estimate according to the assumptions of the model.

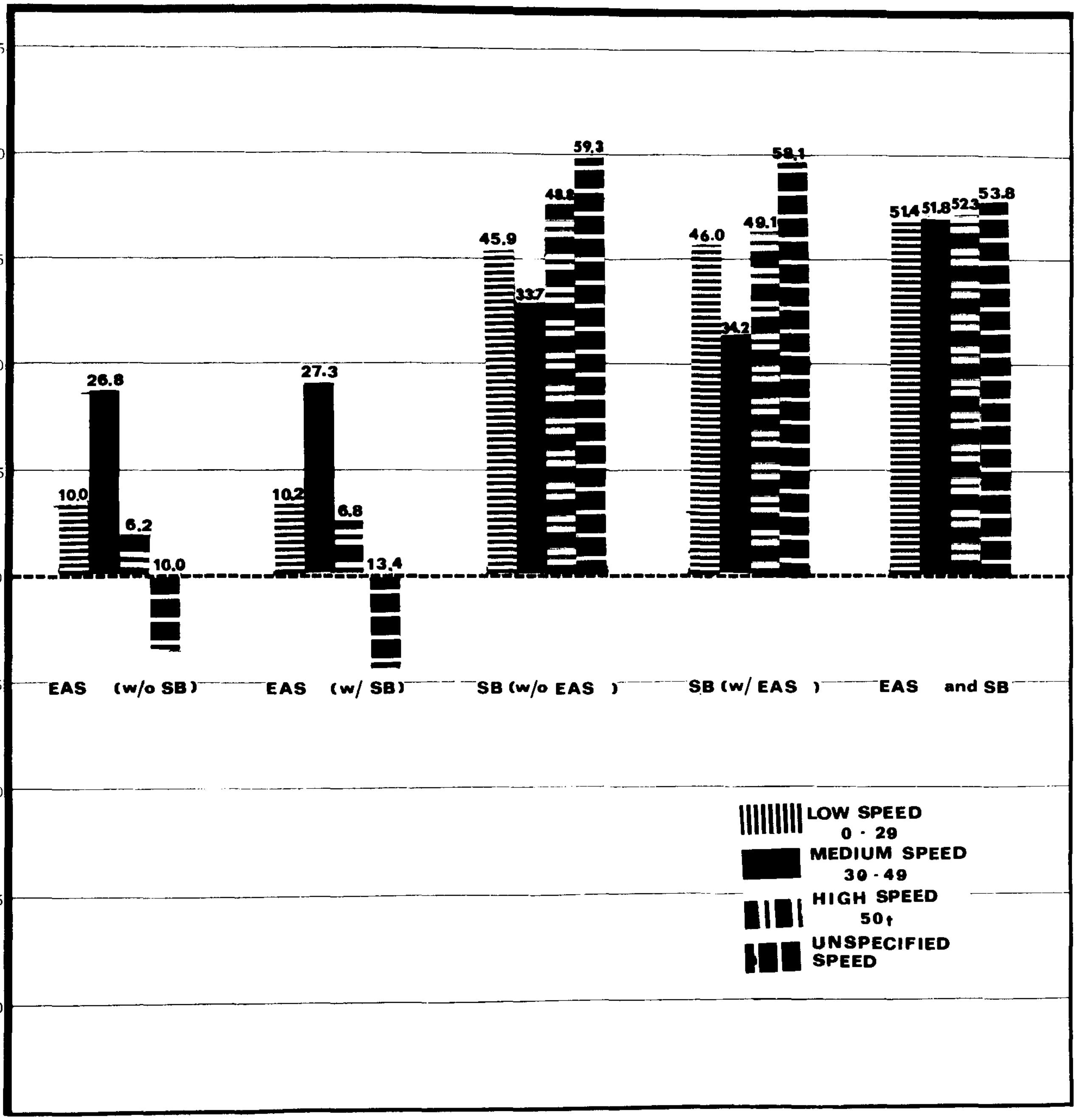

Figure 1. Percentage Reductions in Probability of Serious Injury for ***All*** *Accidents with Speed as a Factor.* The EA steering system is significant for medium speed ($\alpha = .01$) only. The seat belts are significant for low speed ($\alpha = .05$), medium speed ($\alpha = .01$), high speed ($\alpha = .01$) and unspecified speed ($\alpha = .01$).

1

	Low Speed 0-29	Medium Speed 30-49	High Speed 50+	Unspecified Speed
PROBABILITY (Serious) INJURY — SB / EAS				
1 NO NO	.028 (3123)	.076 (4611)	.181 (3928)	.332 (377)
2 NO YES	.026 (1422)	.056 (2063)	.169 (1906)	.365 (244)
3 YES NO	.015 (542)	.051 (700)	.093 (606)	.135 (38)
4 YES YES	.014 (412)	.037 (530)	.086 (499)	.153 (46)
EFFECT OF EAS (w/o SB)				
ACTUAL REDUCTION =(1)-(2)	.003	*** .020	.011	-.033
PERCENT REDUCTION =[(1)-(2)/(1)]	10.0%	26.8%	6.2%	-10.0%
EFFECT OF EAS (w/ SB)				
ACTUAL REDUCTION =(3)-(4)	.002	*** .014	.006	-.018
PERCENT REDUCTION =[(3)-(4)/(3)]	10.2%	27.3%	6.8%	-13.4%
EFFECT OF SB (w/o EAS)				
ACTUAL REDUCTION =(1)-(3)	** .013	*** .026	*** .088	*** .197
PERCENT REDUCTION =[(1)-(3)/(1)]	45.9%	33.7%	48.8%	59.3%
EFFECT OF SB (w/ EAS)				
ACTUAL REDUCTION = (2)-(4)	** .012	*** .019	*** .083	*** .212
PERCENT REDUCTION =[(2)-(4)/(2)]	46.0%	34.2%	49.1%	58.1%
EFFECT OF EAS AND SB				
ACTUAL REDUCTION = (1)-(4)	.015	.040	.094	.179
PERCENT REDUCTION =[(1)-(4)/(1)]	51.4%	51.8%	52.3%	53.8%

The number in parenthesis is frequency for each group
* Significant at α=.10
** Significant at α=.05
*** Significant at α=.01
\# Indicates frequencies are too low to be meaningful

Table 1. Serious Injury for All Accidents with Speed as a Factor.

By comparing one and two above (and/or in Table 2 or Figure 2) it is possible to see the difference in injury among *unbelted* drivers in cars with and without the EA system. The reduction of 8.3% down to 5.8% is a 30% reduction ($\frac{8.3-5.8}{8.3}$ = 30%). This change or reduction is significant at the .01 level.

Next, by comparing lines 3 and 4 it is possible to see any change for *belted* drivers in cars with and without EA systems. Here the reduction is from 6.1% serious injuries down to 4.2%. This too is a 30% reduction ($\frac{6.1-4.2}{6.1}$ = 30%). This amount of reduction is also significant at the .01 level.

Thus in medium speed impacts, the EA system is associated with a 30 percent reduction in frequency of serious injury. When drivers are *not* belted, the EA is associated with a 30 percent reduction. When drivers are belted (and thus sustain lower injuries presumably from benefits of the belt), presence of the EA system is associated with a further reduction of 30 percent. Thus, it appears that the belt and the EA system provide benefits that are additive to a degree. Continuing down the table it is seen that belts (compared to no belts) are associated with a 27 percent reduction when no EA system is in the car (weakly significant—at α = .10) and a 28 percent reduction when there *is* an EA system (also significant at α = .10).

So in medium speed front impacts, the EA system is associated with a 30 percent serious injury reduction; the belt with a 27 percent reduction. Comparing injuries when neither system is in use (8.3% serious injuries) with both systems in use (4.2%) yields a 49 percent reduction (significant at α = .01).

b. Lowest Speed Category. Serious injury is, of course, less frequent in the lower speed range. As can be seen, there is no evidence of any significant effect associated with the EA system in the low speed range. For unbelted drivers, the serious injury rate is 2.8 percent (Table 2 or Figure 2) whether there is or is not an EA steering system. For belted drivers, the serious injury rate is 1.9 percent whether there is an EA system or not. The effect for seat belts is not significant either.

c. Highest Speed Category. In the high speed range the EA is *not* associated with a significant reduction, either for belted drivers (7.2% reduction) or for unbelted drivers (6.6% reduction).

On the other hand, seat belts *are* associated with a significant (at α = .01) reduction of about 40 percent magnitude. This belt benefit is consistent in size and significance both in cars with and without the energy absorbing steering system.

Frontal impacts in summary. Before moving on, it may be well to recap what has just been said, for the findings contain some surprises.

First, on the subject of seat belts, we have shown a benefit associated with seat belts in frontal impacts! The benefit is statistically significant and is appreciable in magnitude—a reduction of 30-40 percent below the level sustained by unbelted drivers. Previous statistical analyses of belt effects have not reported benefits in front impacts.

The "explanation" for the new finding that first comes to mind would be improved car interiors in the newer cars. The reasoning is that in the older cars, belts in frontal impacts may seem of limited benefit, because *other* interior structures are injury-producing when struck.

In the present study, the effect of the seat belt did *not* differ significantly between cars without EA and cars *with* EA. Since those without EA were the older cars (65 to 67 Ford's, 64-66 for other makes) and those with EA

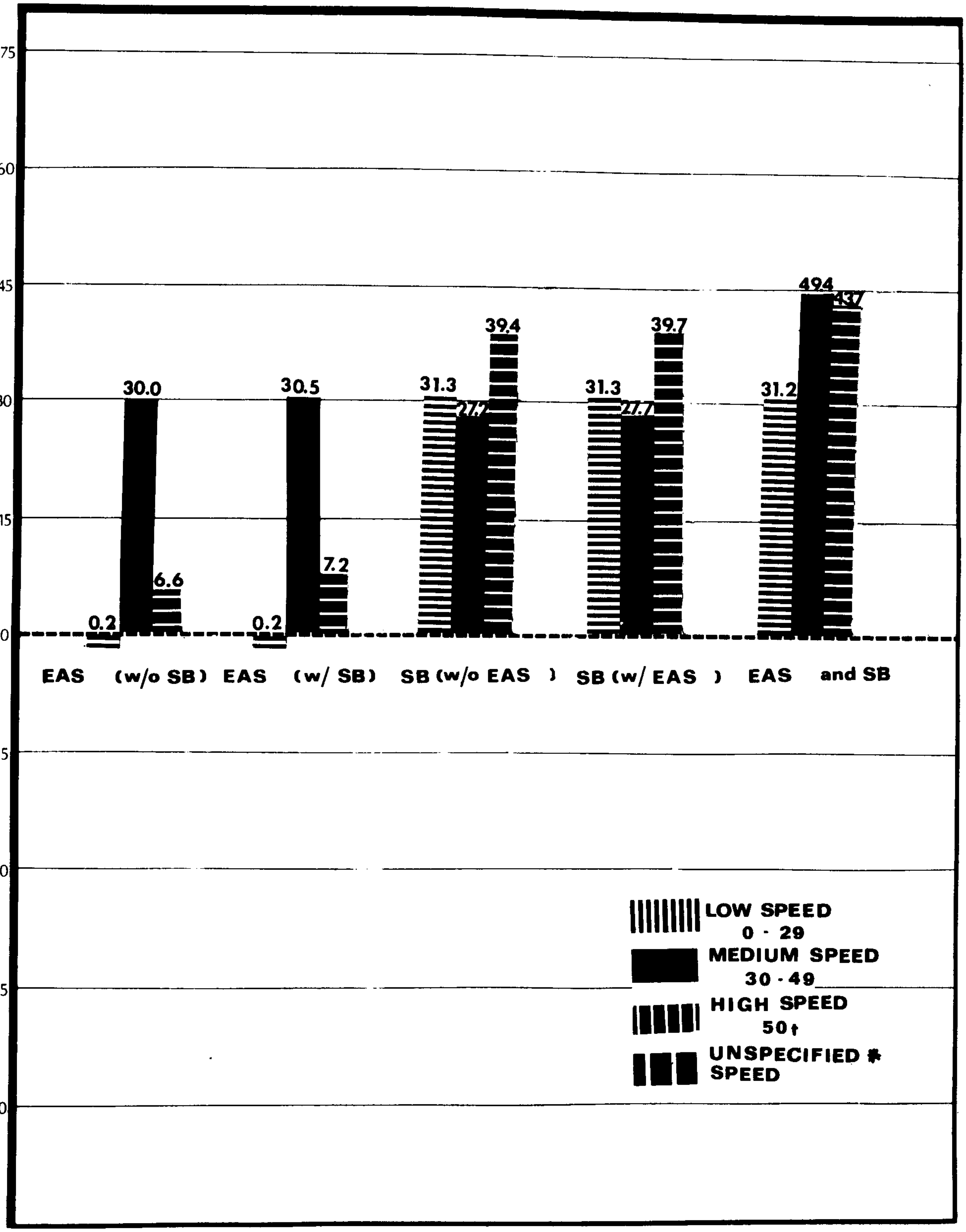

Figure 2. Percentage Reductions in Probability of Serious Injury for Frontal Impact Accidents with Speed as a Factor. The EA steering system is significant for medium speed (α= .01) only. The seat belts are significant for medium speed (α= .10) and high speed (α= .01).

*The frequencies for unspecified speed frontal impacts are too small to have meaningful probabilities.

	Low Speed 0-29	Medium Speed 30-49	High Speed 50+	Unspecified Speed
PROBABILITY (Serious) INJURY				
SB / EAS				
1 NO / NO	.028 (1450)	.083 (2195)	.189 (1246)	# (87)
2 NO / YES	.028 (674)	.058 (985)	.177 (623)	# (43)
3 YES / NO	.019 (261)	.061 (353)	.115 (219)	# (18)
4 YES / YES	.019 (203)	.042 (276)	.107 (177)	# (12)
<u>EFFECT OF EAS (w/o SB)</u>				
ACTUAL REDUCTION =(1)-(2)	-.00004	*** .025	.013	#
PERCENT REDUCTION =[(1)-(2)/(1)]	-0.2%	30.0%	6.6%	#
<u>EFFECT OF EAS (w/ SB)</u>				
ACTUAL REDUCTION =(3)-(4)	-.00003	*** .018	.008	#
PERCENT REDUCTION =[(3)-(4)/(3)]	-0.2%	30.5%	7.2%	#
<u>EFFECT OF SB (w/o EAS)</u>				
ACTUAL REDUCTION =(1)-(3)	.009	* .023	*** .075	#
PERCENT REDUCTION [(1)-(3)/(1)]	31.3%	27.2%	39.4%	#
<u>EFFECT OF SB (w/ EAS)</u>				
ACTUAL REDUCTION = (2)-(4)	.009	* .016	*** .070	#
PERCENT REDUCTION -[(2)-(4)/(2)]	31.3%	27.7%	39.7%	#
<u>EFFECT OF EAS AND SB</u>				
ACTUAL REDUCTION = (1)-(4)	.009	.041	.083	#
PERCENT REDUCTION -[(1)-(4)/(1)]	31.2%	49.4%	43.7%	#

The number in parenthesis is frequency for each group
* Significant at α=.10
** Significant at α=.05
*** Significant at α=.01
\# Indicates frequencies are too low to be meaningful

Table 2. Serious Injury for <u>Frontal Impact</u> Accidents with Speed as a Factor.

were the newer ones (68 and later for Ford, 67 and later for all others), this implies that the effect of the seat belt does not differ significantly between the older and newer cars in the present study. The cars *with* seat belts in Campbell's 1967 study were mainly 1964-67, i.e., about the same model years as the *older* cars in the present study. However, the reduction in serious injury due to seat belts in Campbell's 1968 study was only about 5 percent, while for the present study it was from 30-40 percent. Therefore, the hypothesis of improved interiors is an inadequate explanation.

Some difference *could* result from the greatly increased sample size of the present study, the more powerful analysis used, or from the different sample constituency in the two studies. The previous studies consisted of *all* cars, while the present study uses only cars with VIN's decodeable by the current Highway Safety Research Center computer program (Appendix 2). This eliminates many foreign cars, for example. It is unlikely, though, that these changes alone could have caused the large differences. We are, in fact, at a loss to account for this finding.

Now, let us look at the EA system. It is associated with a statiscally significant injury reduction of an appreciable 30 percent magnitude in medium speed crashes. No significant effect is seen in lower or higher speed events. This is perhaps to be expected. In lower speed crashes the force levels may not be great enough for the EA system to make much difference; that is, the non-EA wheel may suffice in most instances. On the other hand, in higher speed crashes the forces may be so great that even presence of an EA system often cannot help materially—so again the difference is not seen. Another possibility is that the injury scale may be too crude to detect modest differences.

Car-ran-off-road crashes. In setting up this study we saw no reason to expect a significant EA benefit in any category except frontal impacts. This was confirmed except that in medium speed, car-ran-off-road crashes, we also found a reduction in serious and fatal injury associated with the EA system. Table 3 (or Figure 3) shows the results for 5,563 single car crashes, of which 1,568 were in the medium speed category.

As can be seen, the pattern of apparent benefits associated with the EA system and with belts is similar to that already shown for frontal impacts except that the benefit, when significant, seems to be of somewhat greater magnitude.

From statistical data alone, it is not easy to know why this finding emerged for the car-ran-off-road category. The classification system notes only the fact that the car went off the road, and from coded data it is not possible to say in any given case what happened to the car once it left the road. The car could leave the road and then strike an embankment or tree and be a frontal impact. However, it could also skid sideways or overturn.

To gain some insight into this classification problem, an independent random sample of 878 car-ran-off-road accident reports were examined. We found that 47 percent of the State Highway Patrol cases examined were front impacts and 68.1 percent of cases investigated by local police were front impacts. Weighting the results by the proportions of car-ran-off-road accidents in the main study investigated by the State Highway Patrol (77 percent) and by the local police (23 percent), we estimate that, overall, half of car-ran-off-road accidents are front impacts.

The EA system has a reduction of 34.4 percent for unbelted drivers and 35.8 percent for belted drivers. Both are significant for $\alpha = .05$. These medium speed reductions are the only significant ones for car-ran-off-road crashes.

The seat belt effects for the various speeds in car-ran-off-road crashes are also significant whenever there is sufficient data. The reductions in the present study are about 54 percent for high speed (significant at $\alpha = .01$), 46 percent for unspecified speed ($\alpha = .05$) and 42 percent for medium speed ($\alpha = .05$). The largest injury reduction associated with belts is at high speeds as is also true of front impacts.

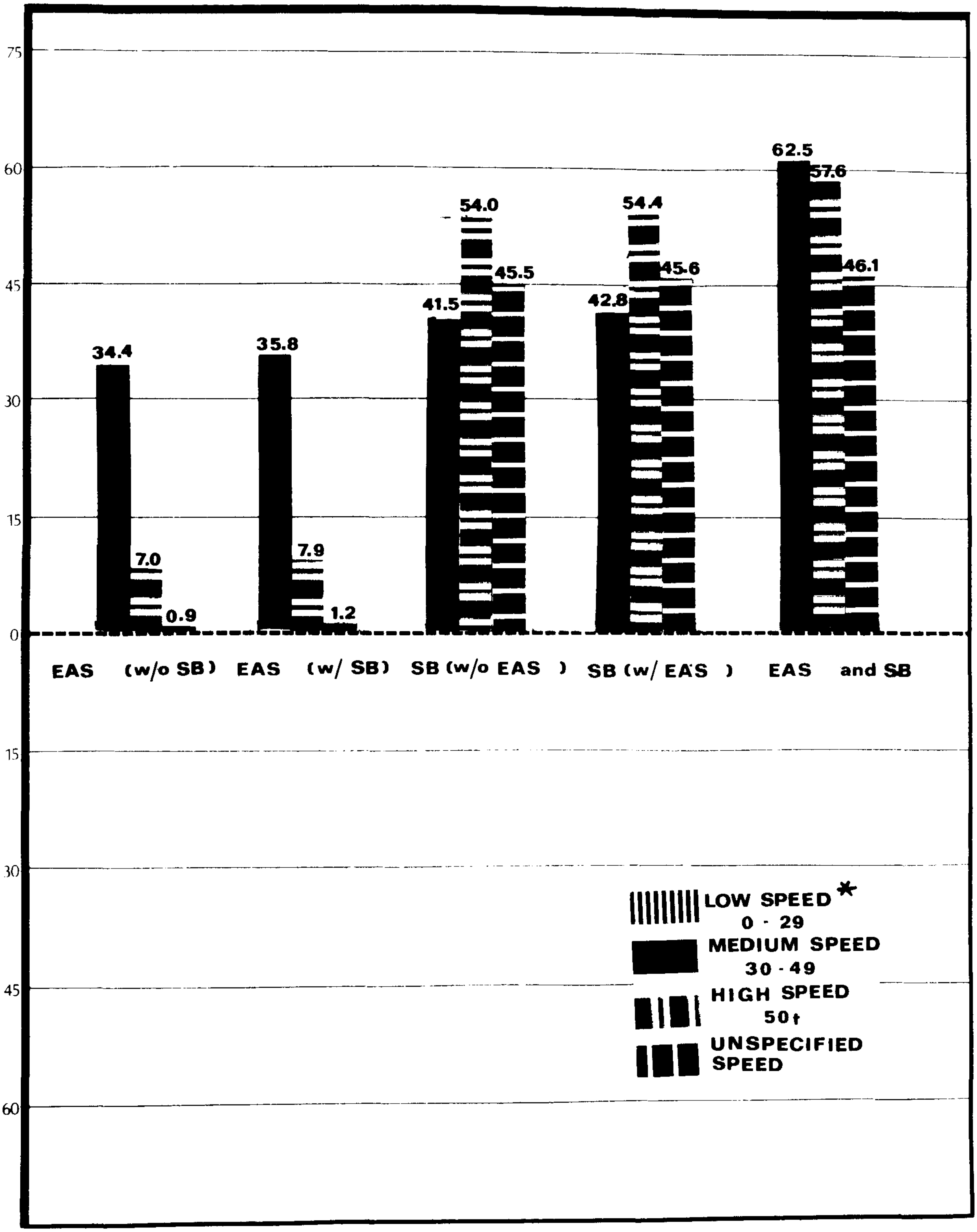

Figure 3. Percentage Reductions in Probability of Serious Injury for Car-Ran-Off-Road Accidents with Speed as a Factor. The EA steering system is significant for medium speed ($\alpha = .05$) only. The seat belts are significant for medium speed ($\alpha = .05$), high speed ($\alpha = .01$) and unspecified speed ($\alpha = .01$).

*The frequencies for low speed car-ran-off-road accidents are too small to have meaningful probabilities.

3

	Low Speed 0-29	Medium Speed 30-49	High Speed 50+	Unspecified Speed
PROBABILITY (Serious) INJURY				
SB / EAS				
1 NO NO	(101)	.131 (923)	.210 (1963)	.448 (236)
2 NO YES	(46)	.086 (415)	.195 (951)	.444 (174)
3 YES NO	(25)	.076 (138)	.097 (261)	.244 (13)
4 YES YES	(6)	.049 (92)	.089 (199)	.241 (20)
EFFECT OF EAS (w/o SB)				
ACTUAL REDUCTION =(1)-(2)	#	** .045	.015	.004
PERCENT REDUCTION =[(1)-(2)/(1)]	#	34.4%	7.0%	0.9%
EFFECT OF EAS (w/ SB)				
ACTUAL REDUCTION =(3)-(4)	#	** .027	.008	.003
PERCENT REDUCTION =[(3)-(4)/(3)]	#	35.8%	7.9%	1.2%
EFFECT OF SB (w/o EAS)				
ACTUAL REDUCTION =(1)-(3)	#	** .054	*** .113	** .204
PERCENT REDUCTION =[(1)-(3)/(1)]	#	41.5%	54.0%	45.5%
EFFECT OF SB (w/ EAS)				
ACTUAL REDUCTION = (2)-(4)	#	** .037	*** .106	** .203
PERCENT REDUCTION =[(2)-(4)/(2)]	#	42.8%	54.4%	45.6%
EFFECT OF EAS AND SB				
ACTUAL REDUCTION = (1)-(4)	#	.082	.121	.207
PERCENT REDUCTION =[(1)-(4)/(1)]	#	62.5%	57.6%	46.1%

The number in parenthesis is frequency for each group
* Significant at α=.10
** Significant at α=.05
*** Significant at α=.01
\# Indicates frequencies are too low to be meaningful

Table 3. Serious Injury for Car-Ran-Off-Road Accidents with Speed as a Factor.

In Campbell's 1968 study, the seat belt was associated with a reduction of 51 percent in high speed car-ran-off-road accidents. This is about the same as the present reduction of 54 percent.

Analysis by impact site. Table 4 (or Figure 4) shows that seat belts are associated with significantly reduced injury in front impacts (about 37 percent reduction), rear impacts (nearly 58 percent reduction), and unspecified impacts—those characterized by single vehicle, ran-off-roadway crashes (about 54 percent). The front and unspecified impact reduction are significant at $\alpha = .01$, and the rear impact effect at $\alpha = .05$. Even the statistically non-significant reductions for seat belts in side impacts suggest a trend of about a 20 percent reduction. The 58% reduction for rear impacts is impressive; in previous studies the data for rear impacts was insufficient for statistical tests.

Analysis by accident type. For all accident types for which there was sufficient data, the seat belt was associated with significant reduction in serious injury. The reductions in Table 5 (or Figure 5) are about 55 percent (significant at $\alpha = .01$) for car-ran-off-road, about 34 percent ($\alpha = .01$) for car vs. car, almost 63 percent for multiple vehicle ($\alpha = .05$) and about 30 percent for car vs. truck ($\alpha = .10$). The single car category consists of car-ran-off-road, car vs. fixed object and car vs. other object. Since the frequencies for the latter two are negligible, single car accidents are effectively car-ran-off-road accidents. A comparison of this study and the previous HSRC study indicates that the benefit of seat belts in car-ran-off-road (single car) accidents is about the same, while the benefit of seat belts in car vs. car accidents is much greater in the new study. This is consistent with the differences already cited between the studies for front impacts and rear impacts in that front and rear impacts are basically car vs. car accidents.

Any Injury

Though serious and fatal injuries are the better means of evaluating belts and EA systems, it is also of interest to record the statistical associations present when the criterion is occurrence of *any* injury.

For all accidents, the reductions in any injury associated with the seat belt are 27%, 24%, 37%, and 58% for low, medium, high and unspecified speeds respectively (see Table 6 or Figure 6). The 27 percent is significant at $\alpha = .05$ while the others are significant at $\alpha = .01$. These reductions are, as expected, less than their corresponding reductions for serious injury (see Table 11). For frontal impacts in the *any* injury category, presence of an EA system did *not* significantly reduce injury at any speed.

Frontal impact. The EA system was not associated with significant reductions in injury (any) at any speed for front impacts. This compares with a reduction of 30 percent in serious injury for medium speed frontal impacts. This greater benefit in reducing serious injury is not unexpected. In a medium speed situation the EA wheel can absorb energy and reduce but not necessarily prevent injury. In a low speed crash when forces are less, the two systems may not be functionally different. It also appears that any differences between the two systems are insignificant when struck with the greater forces of high speed. For seat belts the significant reductions are 29 percent for high speed (significant at $\alpha = .01$) and 25 percent for medium speed ($\alpha = .05$). (See Table 7 or Figure 7.)

These reductions are somewhat less than those for serious injury (39 percent for high speed and 27 percent for medium speed). Since both devices reduce the frequency of injuries, it appears that the mechanism is more likely to be that of reduction of a more serious injury to a less serious injury than a reduction of less serious injury to no injury.

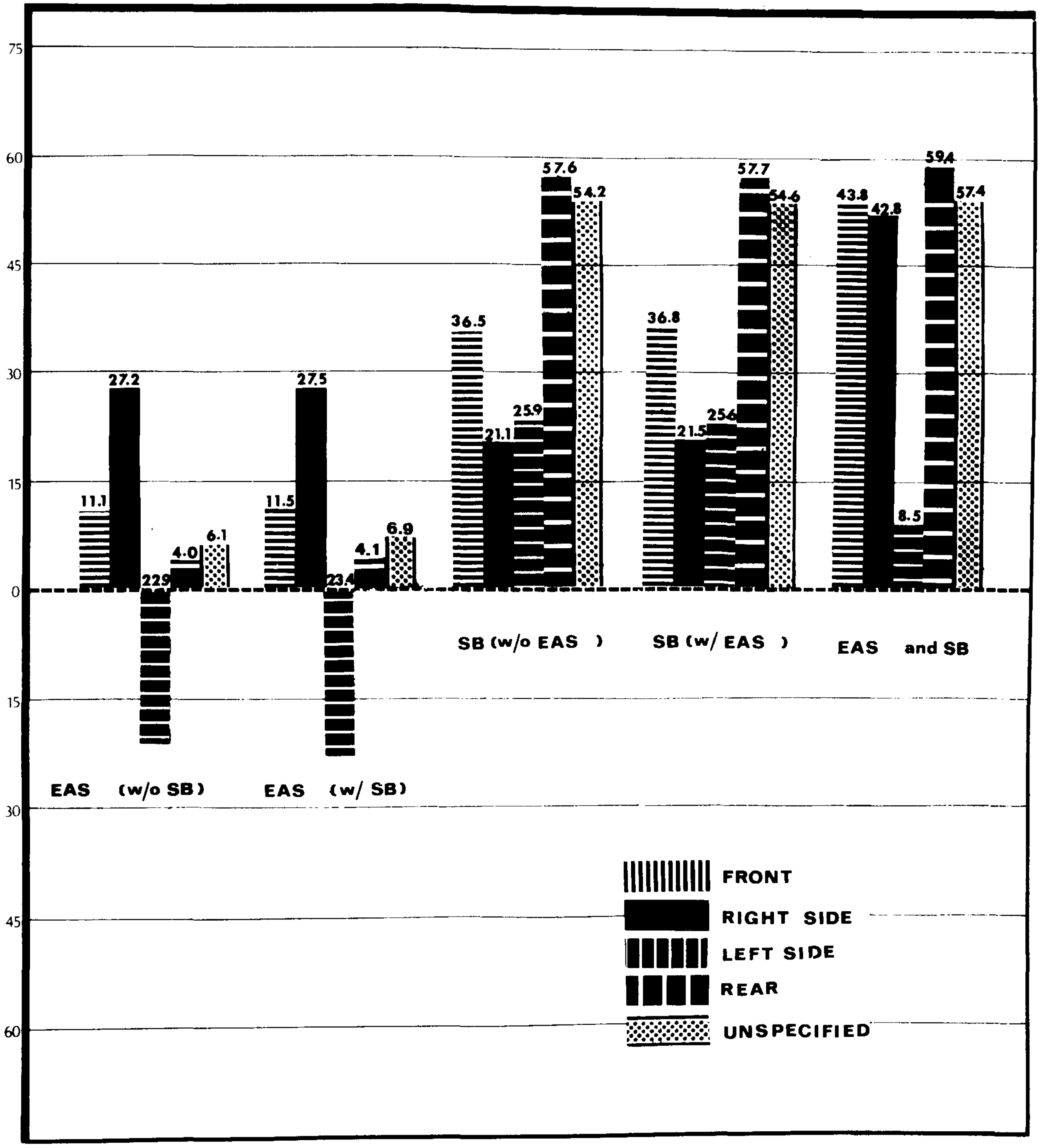

Figure 4. Percentage Reductions in Probability of Serious Injury for All Accidents with Point of Impact as a Factor. The EA system is not significant for any point of impact. The seat belts are significant for front ($\alpha = .01$), rear ($\alpha = .05$) and unspecified ($\alpha = .01$).

4

	Front Impact	Right Side Impact	Left Side Impact	Rear Impact	Unspecified Point of Impact
PROBABILITY (Serious) INJURY — SB / EAS					
1 NO NO	.095 (4983)	.079 (489)	.067 (656)	.022 (2649)	.202 (3262)
2 NO YES	.084 (2328)	.058 (245)	.082 (296)	.021 (1158)	.190 (1608)
3 YES NO	.060 (852)	.063 (100)	.049 (87)	.009 (405)	.093 (442)
4 YES YES	.053 (669)	.045 (66)	.061 (79)	.009 (350)	.086 (323)
EFFECT OF EAS (W/O SB)					
ACTUAL REDUCTION =(1)-(2)	.011	.022	-.015	.0009	.012
PERCENT REDUCTION =[(1)-(2)/(1)]	11.1%	27.2%	-22.9%	4.0%	6.1%
EFFECT OF EAS (W/ SB)					
ACTUAL REDUCTION =(3)-(4)	.007	.017	-.012	.0004	.006
PERCENT REDUCTION =[(3)-(4)/(3)]	11.5%	27.5%	-23.4%	4.1%	6.9%
EFFECT OF SB (W/O EAS)					
ACTUAL REDUCTION =(1)-(3)	*** .035	.017	.017	** .013	*** .110
PERCENT REDUCTION =[(1)-(3)/(1)]	36.5%	21.1%	25.9%	57.6%	54.2%
EFFECT OF SB (W/ EAS)					
ACTUAL REDUCTION =(2)-(4)	*** .031	.012	.021	** .012	*** .104
PERCENT REDUCTION =[(2)-(4)/(2)]	36.8%	21.5%	25.6%	57.7%	54.6%
EFFECT OF EAS AND SB					
ACTUAL REDUCTION = (1)-(4)	.042	.034	.006	.013	.116
PERCENT REDUCTION =[(1)-(4)/(1)]	43.8%	42.8%	8.5%	59.4%	57.4%

The number in parenthesis is frequency for each group
* Significant at α=.10
** Significant at α=.05
*** Significant at α=.01
\# Indicates frequencies are too low to be meaningful

Table 4. Serious Injury for All Accidents with Point of Impact as a Factor.

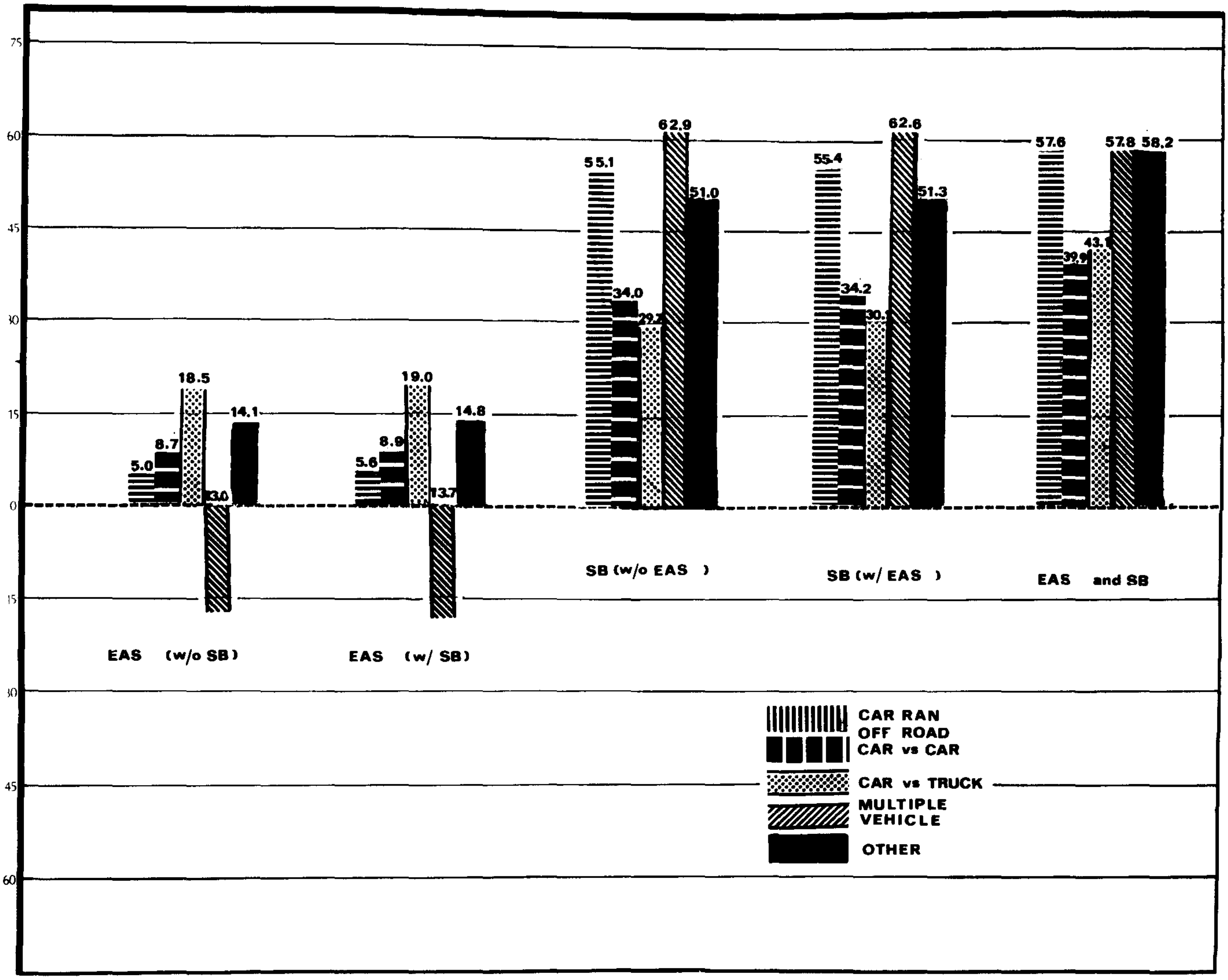

Figure 5. Percentage Reductions in Probability of Serious Injury for All Accidents with Type of Accident as a Factor. The EA system is not significant for any type of accident. The seat belts are significant for car-ran-off-road (α= .01), car vs. car (α= .01), car vs. truck (α= .10) and multiple vehicle (α= .05).

*The frequencies for car vs. fixed object and car vs. object are too small to have meaningful probabilities.

5

	Car Ran Off Road	Car Vs. Fixed Object	Car Vs. Object	Car Vs. Car	Car Vs. Truck	Multiple Vehicle	Other
PROBABILITY (Serious) INJURY — SB / EAS							
1 NO NO	.202 (3223)	# (85)	# (37)	.063 (6515)	.097 (1222)	.073 (795)	.095 (162)
2 NO YES	.192 (1586)	# (41)	# (18)	.058 (2970)	.079 (568)	.082 (358)	.081 (94)
3 YES NO	.091 (437)	# (11)	# (6)	.042 (1040)	.068 (218)	.027 (138)	.046 (36)
4 YES YES	.086 (317)	# (13)	# (3)	.038 (835)	.055 (169)	.031 (125)	.040 (25)
EFFECT OF EAS (w/o SB)							
ACTUAL REDUCTION =(1)-(2)	.010	#	#	.006	.018	-.009	.013
PERCENT REDUCTION =[(1)-(2)/(1)]	5.0%	#	#	8.7%	18.5%	-13.0% ▼	14.1%
EFFECT OF EAS (w/ SB)							
ACTUAL REDUCTION =(3)-(4)	.005	#	#	.004	.013	-.004	.007
PERCENT REDUCTION =[(3)-(4)/(3)]	5.6%	#	#	8.9%	19.0%	-13.7%	14.8%
EFFECT OF SB (w/o EAS)							
ACTUAL REDUCTION (1)-(3)	*** .111	#	#	*** .022	** .029	** .046	.048
PERCENT REDUCTION =[(1)-(3)/(1)]	55.1%	#	#	34.0%	29.7%	62.9%	51.0%
EFFECT OF SB (w/ EAS)							
ACTUAL REDUCTION = (2)-(4)	*** .106	#	#	*** .020	** .024	** .051	.042
PERCENT REDUCTION =[(2)-(4)/(2)]	55.4%	#	#	34.2%	30.1%	62.6%	51.3%
EFFECT OF EAS AND SB							
ACTUAL REDUCTION = (1)-(4)	.116	#	#	.025	.042	.042	.055
PERCENT REDUCTION =[(1)-(4)/(1)]	57.6%	#	#	39.9%	43.1%	57.8%	58.2%

The number in parenthesis is frequency for each group
* Significant at α=.10
** Significant at α=.05
*** Significant at α=.01
\# Indicates frequencies are too low to be meaningful

Table 5. Serious Injury for All Accidents with Type of Accident as a Factor.

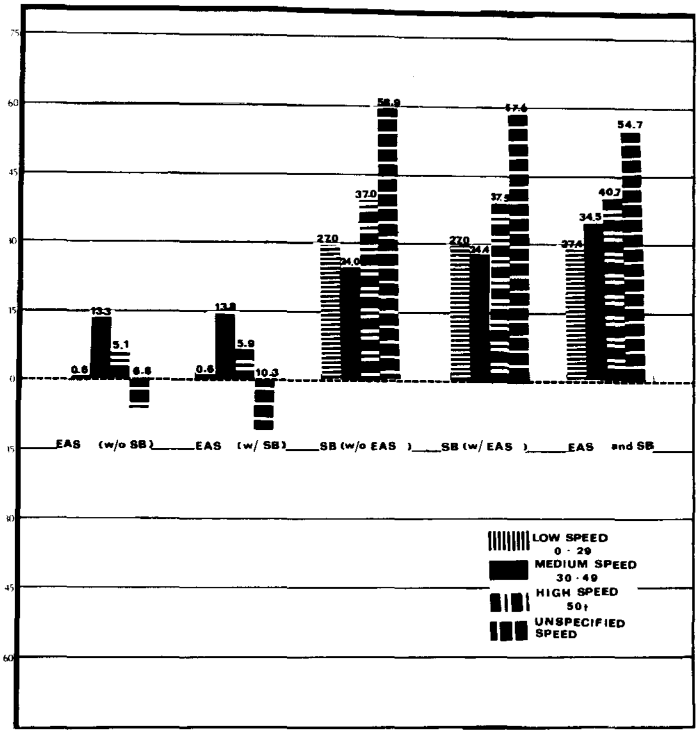

Figure 6. Percentage Reductions in Probability of Any Injury for All Accidents with Speed as a Factor. The EA **steering** system is significant for medium speed (∝= .01) only. The seat belts are significant for low speed (∝= .05) medium speed (∝= .01), high speed (∝= .01), and unspecified speed (= .01).

6

	Low Speed 0-29	Medium Speed 30-49	High Speed 50+	Unspecified Speed
PROBABILITY (Any) INJURY — SB / EAS				
1 NO NO	.074 (3123)	.143 (4611)	.292 (3928)	.441 (377)
2 NO YES	.073 (1422)	.124 (2063)	.277 (1906)	.471 (244)
3 YES NO	.054 (542)	.109 (700)	.184 (606)	.181 (38)
4 YES YES	.053 (412)	.094 (530)	.173 (499)	.200 (46)
EFFECT OF EAS (w/o SB)				
ACTUAL REDUCTION =(1)-(2)	.0004	*** .019	.015	-.030
PERCENT REDUCTION =[(1)-(2)/(1)]	0.6%	13.3%	5.1%	- 6.8%
EFFECT OF EAS (w/ SB)				
ACTUAL REDUCTION =(3)-(4)	.0003	*** .015	.011	-.019
PERCENT REDUCTION =[(3)-(4)/(3)]	0.6%	13.8%	5.9%	-10.3%
EFFECT OF SB (w/o EAS)				
ACTUAL REDUCTION =(1)-(3)	** .020	*** .034	*** .108	*** .260
PERCENT REDUCTION =[(1)-(3)/(1)]	27.0%	24.0%	37.0%	58.9%
EFFECT OF SB (w/ EAS)				
ACTUAL REDUCTION = (2)-(4)	** .020	*** .030	*** .104	*** .271
PERCENT REDUCTION =[(2)-(4)/(2)]	27.0%	24.4%	37.5%	57.6%
EFFECT OF EAS AND SB				
ACTUAL REDUCTION = (1)-(4)	.020	.049	.119	.241
PERCENT REDUCTION =[(1)-(4)/(1)]	27.4%	34.5%	40.7%	54.7%

The number in parenthesis is frequency for each group
* Significant at α=.10
** Significant at α=.05
*** Significant at α=.01
\# Indicates frequencies are too low to be meaningful

Table 6. Any Injury for All Accidents with Speed as a Factor.

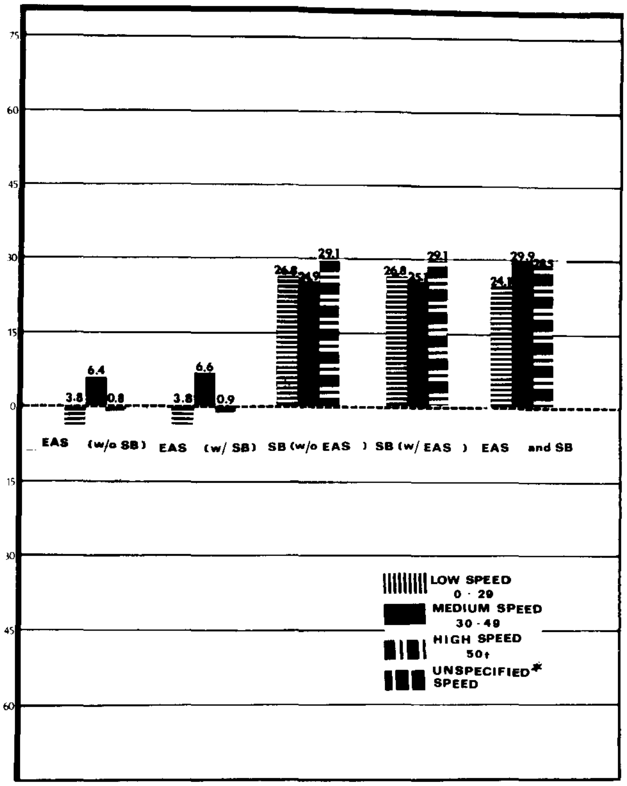

Figure 7. Percentage Reduction in Probability of Any Injury for Frontal Impact Accidents with Speed as a Factor. The EA steering system is not significant at any speed. The seat belts are significant for medium speed ($\alpha = .05$) and high speed ($\alpha = .01$).

*The frequencies for unspecified speed frontal impacts are too small to have meaningful probabilities.

7

	Low Speed 0-29	Medium Speed 30-49	High Speed 50+	Unspecified Speed
PROBABILITY OF Any [illegible] SB [illegible] EAS				
1 [illegible]	.061 (1459)	.135 (2195)	.277 (1246)	# (87)
[illegible]	.063 (674)	.127 (985)	.279 (623)	# (43)
[illegible]	.045 (261)	.102 (353)	.196 (219)	# (18)
[illegible] YES	.046 (203)	.095 (276)	.198 (177)	# (12)
[illegible]				
[illegible]	-.002	.009	-.002	#
[illegible]	- 3.8%	6.4%	- 0.8%	#
[illegible]				
ACTUAL REDUCTION [illegible]	-.002	.007	-.002	#
PERCENT REDUCTION [illegible]	- 3.8%	6.6%	- 0.9%	#
[illegible]				
[illegible]	.016	** .034	*** .081	#
[illegible]	26.8%	24.9%	29.1%	#
[illegible]				
ACTUAL REDUCTION [illegible]	.017	** .032	*** .081	#
[illegible]	26.8%	25.1%	29.1%	#
[illegible]				
[illegible]	.015	.040	.079	#
[illegible]	24.1%	29.9%	28.5%	#

[illegible]
*** [illegible]
# [illegible]

Table 7. Any Injury for Frontal Accidents with Speed as a Factor.

Car-ran-off-road accidents. Whereas medium speed was the only speed for which the EA system was associated with a significant reduction in serious injury, we find that when using the criterion of *any* injury the EA system is associated with benefits for both medium *and* high speed. The reductions in injury in Table 8 (or Figure 8) are about 38 percent (significant at α= .01) for medium speed and about 11 percent (α= .05) for high speed. For serious injury the reductions were 35 percent and 7 percent. These larger reductions from the EA system for *any* injury as opposed to serious injury are contrary to what was obtained for front impacts.

The reductions associated with seat belts are all significant at .01. The values for any injury are about 43%, 44%, and 49% for medium, high and unspecified speed respectively. At the speed at which seat belts are most effective in reducing serious injury (high), they are considerably less so for reducing any injury. (See Table 11.)

Analysis by impact site. Table 9 (or Figure 9) shows significant reductions in injury (any) related to seat belt for front (nearly 29%) and unspecified impact (about 48%) but not for rear (only about 12%). Both reductions are significant at α = .01. Note that all reductions are less than the corresponding ones for serious injury, with the reduction for rear impact dropping drastically from 58 percent to 12 percent (see Table 11).

Analysis by accident type. The reductions in Table 10 (or Figure 10) for any injury associated with seat belt use were about 48 percent for car-ran-off-road, almost 23 percent for car vs. car and nearly 44 percent for multiple vehicle (see Table 10). Again, as expected, these reductions are lower than the corresponding ones for serious injury. The largest change, though, is one from 30 percent to 2.4 percent for car vs. truck. (See Table 11.)

Seat Belt Reduction for Serious Injury Vs. Any Injury

In most cases the magnitude of changes in serious injury associated with belts was greater than that for any injury. The table below lists the ratio of the percent reduction in serious injury relative to that of any injury when the reductions were significant for both injury categories.

For the type of accident as factor, note that the car-ran-off-road yeilds the lowest ratio of 1.15. This low value is further detailed by the values for car-ran-off-road accidents analysis with speed as a factor. At medium and unspecified speeds, the belt is slightly less effective in reducing serious injuries than it is for any injuries.

When all accidents are considered, the ratio of reduction for serious injury to reduction for any injury ranges from .92 to 1.70 with all but two values greater than 1.0. When speed is the factor, we see that the ratio goes from a high of 1.70 at low speed down to 1.31 for high speed (and 1.01 for unspecified speed) implying that the greater effectiveness of the seat belt for serious injuries as opposed to any injuries decreases as speed increases.

Energy Absorbing Steering System and Seat Belt

The energy absorbing steering system is most effective at medium speeds, to a much lesser degree at high speeds and even less so at low speeds. The seat belt, though, is more effective at higher speeds than it is at medium speeds.

When the energy absorbing steering system and seat belt are considered simultaneously (as one item), it can be easily determined at which speed this combination is most effective.

For all accidents and for the groups of both the car-ran-off-road and front impact accidents, the EA system with seat belt provides at most speeds substantial benefit over and above that afforded by the seat belt. This is particularly true for medium speeds where ratios of about 1.50 are usually found. Table 12 lists the ratios of percent reduction for EA system and seat belt (SB) to percent reduction for SB alone.

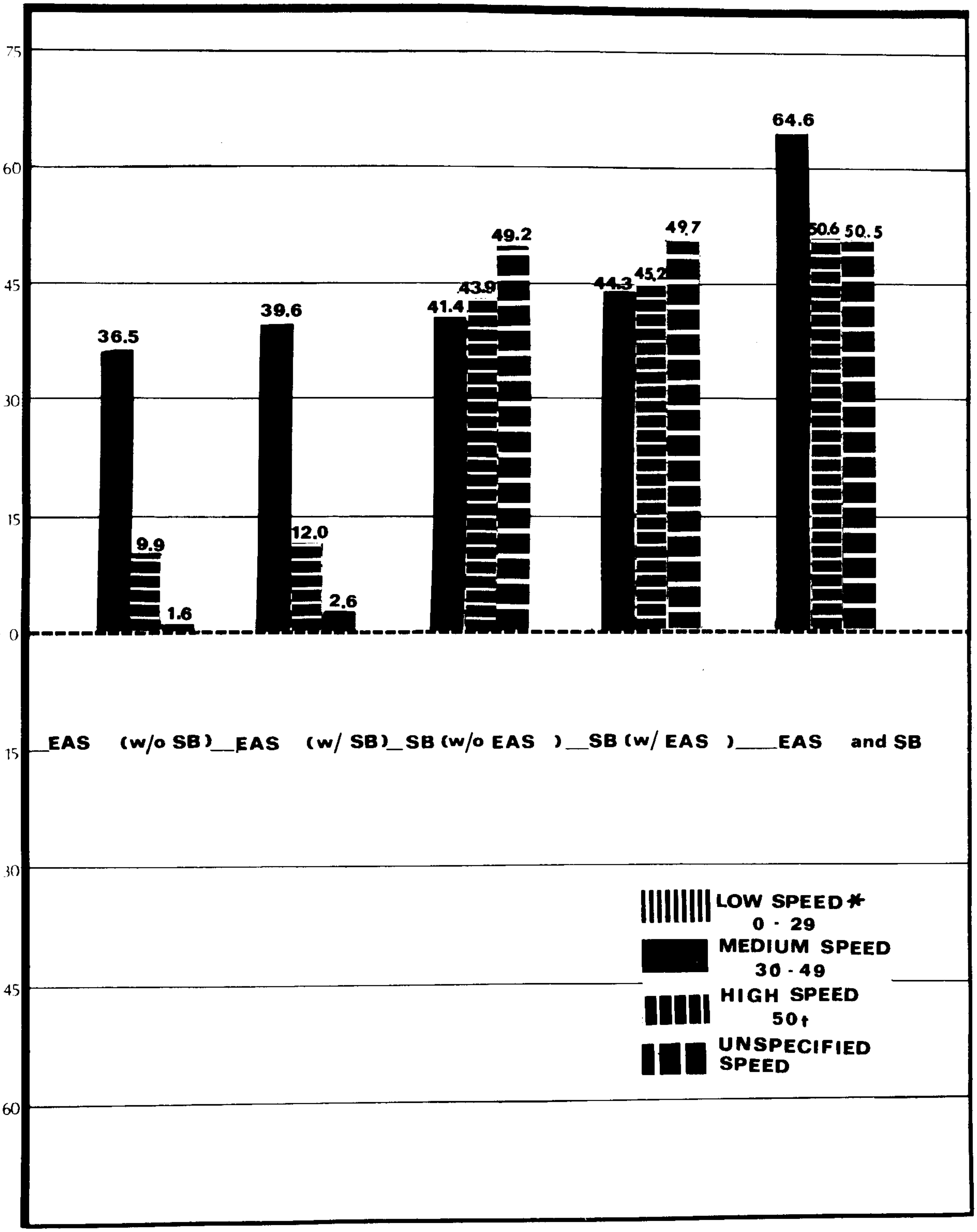

Figure 8. Percentage Reductions in Probability of Any Injury for Car-Ran-Off-Road Accidents with Speed as a Factor. The EA steering system is significant for medium speed ($\alpha = .01$) and high speed ($\alpha = .05$). The seat belts are significant for medium speed ($\alpha = .01$), high speed ($\alpha = .01$) and unspecified speed ($\alpha = .01$).

*The frequencies for low speed car-ran-off-road accidents are too small to have meaningful probabilities.

8

	Low Speed 0-29	Medium Speed 30-49	High Speed 50+	Unspecified Speed
PROBABILITY (Any) INJURY				
SB / EAS				
1 NO NO	# (101)	.257 (923)	.352 (1963)	.575 (236)
2 NO YES	# (46)	.163 (415)	.317 (951)	.565 (174)
3 YES NO	# (25)	.151 (138)	.197 (261)	.292 (13)
4 YES YES	# (6)	.091 (92)	.174 (199)	.284 (20)
EFFECT OF EAS (w/o SB)				
ACTUAL REDUCTION =(1)-(2)	#	*** .094	** .035	.009
PERCENT REDUCTION =[(1)-(2)/(1)]	#	36.5%	9.9%	1.6%
EFFECT OF EAS (w/ SB)				
ACTUAL REDUCTION =(3)-(4)	#	*** .060	** .024	.008
PERCENT REDUCTION =[(3)-(4)/(3)]	#	39.6%	12.0%	2.6%
EFFECT OF SB (w/o EAS)				
ACTUAL REDUCTION =(1)-(3)	#	*** .106	*** .155	*** .283
PERCENT REDUCTION =[(1)-(3)/(1)]	#	41.4%	43.9%	49.2%
EFFECT OF SB (w/ EAS)				
ACTUAL REDUCTION = (2)-(4)	#	*** .072	*** .143	*** .281
PERCENT REDUCTION =[(2)-(4)/(2)]	#	44.3%	45.2%	49.7%
EFFECT OF EAS AND SB				
ACTUAL REDUCTION = (1)-(4)	#	.166	.178	.290
PERCENT REDUCTION =[(1)-(4)/(1)]	#	64.6%	50.6%	50.5%

The number in parenthesis is frequency for each group
* Significant at α=.10
** Significant at α=.05
*** Significant at α=.01
\# indicates frequencies are too low to be meaningful

Table 8. Any Injury for Car-Ran-Off-Road with Speed as a Factor.

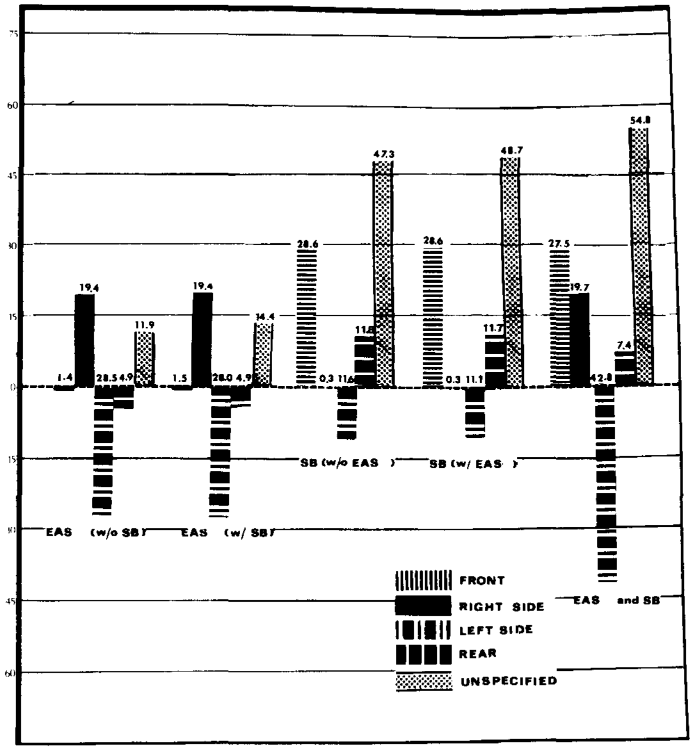

Figure 9. Percentage Reductions in Probability of Any Injury for All Accidents with Point of Impact as a Factor. The EA system is not significant for any point of impact. The seat belts are significant for front (α= .01) and unspecified (α= .01).

9

	Front Impact	Right Side Impact	Left Side Impact	Rear Impact	Unspecified Point of Impact
PROBABILITY (Any) INJURY — SB / EAS					
1 NO NO	.150 (4983)	.112 (489)	.116 (656)	.085 (2649)	.338 (3262)
2 NO YES	.152 (2328)	.090 (245)	.149 (296)	.089 (1158)	.298 (1608)
3 YES NO	.107 (852)	.112 (100)	.129 (87)	.075 (405)	.178 (442)
4 YES YES	.109 (669)	.090 (66)	.165 (79)	.079 (350)	.153 (323)
EFFECT OF EAS (w/o SB)					
ACTUAL REDUCTION =(1)-(2)	-.002	.022	-.033	-.004	*** .040
PERCENT REDUCTION =[(1)-(2)/(1)]	- 1.4%	19.4%	-28.5%	- 4.9%	11.9%
EFFECT OF EAS (w/ SB)					
ACTUAL REDUCTION =(3)-(4)	-.002	.022 #	-.036	-.004	*** .026
PERCENT REDUCTION =[(3)-(4)/(3)]	- 1.5%	19.4%	-28.0%	- 4.9%	14.4%
EFFECT OF SB (w/o EAS)					
ACTUAL REDUCTION =(1)-(3)	*** .043	.0004	-.013	.010	*** .160
PERCENT REDUCTION =[(1)-(3)/(1)]	28.6%	0.3%	-11.6%	11.8%	47.3%
EFFECT OF SB (w/ EAS)					
ACTUAL REDUCTION = (2)-(4)	*** .043	.0003	-.017	.010	*** .145
PERCENT REDUCTION =[(2)-(4)/(2)]	28.6%	0.3%	-11.1%	11.7%	48.7%
EFFECT OF EAS AND SB					
ACTUAL REDUCTION = (1)-(4)	.041	.022	-.050	.006	.185
PERCENT REDUCTION =[(1)-(4)/(1)]	27.5%	19.7%	-42.8%	7.4%	54.8%

The number in parenthesis is frequency for each group
* Significant at α=.10
** Significant at α=.05
*** Significant at α=.01
# Indicates frequencies are too low to be meaningful

Table 9. Any Injury for All Accidents with Point of Impact as a Factor.

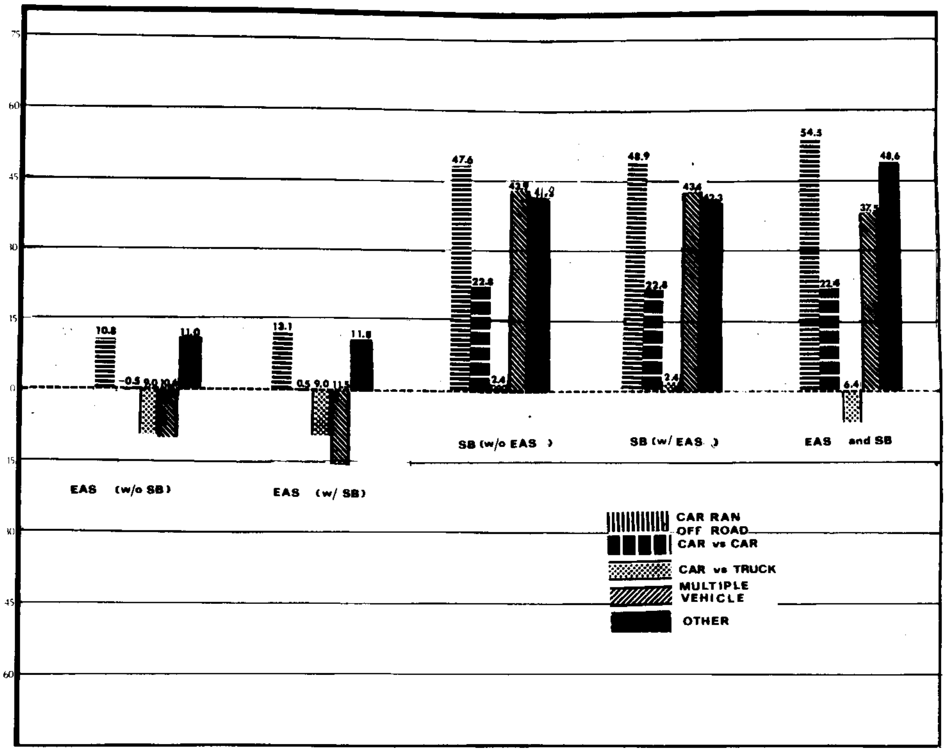

Figure 10. Percentage Reductions in Probability of Any Injury for All Accidents with Type of Accident as a Factor. The EA system is not significant for any type of accident. The seat belts are significant for car-ran-off-road (α= .01), car vs. car (α= .01), and multiple vehicle (α= .01).

*The frequencies for car vs. fixed object and car vs. object are too small to have meaningful probabilities.

10

PROBABILITY (Any) INJURY	Car Ran Off Road	Car Vs. Fixed Object	Car Vs. Object	Car Vs. Car	Car Vs. Truck	Multiple Vehicle	Other
SB / EAS							
1 NO / NO	.337 (3223)	# (85)	# (37)	.117 (6515)	.148 (1222)	.146 (795)	.159 (162)
2 NO / YES	.301 (1586)	# (41)	# (18)	.118 (2970)	.161 (568)	.162 (358)	.141 (94)
3 YES / NO	.177 (437)	# (11)	# (6)	.091 (1040)	.144 (218)	.082 (138)	.092 (36)
4 YES / YES	.154 (317)	# (13)	# (3)	.091 (835)	.157 (169)	.091 (125)	.082 (25)
EFFECT OF EAS (w/o SB)							
ACTUAL REDUCTION =(1)-(2)	*** .037	#	#	-.0006	-.013	-.015	.017
PERCENT REDUCTION =[(1)-(2)/(1)]	10.8%	#	#	- 0.5%	- 9.0%	-10.6%	11.0%
EFFECT OF EAS (w/ SB)							
ACTUAL REDUCTION =(3)-(4)	*** .023	#	#	-.0005	-.013	-.009	.011
PERCENT REDUCTION =[(3)-(4)/(3)]	13.1%	#	#	- 0.5%	- 9.0%	-11.5%	11.8%
EFFECT OF SB (w/o EAS)							
ACTUAL REDUCTION =(1)-(3)	*** .161	#	#	*** .027	.004	*** .064	.066
PERCENT REDUCTION =[(1)-(3)/(1)]	47.6%	#	#	22.8%	2.4%	43.9%	41.8%
EFFECT OF SB (w/ EAS)							
ACTUAL REDUCTION = (2)-(4)	*** .147	#	#	*** .027	.004	*** .070	.060
PERCENT REDUCTION =[(2)-(4)/(2)]	48.9%	#	#	22.8%	2.4%	43.4%	42.3%
EFFECT OF EAS AND SB							
ACTUAL REDUCTION = (1)-(4)	.184	#	#	.026	-.009	.055	.077
PERCENT REDUCTION =[(1)-(4)/(1)]	54.5%	#	#	22.4%	- 6.4%	37.5%	48.6%

The number in parenthesis is frequency for each group
* Significant at α=.10
** Significant at α=.05
*** Significant at α=.01
\# Indicates frequencies are too low to be meaningful

Table 10. Any Injury for All Accidents with Type of Accident As a Factor.

Table 11. Ratio of the Percentage Reduction for Probability of Serious Injury to the Percentage Reduction for Probability of Any Injury.

Class of Accidents	Factor	"level" of factors	ratio	serious	any
All	point of impact	front	1.28	***	***
		unspecified	1.13	***	***
All	type of accident	car ran off road	1.15	***	***
		car vs. car	1.50	***	**
		multiple vehicle	1.44	**	***
All	speed	low	1.70	**	**
		medium	1.40	***	***
		high	1.31	***	***
		unspecified	1.01	***	***
Front point of impact	speed	medium	1.10	*	**
		high	1.36	***	***
Car ran off road	speed	medium	.98	**	***
		high	1.22	***	***
		unspecified	.92	**	***

* Significant at $\alpha = .10$
** Significant at $\alpha = .05$
*** Significant at $\alpha = .01$

Table 12. Ratio of the Percentage Reduction for Probability of Injury for EA and SB Together to the Percentage Reduction for Probability of Injury for SB Alone.

Speed	Group of Accidents	Ratio for Serious Injury	Ratio for Any Injury
low	All	1.12	1.01
medium		1.53	1.43
high		1.07	1.09
unspecified		0.92	0.94
low	front impact	1.00	0.90
medium		1.80	1.20
high		1.10	0.98
unspecified		+	+
low	car-ran-off-road	+	+
medium		1.48	1.51
high		1.06	1.14
unspecified		1.01	1.07

+ - insufficient frequencies

For all accidents the combination of EA system has a weighted (over the speeds) reduction in serious injury of 51.9 percent or 8.9 percent higher than the SB alone (43.0%) and 37.7 percent higher than the EA system alone (14.2%).

CONCLUSIONS

This study presents results on the energy absorbing steering system and seat belt. The energy absorbing steering system results indicate that:

- The effectiveness of the EA system is independent of seat belt usage.
- The EA system is (most) effective for medium speed, frontal impacts and car-ran-off-the-road (or unspecified impacts) accidents.
- The EA system can reduce serious injuries by 14.2 overall and 27.1 (significant at = .01) for all medium speed accidents.
- The EA system reduces serious injury in all frontal impacts by 14.0 and by 30.3 (significant at = .01) in medium speed frontal impacts.
- The EA system reduces serious injury in all car-ran-off-road accidents by 13.7 overall, and by 35.1 (significant at = .01) in medium speed car-off-road accidents.

Some of the results for seat belts are in contrast to previous studies. The results from the seat belt indicate that:

- The SB's effectiveness is independent of the presence of the EA system.
- The SB is effective in reducing serious injury for all speeds and in particular at high speeds and the unspecified speed category.
- The SB is effective in reducing serious injury for front, rear (for serious injury) and unspecified points of impact and car-ran-off-road, car vs. car and multiple vehicle accidents.
- The SB can reduce serious injury by 43 percent overall (as opposed to 37 percent found previously) and 49 percent (significant at = .01) for high speeds.
- The SB can reduce serious injury in frontal impacts by 32.5 percent (significant at = .01) overall (in contrast to the previous studies which indicated no significant reduction) and by 39.6 percent (significant at = .01) for high speed frontal impacts.
- The SB can reduce serious injury in car-ran-off-road accidents by 49.5 percent overall and by 54.2 percent (significant at = .01) for high speed car-ran-off-road accidents.
- The SB can reduce serious injury in rear impacts by 58 percent (significant at = .05) overall.

The results for the EA and SB together indicate that:

Together they can reduce serious injury about 51.9 percent whereas the SB and EA system individually reduce them by 43.0 percent and 14.2 percent respectively.

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Appendix I

STUDY VARIABLES

1. Seat Belt Use by Driver
2. Energy Absorbing Steering Systems
3. Speed of Car
4. Site of Impact on Car
5. Type of Accident
6. Injury to Driver

Study Variables

The Variables in this study include:

1. Seat Belt Use by Driver
2. Presence or Absence of Energy Absorbing Steering System
3. Speed of Car
4. Impact Site
5. Type of Accident
6. Injury to Driver

1. Seat Belt Use by Driver

For each driver in the accident the patrol officer is instructed to report belt use. He reports "belt used", or "belt not used," or "belt use not known."

This study is confined to cases in which the officer positively reported one way or the other. The "belt use unknown" cases were discarded. The officer writes in the information in a designated place on the form. A large percentage of the data were eliminated because local police do not record this information.

2. Energy Absorbing Steering Systems

The following tables shows our definition of car groups with and without energy absorbing steering systems:

Without EA systems	With EA systems
64, 65 and 66 GM Cars	67 and later GM Cars
64, 65 and 66 American Motors Cars	67 and later American Motors Cars
64, 65 and 66 Chrysler Motors Cars	67 and later Chrysler Motors Cars
65, 66 and 67 Ford Motor Cars	68 and later Ford Cars

Only a few 69 models are included and no 1970 models.

The non-EA group was limited to the three model years prior to the introduction of the EA steering system; this helps to keep the effects of other safety features as constant as possible while still retaining a sufficient sample size.

Later in this section there is a description of the computer procedures for determining make and year of car for the above categories.

3. Speed of Car

The police officer is provided a space on the accident report form for the estimated speed of each vehicle just before onset of the accident process. For analysis purposes in single vehicle-crashes, this speed is used directly. In two-vehicle front-rear crashes, the difference in the two speeds is used. In front-side or front-front crashes, the highest speed reported for either car is assigned to *both* cars. Thus, if a parked car (zero mph.) is struck by a car traveling 30 mph., then the value of 30 mph. is assigned to both cars.[6] This is not a particularly sophisticated way of handling speeds, but is felt to be refined enough, considering possible errors in speed estimates, and also considering the fact that the speeds were rather grossly grouped as follows.

Lower Speed Group – 0 to 29 mph
Middle Speed Group – 30 to 49 mph
Higher Speed Group – 50 mph and greater
Unspecified Speed Group – speed not reported

4. Site of Impact on Car

Each car was classified according to the part of the car on which the principal damage was located. The groupings were as follows:

Front
Right Side
Left Side
Rear
Unspecified

Obviously, in some crashes damage is sustained on more than one part of the car, but the officer usually only reports one area of damage, and that is usually the area of most severe damage. Note that the unspecified category includes more than just those cases in which no report is made. It includes most of the single-vehicle, ran-off-road crashes, and therefore includes most of the overturn accidents.

5. Type of Accident

The data were also classified according to type of crash, and the following categories were used:

Car ran off roadway
Car hit fixed object (in roadway area; including railway trains)
Car hit other object (in roadway area)
Car collided with other car
Car collided with truck
Cars in crashes involving 3 or more cars
Other Crashes

The first category includes all vehicles that ran off the roadway before striking any object, and includes those that went off the road and struck a tree as well as those that went off the road and rolled over without striking anything.

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6 Because of complications, in the event of a three-or-more car crash, each car was assigned its own speed without reference to the other cars. All these cars are placed in the multiple-vehicle category.

In reference to the "multiple" vehicle category, all cars in a three-or-more vehicle crash are included in the Multiple-Vehicle class. When the number of cars exceeded four, the cars depicted on the "trailer cards" were eliminated because of processing difficulties.

Both vehicles in a car-to-car crash are classified. If one strikes the other in the side, both are placed in the car-vs.-car category. One is classified as having struck with the front, and the other is classified as having been struck on the side. If a car and a truck collide, both are placed in the car-vs.-truck category (for purposes of defining the reference group). If two trucks collide, both are placed in the "other" category.

It was possible to classify nearly all cases with respect to these variables. The principal cases that were discarded in this edit-check process were those that had "illegal" punches on the card, some vehicles in four-or-more vehicle crashes, and vehicles that struck bicyclists, pedestrians, or animals.

6. Injury to Driver

Driver injuries are classified by the officer at the scene (or on the basis of the officer's follow-up investigation). The classification follows the nationally used *Manual on Classification of Motor Vehicle Traffic Accidents* (USA Standards Institute Standard D 16.1), National Safety Council, Chicago, 1962. On page 14 of this manual, injuries are classified on a five-point scale as follows:

1. no injury

2. "C" injury. Non-Visible Injury—is a complaint of pain without visible signs of injury, or momentary unconsciousness.

3. "B" injury. Minor Visible Injury—is an abrasion, bruise, swelling, limping or obviously painful movement.

4. "A" injury. Serious Visible Injury—is a bleeding wound, distorted member, or any condition that requires the victim to be carried from the scene of the accident.

5. Fatal injury. An injury that results in death within 12 months of the accident.

It should be noted here that while the definitions' manual provides that death within one year following the accident (and directly attributable thereto) is counted as a motor vehicle fatality, and while the state and national figures are corrected for such delayed fatalities, and while the relevant accident report forms themselves are corrected where possible, it is nevertheless true that the accident report itself may not always be corrected. Therefore, there may be at least some cases in which the driver is reported as having an "A" injury based on the situation a few days following the crash but the patient eventually dies. In those cases in which the records are not updated, such an event would sometimes be counted as an "A" injury.

Appendix II

DESCRIPTION OF COMPUTER PROCEDURES FOR DETERMINING MAKE AND YEAR OF CAR

Description of Computer Procedures for Determining Make and Year of Car

With respect to car year, the accident report form includes a space for the officer to record the make and year of the vehicle in question. Whatever year the officer records is transcribed to computer tape and used in this study as the year of the car. There is, however, one circumstance in which the computer program overrides the officer's year designation. This is based on the fact that the VIN has a digit or letter denoting the year of the car.

Therefore, if *all three* of the following conditions hold, the computer program overrides the officer's year designation: (1) the officer's year designation is inconsistent with the VIN, (2) the VIN appears correct in *every* respect (this implies several consistency checks) and (3) the year indicated by the VIN is only one year different from the officer's entry.

When all these conditions are met, the computer program substitutes the year indicated in the VIN in place of the year indicated by the officer. If the officer's entry disagrees with the VIN by *more* than one year, the case is discarded.

This procedure is based on the assumption that with cars a few years old the officer may designate the correct make, and may be able to recall the "vintage" of that particular car within a year or so, but he may be unable to recall the specific year. Such an occurrence is reasonable in view of the fact that sometimes only minor styling changes differentiate the external appearance of one year's model from the next.

On the accident report form, the officer is instructed to write down the make of the car, and of course many spelling variations are seen. For example, the officer may write down "Ford" or "Galaxie" to designate a standard-sized Ford, or he may write "Chevelle", "Malibu", "Chevrolet", or "Chevy", to indicate the Chevelle series. The computer program first reads the officer's English language indication with respect to make and model, using only the first four letters of the word. The program accepts many spellings. Thus, the following initial spellings would be accepted and would activate the computer search program:

Dodg
Ford
GTO
Dart
Plym
Must (ang)

Spellings to be used were decided with assistance of a dictionary of *all* spellings in the entire data file. All but the least common are included. The various spellings that might represent a particular make of car are then channeled into the same computer program routine.

Next, the VIN written down by the officer is checked by the computer program. The question is two-fold. First, does the VIN indicate the same brand of car the officer indicated? And, second, is the VIN formatted properly and acceptably?

The VIN varies from 6 to 13 characters, and has both alpha and numeric characters. The format of the VIN varies from corporation to corporation within the same year, and from car line to car line within a single corporation in a single year. Sometimes, for example, the model year is indicated by a number and sometimes by a letter; sometimes the year designation is the *first* character in the string, and sometimes it is in another position.

In any event, for a car to be accepted as a given make, the VIN must be formatted properly for that particular car make in terms of number of characters, proper placement of alpha and numeric characters within the sequence, and also "legality" of characters in a given position. As an example, one corporation designates the factories where the car was made by a letter in a certain position, and not all letters are used; therefore, the program will accept only a correct letter in that particular position. For some companies the VIN is just a sequence number which does not carry any information, and does not therefore lend itself to any checks.

Naturally, this detailed checking process resulted in the elimination of many cars because the reported VIN was not correctly formatted. The recording error could have been committed by the policeman at the scene, trying to copy the number under less-than-ideal conditions, or it could have been a clerical error in the various transcriptions of the data. Perhaps it is not beyond the realm of possibility that the number may even have been affixed erroneously at the factory.

In preparing the computer program to ascertain car make from VIN, the reference materials were:

Motor Vehicle Identification Manual, National Automobile Theft Bureau, published by Palmer Publications Company, Downers Grove, Illinois.

NADA Official Used Car Guide, published by National Automobile Dealers Used Car Guide Company, Washington, D.C.

Unfortunately, these two books did not always agree exactly as to VIN for a given make, but in such cases we allowed for both possibilities.

As a result of the computer program, very many make-model-body-style combinations were uniquely identified—several hundred, in fact.

Additional details of this computer program, as well as the exact constituency of all cars identified, have previously been reported in "Driver Injury in Automobile Accidents Involving Certain Car Models" by B.J. Campbell, University of North Carolina Highway Safety Research Center, July 1970.

Appendix III

THEORY OF STATISTICAL ANALYSIS

Theory of Statistical Analysis

The data to be analyzed consisted of four separate groups, depending upon the status of seat belt use and upon the presence of an energy absorbing steering system. The groups were designated as follows: SB yes-EAS yes; SB yes-EAS no; SB no-EAS yes; SB no-EAS no. For each subdivision above and for each injury group (serious injury and *any* injury), the log $\frac{\text{Probability (injury)}}{\text{Probability (no injury)}}$ or log Pr (injury)/Pr (no injury) was estimated by log (number with injury/number without injury). Some of the numbers involved in estimating these probability ratios were very small. Since the probability of injury itself would therefore have been quite irregular, the more consistent log ratio (logit) was used.

From these estimated log ratios, the effects of seat belt use and energy absorbing steering wheel system presence were estimated. Consider, for example, the analysis of front impact accidents with speed as a factor. For each speed—low, medium, high and unspecified—the following operation is performed. The log [Pr (injury)/Pr (no injury)] is set equal to a mean or average effect (α) for each speed; plus a seat belt effect (β) for each speed if the seat belt is worn (minus the effect if it is not worn); plus an EAS effect (γ) if the EA system is present (minus the effect if it is not present). The resulting equations for speed are

$$\begin{aligned} \log \text{Pr (injury)/Pr (no injury)} &= \alpha + \beta + \gamma \quad \text{for SB yes, EA system yes} \\ & \alpha + \beta - \gamma \quad \text{for SB yes, EA system no} \\ & \alpha - \beta + \gamma \quad \text{for SB no, EA system yes} \\ & \alpha - \beta - \gamma \quad \text{for SB no, EA system no} \end{aligned}$$

The parameters α, β and γ differ for each speed. They are estimated using a program for the analysis of categorical data by linear models.[7] The familiar linear models approach for continuous data has been extended to categorical (discrete) data.

Once these parameters are estimated, the model is tested to see whether it actually fits the data. In every analysis performed, the model did indeed fit the data. This means that the seat belt and energy absorbing steering wheel are additive, i.e., the benefit of the use of seat belts is itself not affected by the presence or absense of the EA system and vice versa. The total reduction in probability of injury is increased, though, when both the seat belt and the energy absorbing steering wheel are present.

The probabilities used throughout the study come from this model. These probabilities are more reliable than the probabilities calculated from the raw data because the different parameters α, β and γ are calculated using data from all four groups. If the probabilities were calculated from the raw data, they would be based on only that particular group. The resulting model probabilities are based on more observations and are more reliable; this is partiuclarly so when a particular group has few observations while other groups have many.

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[7] James E. Grizzle, C. Frank Starmer and Gary G. Koch, "Analysis of Categorical Data by Linear Models," *Biometrics,* 25 (September, 1969), 489.

To obtain the probability, it is necessary to take the inverse of the logarithm, and perform a division, e.g., for SB yes and EA yes.

$$\begin{aligned}\Pr(\text{injury}) &= \text{inverse log}(\alpha + \beta + \gamma)/[1 + \text{inverse log}(\alpha + \beta + \gamma)] \\ &= \text{Exp}(\alpha + \beta + \gamma)/[1 + \exp(\alpha + \beta + \gamma)]\end{aligned}$$

As an example, for medium speed front impact accidents and serious injury

α = -2.7620
β = -.17077
and γ = -.19159

so that for EAS yes, SB yes, Pr (serious injury) = .042 or there is a 4.2% chance of serious injury.