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PASSENGER CAR OCCUPANT EJECTION

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16. Abstract

This is the final report for Project Number 1153 entitled "Occupant Ejection/Accident Data Analysis," sponsored by the Motor Vehicle Manufacturers Association. The project aimed to determine the influence of various vehicle systems in preventing (or not preventing) occupant ejection from passenger cars.

Accident data from the National Highway Traffic Safety Administration's Fatal Accident Reporting System and from the National Crash Severity Study (NCSS) were examined. In addition, a special analysis was completed for a subset of the NCSS data in which only one of two front-seat occupants was ejected.

The reduction in ejection rate associated with the advent of improved door latches and glazing components appears to have levelled off. In the mix of cars of varied size, there are complex interactions of factors associated with ejection. While smaller cars generally have higher ejection rates, these are largely explained by a higher propensity to rollover and by the predominance of young drivers in these cars.

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SUMMARY

The incidence of ejection from passenger cars has declined steadily with the newer model years since the topic was brought to public attention in the early 1960's. A number of automotive design modifications resulted from these early findings, including strengthened latching mechanisms and improved glazing. Yet even for the more recently produced cars, according to reports in the NHTSA's Fatal Accident Reporting System, more than one in five occupant fatalities is associated with ejection. A similar trend (with model year) exists for non-fatal accidents as represented by the National Crash Severity Study (NCSS) data. The most obvious determinant of ejection is the lack of restraint usage. With few exceptions, no properly restrained car occupants were completely ejected.

The next most apparent single factor is vehicle size, the (NCSS) ejection rate for foreign sports cars being nearly six times as great as for standard/full size cars (3.90% versus 0.66%). Many other factors also associate with ejection, and some of these interact strongly with car size. Ejections are more common with rollover, in rural areas (compared to urban), among young drivers, in the summer, and on road classes with fewer intersection conflicts. Ejection frequency is also high for infants (0 and 1 years of age), although the sample size available for this determination is small. A model interrelating several of the more important variables provides mixed results relative to car size, and perhaps a better understanding of the ejection phenomenon.

The detail available in the NCSS data allows an assessment of the frequency of door opening by model year, and the frequency of this has declined by nearly 30% since the 1960's (10.1% of the crashes of 1964-68 cars had at least one door open as compared with 7.1% for 1974-78 cars). Considering car sizes in just two groups--compacts and smaller versus intermediates and larger--a difference in the distribution of ejection

portal is apparent. Small cars have a door ejection rate 1.3 times that of the large cars, but a window ejection rate 3.7 times as large.

In the NCSS data rear-seat occupants are somewhat less likely to be ejected than front-seat occupants (0.8% versus 1.0%), and drivers and right-front occupants have nearly equal ejection rates (0.976% versus 0.988%). The incidence of ejection for persons wearing available restraints is very low--less than 0.1%. Individual case reviews of the four restrained ejectees suggest that half of these were improperly reported, and that the true rate is even lower. In one older (1964) car, the lap belt anchoring bolts pulled through the rusted floorpan, leading to an ejection. In the fourth case, a passive (upper torso only) restraint permitted ejection through a rear window/door.

A special analysis of NCSS cases in which only one of two front seat occupants was ejected permits an assessment of the degree of injury for ejected and unejected occupants under similar crash conditions. In 74 such "matched pair" cases, 16 ejectees but none of the contained (unejected) occupants were fatally injured. For ejectees, driver and right-front injury (severity) distributions were essentially the same.

The analyses presented in this report are based on accidents which occurred in the period January 1977 through March 1979 and, of course, represent the car population extant at that time. Since then the U. S. has experienced a definite shift toward smaller cars; hence the evidence of higher ejection rates in smaller cars, particularly in non-rollover crashes, might be cause for concern. Restraint usage was nearly zero among ejectees, and almost negligible (less than 10%) even among those who were not ejected. On the other hand, it is clear from these analyses that occupants who use available restraints are almost never completely ejected.

The reduction in ejection rate which can be associated with major modifications to door and glazing components in the cars seems to have leveled off, and one could speculate that the trend toward very small passenger cars may lead to an increase in ejection frequency in the future. The one countermeasure most likely to produce a continued downward trend in this statistic is restraint usage, and the importance of this in the 1980's should be apparent from this presentation.

1.0 INTRODUCTION

Ejection from a passenger car as the result of a crash has long been recognized as a dangerous event. The literature regarding ejection is typically concentrated on one of two topics--ejection, per se, and rollover (because of the strong association of ejection with rollover). Ejection was certainly recognized as an injury-increasing factor in early reports from the Cornell Aeronautical Laboratories (now CALSPAN). Many other authors have reported on the topic since that time. As a result of these earlier findings, three major changes have resulted--the strengthening of door locks, windshield improvements such as retention and high penetration resistance (HPR) glazing, and the installation of belt restraints in almost all passenger cars.

With these improvements, the proportion of fatalities involving ejection has shown a steady decline, as illustrated in the data of Figure 1 taken from the 1979 FARS. Two regression lines, one from 1962 to 1966 and the second from 1967 tO 1980, indicate that this proportion was on the order of 27% for models produced in the early sixties, and about 22% for the late seventies. Nevertheless, the fact that one of five passenger fatalities is associated with ejection in the most modern cars is cause for continuing concern.

With the availability of the National Crash Severity Study data, a 27-month in-depth accident data collection effort concentrated on passenger car and light truck involvements, it is appropriate to review the ejection phenomenon.

The NCSS data set contains detail not previously available in a file representative of the general accident population. Injuries are coded using the AIS[1] and OIC[2] codes; portal of ejection has been

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[1] The Abbreviated Injury Scale (1976 Revision). American Association for Automotive Medicine. 1976.

[2] "An Occupant Injury Classification Procedure Incorporating the Abbreviated Injury Scale." J. C. Marsh, Proceedings of the International Accident Investigation Workshop, Pilot Study on Road

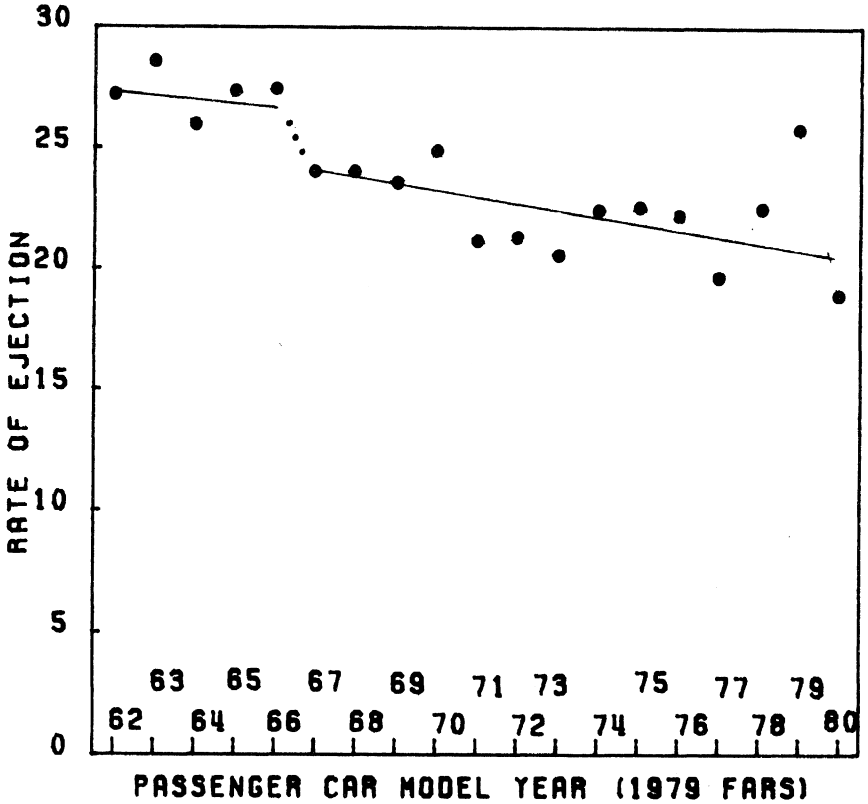

FIGURE 1
Percent of Fatal Occupants Who Were Ejected
(Complete and Partial)

recorded when it was known; and the vehicle and accident characteristics are provided in good detail. This report is primarily based on the NCSS data, and includes (1) a general review to learn what is different about accidents involving ejection, (2) descriptive statistics about the frequency of ejection by portal, by car type, etc., (3) case reviews of ejections of restrained occupants, and (4) reviews of matched pairs (one ejection, one non-ejection) in the same crashed vehicle.

The remainder of this report is organized as follows: Section 2 contains a review of the recent literature in both the ejection and rollover areas. Section 3 reviews the differences between ejection and non-ejection crashes. Section 4 provides a variety of descriptive statistics from NCSS and FARS about ejectees and their crashes. Section 5 presents a review of the small number of cases of belted occupant

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Safety for Committee on the Challenges of Modern Society, NATO, June 28-29, 1973, pp. 143-162. 1974.

ejections. Section 6 reports on the matched pair comparison of belted and unbelted persons. Appendix A presents information from a hard-copy review of 11 fatal-ejection accidents. Also included are comments on the NCSS data based on the detailed explanation of these 11 case reports.

2.0 LITERATURE REVIEW

For some time the problem of occupant ejection has been a subject of concern and interest in the highway safety community. In a paper prepared for the American Medical Association Journal in 1962, Robert A. Wolf discussed the history of the subject.[3]

Wolf outlined four Cornell University studies in his paper.[4] He noted that ejection was first "discovered" in 1954 by John Moore and Boris Tourin following a Cornell Automotive Crash Injury Research project (ACIR). Moore and Tourin were later joined by John W. Garrett in the ACIR studies, and together, helped lay much of the groundwork for the study of ejection. In 1955, a comparison study of old (1940-1949) and new (1949-1954) passenger cars looked at door opening, ejection, and other injury producing events associated with accidents.[5] Moore, Tourin, and Garrett concluded in this study that, though there was a difference in ejection rates between the two groups of passenger cars, this difference was not significant.

In 1956, the automobile manufacturers introduced "new-style" door latches. The design of these latches differed by manufacturer but were essentially the same in effect. That is, they were designed to resist forces from three directions rather than two as was the case with "older" latches.

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[3]"The Discovery and Control of Ejection in Automobile Accidents," R. A. Wolf. American Medical Association Journal, Vol. 180, No. 3, pp. 220-224. 21 April 1962.

[4]A Study of Automobile Doors Opening Under Crash Conditions; the Relationship Between the Opening of Front Doors and the Area of the Passenger Automobile Sustaining the Principal Impact, J. O. Moore and B. Tourin, Automobile Crash Injury Research Report. August 1954.

[5]A Study of Crash Injury Patterns as Related to Two Periods of Vehicular Design, a Comparative Study of Accident and Injury Factors in 1940-49 Automobiles and 1950-54 Automobiles, J. O. Moore, B. Tourin, and J. W. Garrett, Automobile Crash Injury Research Report. March 1955.

In 1958, in another ACIR study, ejection was again examined. One important difference in this study was that it was a sample of a broad range of injury producing accidents. Where the earlier study concerned itself mainly with fatal accidents, this sample used five categories of injury severity ranging from "minor" to "extremely severe." It was found that 13.6% of the occupants in this later sample were ejected. Of these, approximately 12% were fatally injured. Of the occupants who remained in their vehicles, 2.5% were fatally injured. Ejection was found to be one of the major injury producing events associated with accidents, and was also found to present a higher risk for fatal injuries than non-ejection. In addition it was found that a number of ejection fatalities occurred in crashes of relatively low severity.

In 1960, Cornell evaluated safety belts in their ACIR-California study by Garrett and Tourin. They concluded that safety belts reduce the possibility of an occupant being ejected from a vehicle as well as helping to reduce the severity of injury. This study indicated that belt users were injured as often as non-users, but that the severity of injury was lower for the belt-users.

In 1961, Garrett published Evaluation of Door Lock Effectiveness: Pre-1956 versus Post-1955 Automobiles.[6] He determined that the frequency of door opening was reduced by about 33% with the advent of improved door latches. Along with the lowering of door opening frequency came a reduction in the ejection rate.

Donald F. Huelke and Paul W. Gikas presented results of a study on ejection to the 10th Stapp Conference in 1964.[7] In a four-year study of serious accidents that had been investigated on-scene they found that 41% of the occupants were ejected. Of these ejected persons, approximately one-third were fatally injured prior to ejection. They

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[6]An Evaluation of Door Lock Effectiveness Pre-1956 versus Post-1955 Automobiles, J. W. Garrett, Automobile Crash Injury Research Report, 1962.

[7]"Ejection--The Leading Cause of Death in Automobile Accidents," D. F. Huelke, and P. W. Gikas. Proceedings of the 10th Stapp Car Crash Conference, Society of Automotive Engineers, pp. 260-294. 1966.

also found that 64% of those ejected exited the vehicles through open doors.

In 1964, Kihlberg, Narragon, and Campbell released another Cornell ACIR study.[8] They looked at rural accidents and 12,835 vehicles whose occupants were injured. The study was mainly concerned with comparing accident features of different car sizes under statistically controlled conditions of accident type and severity. They found that in standard-size cars, 11% of the occupants had been ejected; in compact cars, 13.8%; and in smaller cars, 17.9%. They noted that ejection occurred much more often in rollovers than in collisions, and that the difference in ejection rate by car size was much more prominent in rollovers than in collisions. The compact car ejection rate was much like the standard size car in collisions, while in rollovers it was more like that of the smaller cars.

In 1972, J. I. Tonge of Australia compared injury patterns of crash victims from fatal accidents occurring between 1963 and 1968 with those of occupants of vehicles in accidents from 1935 to 1963.[9] He noted that the later group showed a decrease in head, abdominal, and major organ injuries. Rollovers produced considerably more ejections than other collision types. There were more ejections from accidents with speeds reported as over 40 miles per hour than non-ejections from the same group. He judged that 81% of the ejectees were fatally injured prior to ejection, 13% of the ejectees were outside the vehicle at the time they were killed, and 6% were crushed beneath a vehicle. Of some significance in this report was the distinction made between fatally injured ejectees and persons who were ejected, but fatally injured prior to their ejection.

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[8] Automobile Crash Injury in Relation to Car Size, J. K. Kihlberg, E. A. Narragon, and B. J. Campbell. Automotive Crash Injury Research, November 1964.

[9] "Traffic Crash Fatalities, Injury Patterns and Other Factors," J. I. Tonge et al., Queensland State Health Laboratory, Brisbane (Australia), July 1972.

Anderson[10] found, like others before him, that rollover was the accident type most likely to produce ejection. In addition, he reported that there were differences in ejection portals between differing collision types. He noted that in a non-rollover collision, the door was the primary ejection portal, followed by the door window. In a rollover, the door window is the primary portal and the door the second most likely ejection area. He postulated that rollover ejection may be due to the increased probability of occupants being propelled toward the sides of the vehicle, that forces acting on the vehicle may be more likely to produce door opening in rollovers, that side impacts offer the greatest ejection potential of non-rollover collisions, and that ejection route (or portal) does not seem to influence injury severity. Anderson concluded that the use of lap and shoulder belts would probably be more effective in preventing ejection than redesigning vehicles.

The Swiss Federal Department of Justice and Police initiated a one year study of injured seat belt users in 1976. F. Walz and U. Zollinger reported their findings in 1979.[11] Their data came from 304 accidents that involved 410 occupants, all of whom were belted. Each accident had to have had at least one occupant with an AIS of 2 or above. These cases were examined with regard to the 15 occupants who were ejected, though they had been using safety belts. Walz and Zollinger found that the two main reasons for the ejection of these belted occupants were (1) slipping out of two-point belts in rollovers and (2) torn three point belts. In one of these ejections there was no damage to the belt, but the wearer was partially, rather than completely, ejected. Walz and Zollinger reported that the degree of protection provided by belts is to some extent dependent on the belt's ability to prevent ejection effectively.

Numerous other studies have concerned themselves with the topic of ejection or commented on the phenomenon and its characteristics.

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[10]Ejection Risk in Automobile Accidents, Final Report. T. E. Anderson. Calspan Corporation, Buffalo, New York. October 1974.

[11]"Ejection and Safety Belts," F. Walz, V. Zollinger, and P. Niederer. Accident Analysis and Prevention, Vol. 11, No. 1, pp. 19-22. March 1979.

Cameron, in an Australian study in 1977, reported that the ejection rate for belt users was eight times lower than that of unrestrained occupants, 1.6% versus 12.4%. Though using a different sampling frame that looked at more serious accidents, Huelke reported an ejection rate of 4% for belt users and 25% for non-belted passengers. Tarriere[12] found a fatality rate of contained (i.e., belted) occupants of 1.8% as opposed to 39.4% for ejected persons.

Clearly ejection remains a topic of concern. It seems appropriate now to take another look at ejection using the most current data (NCSS) to determine the present state of the problem.

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[12] Effectiveness of Three-Point Safety Belts in Real Accidents, C. Tarriere. Peugeot-Renault Association, Physiology and Biomechanics Laboratory. March 1973.

3.0 COMPARISON OF EJECTION AND NON-EJECTION CRASHES

The NCSS data set is a stratified-random sample of towaway passenger car (and some light truck) accidents investigated in seven widely dispersed geographical regions of the U. S. The applicability of the statistics taken from NCSS to represent the total U.S. passenger car accident population has been discussed in an analysis report prepared by the HSRI staff,[13] and will not be treated in detail here. Although there are some problems in estimating total frequencies of events for the U.S. from these data, the distributions for many factors taken from NCSS are believed to be the best representation of U.S. accidents available at this time.

As a part of each NCSS case, the accident investigator was asked to record whether each occupant was ejected, the degree of ejection, and the portal of ejection, as well as such detail as injury source, extent, etc. The final judgment of ejection represents the investigator's opinion, and may be based on information from the police report, interviews with vehicle occupants, inspection of the vehicle, and assessment of the injuries. The NCSS field reporting forms also provided codes for the investigator to report both "unknown if ejected" and "ejected but portal unknown." The use of unknown codes varied from team to team (and from one investigator to another). For the most part, ejection was coded "no" unless there was some positive evidence available, but evidently some investigators coded "unknown" when they judged that the accident could have produced an ejection even though no one had reported it. In the table below, it can be seen that there is a large number of cases in which ejection is unknown, but we believe (on the basis of a more detailed examination of the case material) that most of these should be coded as "not ejected." Table 1 displays, for all

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[13] Statistical Analysis of the National Crash Severity Study Data, P. A. Gimotty et al. Highway Safety Research Institute, The University of Michigan. Final Report No. UM-HSRI-79-11. March 1979.

(weighted) occupants in the NCSS data set, the frequency of ejection and the degree of knowledge about these ejections.

TABLE 1
NCSS Ejections by Degree of Ejection and Knowldge About the Portal
(Weighted Data)

Degree of Ejection	Not Ejected	Ejected, Portal Known	Ejected, Portal Unknown	Unknown if Ejected	Total
Not Ejected	104,069	0	0	0	104,069
Complete Ejection	0	514	292	0	806
Partial Ejection	0	149	51	0	200
Partial+Trapped	0	8	8	0	16
Ejection (unknown degree)	0	4	8	0	12
Other & Missing	0	6	0	7	13
Unknown		0	0	1647	1647
Total	104069	681	359	1654	106763

Of the 106,763 estimated occupants of crashed/towed passenger cars, 1034 or 1040 (depending on the choice of variable) persons were known to be ejected. The ejection portal was reported for only about two-thirds of these. A small number of persons were classified as both trapped and partially ejected.

The degree of uncertainty about ejection portal is reflected in the same table. Investigators were asked to report ejection portal in some detail--e.g., left-front window, left-front door--and if a particular portal could not be assigned, the "unknown" category was used. Approximately 25% of the partial ejections, and 37% of the complete ejections were coded "unknown." In a review of a sample of written case material undertaken during the present study, we judge that in as many as two-thirds of these "unknown portal" cases, some further identification of the portal could be made. For example, the investigator might have known that the ejection was through either a left door or window, but was required by the reporting protocol to report "unknown" if he could not determine which. The sample review does not permit the correction and updating of the entire NCSS file.

3.1 Factors Associating With Ejection

We have reviewed the relationship between ejection and many of the variables contained in the NCSS data, and find significant variation with most of those studied. Teams operating primarily in urban areas found relatively low ejection rates; rural teams displayed the opposite. In the SWRI (Texas) rural area, 3% of all occupants were ejected; in Miami (an urban area) only 0.36% were so categorized.

Rear-seat occupants are slightly less likely to be ejected (0.85%) than front-seat occupants (0.97%). By occupant age, nearly 3% of the infants (under 1 year of age) were ejected, although the sample size is small. The peak ejection rate for a 10-year age group is 1.36% for the 11-20 year-olds; this contrasts with 0.36% for 41-50 year-olds.

With respect to injury level, ejectees account for only 0.03% of uninjured occupants, 3.3% of those moderately (AIS-2) injured, and 25.7% of those in the AIS-6 category. Of interest is the difference in injury level for persons ejected and not ejected in the same crashes (or adjusted for crash severity). This is examined in Section 6.

For persons using available restraint systems (lap or lap+torso) the ejection rate was less than 0.1% as compared with nearly 1% for unbelted persons. A small number of persons reported wearing restraints were fully ejected; these will be discussed in the case review section below.

One of the most significant variations with ejection frequency was that of car model (size). Using the 2-digit model designation of the CPIR code,[14] these data are displayed in Table 2. Row entries have been

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[14] Multidisciplinary Accident Investigation Data File, Editing Manual and Reference Information, J. C. Marsh and S. E. Tolkin. Highway

placed in the order of decreasing complete ejection percentage. The last column reports the sum of complete and partial ejection.

TABLE 2
Frequency of Ejection from Towed/Crashed Passenger Cars

Car Size	Total Occupants	Ejection Rate	
		Complete Ejection	Complete and/or Partial Ejection
Pickup car	509	4.10%	4.32%
Foreign Sport	1819	3.30%	3.90%
Super Sport	595	2.52%	3.36%
Subcompact/Import	11576	1.14%	1.40%
Mini specialty	1941	0.88%	1.03%
Compact	14907	0.86%	1.04%
Specialty Pony	9669	0.72%	1.19%
Subcompact USA	7380	0.70%	1.03%
Intermediate	19858	0.67%	0.84%
Standard/full	22833	0.56%	0.66%
Personal luxury	1968	0.46%	0.66%
Luxury limousine	3802	0.32%	0.42%
Specialty Intermediate	5923	0.32%	0.41%

Source: NCSS Combined 27-month file of towed passenger cars.

The ejection percentage generally associates inversely with car size, proceeding from 3.3% for the foreign sports cars (many of which

Safety Research Institute, The University of Michigan. Report No. UM-HSRI-SA-75-7. March 1975.

are convertibles) to 0.32% for the luxury limousine (e.g., the Cadillac Sedan de Ville).

While Table 2 indicates a relatively consistent inverse relationship between ejection and car size, the two-way tabulation cannot take into account the possibility of other factors which may interact with both ejection and car size. In order to further explore this area, a multivariate analysis of the weighted NCSS data has been conducted. A number of log-linear models were tried using the ECTA[15] computer program. Data for this analysis were limited to unbelted occupants, but otherwise include all passenger car occupants in vehicle types shown in Table 3.

Variables included in the model were rollover (yes or no), season (winter or summer), driver age (less than 25 years versus 25 years and older), car size (in 11 categories), and ejection (yes or no). From a number of attempts, the most satisfactory model fitted to the NCSS data was nearly a saturated model, indicating that the interaction among these factors is complex. One way of presenting the results is in a table of the percent of persons ejected for each cell of the complete tabulation. Since it was not possible to collapse the tabulation any further, interpretation must be done by comparing individual cells (or groups of cells) from this table.

In Table 3, an asterisk has been placed on the entry for all cells with fewer than 10 (weighted) ejections. While the relationships exhibited by these (low count) cells may be inspected, the findings should not be considered reliable. The more common vehicle categories (standard, intermediate, compact, and sub-compact import) have adequate data for most cells and may be directly compared.

Several global observations may be made. Within a given car size, rollover condition, and season, young drivers of standard and compact have higher ejection rates than old. Similarly, other things being equal, summer usually exhibits somewhat more ejections than winter. It

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[15]<u>ECTA, A Program For the Log-Linear Analysis of Contingency Tables</u>. The Population Studies Center of The University of Michigan. December 1975.

TABLE 3

Percent of Drivers Ejected From Towed Passenger Cars
(From ECTA Analysis of NCSS 27-Month Data)
(Weighted Data)

Car Type	Rollover				No Rollover			
	Winter		Summer		Winter		Summer	
	Old Drivers	Young Drivers	Old Drivers	Young Drivers	Old Drivers	Young Drivers	Old Drivers	Young Drivers
Luxury	.91*	1.73*	6.04*	5.24*	0.46	0.81	0.38*	0.31*
Standard . . .	8.65	9.47	9.89	12.62	0.30	0.43	0.38	0.68
Specialty Intermediate	4.61*	19.22*	5.46*	12.60*	0.17*	0.27*	0.32*	0.15*
Intermediate .	10.74	7.48	8.70	7.70	0.52	0.48	0.54	0.60
Pickup Car . .	0*	0*	98.5*	0*	1.36*	6.35*	0.04*	14.25
Compact	0.59*	6.13	5.03*	10.31	0.17	1.02	1.03	1.17
U.S. Sub-compact . . .	1.32*	2.67*	4.31*	5.73	0.36*	0.75	1.22	1.67
Pony	2.39*	10.15	5.24*	10.05	0.23*	0.75	0.88	1.26
Mini-Special & Import Subcomp.	4.68	4.37	6.59	6.00	0.87	0.84	1.20	1.13
Super-sport . .	6.44*	19.22*	16.13*	16.13*	0.24*	3.23*	1.16*	4.51*
Foreign Sport .	3.04*	7.16*	11.32*	53.99	2.88	2.01	0.47*	3.10

*Indicates fewer than 10 ejections in this cell.

has been suggested that this might associate with open windows in the summer.

An interesting relationship among car size, rollover, and ejection may be observed. Given a rollover, ejections were more frequent in larger cars than in smaller cars. When rollover does not occur, larger cars have a lower ejection frequency. Table 4 indicates the proportion of cars in certain cells which experienced a rollover, suggesting a fairly direct relationship between size and rollover potential. One could infer that smaller cars experience rollovers at lower crash severity (energy) levels and that the chance of ejection of rollover is lower than for large cars. Alternatively, it seems possible that the smaller cars may have a smaller ejection area (smaller windows), thus reducing the chance of ejection. The non-rollover statistics seem to favor the former explanation, since the smaller cars exhibit a higher ejection rate for non-rollovers as well as a higher overall rate.

TABLE 4
Percent of Vehicles Experiencing Rollover (NCSS Weighted Data) in Cells Corresponding to Table 3.

Vehicle Type	Winter		Summer	
	Old Drivers	Young Drivers	Old Drivers	Young Drivers
Standard	1.7%	2.4%	2.6%	3.8%
Intermed.	2.9%	6.3%	3.2%	6.1%
Compact	*	5.8%	*	9.4%
Subcomp. (USA)	*	*	*	6.5%
Spec.Pony	*	3.8%	*	8.6%
Subcomp. (Import)	8.2%	10.1%	8.7%	17.4%
Foreign Sports	*	*	*	12.5%

*Fewer than 10 rollovers.

The pickup car, which exhibits a high ejection rate in Table 2, has nearly all of its ejections in one cell--12 ejections for young drivers in the summer in non-rollover. Since these are driver ejections, they are not of persons seated in the bed of the pickup car. The other high values for non-rollover are associated with the lightest weight foreign sports cars. More than half of the ejections from this category were from convertibles, suggesting an explanation for the extremely high rate associated with young drivers in the summer with rollover.

The NCSS program reported accidents involving cars of all model years, and thus provides a convenient source to compare ejection frequency across the period in which design changes to inhibit ejection were taking place. Table 5 shows the ejection percentages for drivers as a function of model year (in five-year groupings). Although no account is made of possible interacting factors, the reduction in both ejection and door opening percentages for cars manufactured after 1968 is clear. The reason for the inversion in the driver ejection rate between 1969-1973 and 1974-1978 is not apparent.

TABLE 5
Ejections and Door Openings in Towaway Crashes
(NCSS I and II Passenger Cars)

Model Years	Driver Completely Ejected	L.F.Door Opened in Crash	Some Door Opened in Crash
1974-1978	0.238%	2.33%	7.1%
1969-1973	0.181%	2.35%	7.8%
1964-1968	0.456%	2.98%	10.1%
1901-1963	0.644%	3.99%	12.6%
Average	.260%	2.49%	8.0%

4.0 DESCRIPTIVE STATISTICS OF EJECTION CRASHES

The following section presents descriptive statistical information pertaining to the phenomenon of ejection. While many of the ejection related factors may interact, the simple distributions do not take account of such interactions, but do describe the overall phenomenon with respect to who is being ejected, and when, why, where, and how ejection occurs.

In the weighted NCSS data, detailed information for 106,763 passenger car occupants is available. Non-ejected (including trapped) occupants account for 96.6% of this population and another 1.8% were probably not ejected (categorized "unknown if ejected"). As seen in Table 6, more of the occupants were males (58.7%) than females (40.2%). Sex of an occupant was reported as "unknown" for 1.1% of the NCSS drivers and passengers. Males were much more likely to be ejected than females. The ejection rate for the male population was 1.13%, while for females it was 0.75%. Similarly, males were more likely to have been trapped in a car, 0.69% versus 0.57% for females.

Occupant age was found to be strongly related to the likelihood of ejection. In a comparison of passenger car occupants in (mostly) ten-year age groupings, ejection rate ranged from a high of 2.96% for those under 1 year of age to 0.0% for those 91 years of age or older. Though they represent the extremes in ejection rate, those 91 and older and infants 1 year old or less are represented in limited numbers, and thus their ejection rates should not be given as much credence as other age groups with numerically higher representation in the data set. Figure 2 shows ejection frequency for passenger car occupants in NCSS. Of particular interest are the high ejection rates of the 11 to 20 year-olds and the 21 to 30 year olds. In sheer numbers, these two groups account for 80% of the entire ejection population, as may be seen in the pie chart, Figure 3. The high rate for 61-70 year-olds is an unexplained anomaly, but may result from the small sample. Age has been

TABLE 6
Ejection Status by Sex of Occupant
NCSS 27-Month (Weighted) Data (All Occupants)

	No Ejection	Ejection	Trapped	Other and MD	Unknown if Eject.	Total
Males	60,431 93.3%	711 1.13%	430 0.69%	11 0.02%	1151 1.8%	62,644 (58.7%) 100%
Females	41,636 97%	322 0.75%	245 0.57%	1 0.0%	718 1.7%	42,922 (40.2%) 100%
Unknown	1,111 93%	1 0.0%	0 0.0%	0 0.0%	83 6.9%	1195 (1.1%) 100%
Missing Data	1 50%	- -	- -	1 50%	- -	2 (0.0%) 100%
Total	103,089 96%	1034 0.97%	675 0.6%	13 0.01%	1952 1.8%	106,763 100%

included as a factor in the multivariate analysis of Section 2, but limited to just two values--young versus old.

Figure 4 shows the ejection counts of passenger car occupants by seat location and by portal of ejection. It may be seen that there is little variation in ejection frequency between the driver and the right-front position. The nearside door and window show the highest rates. Second seat occupants are less likely to be ejected than their front seat counterparts.

Ejection rates in the NCSS data varied from one investigation team to another. The highest ejection rate among the seven NCSS data collection teams was 1.7 % at Indiana University, followed by HSRI at 1.3 %, The University of Kentucky at 1.2 %, and Southwest Research at 1.1 %. The lowest rate was seen at Dynamic Science, 0.6 %. The variation in rate of ejection by individual teams correlates with the

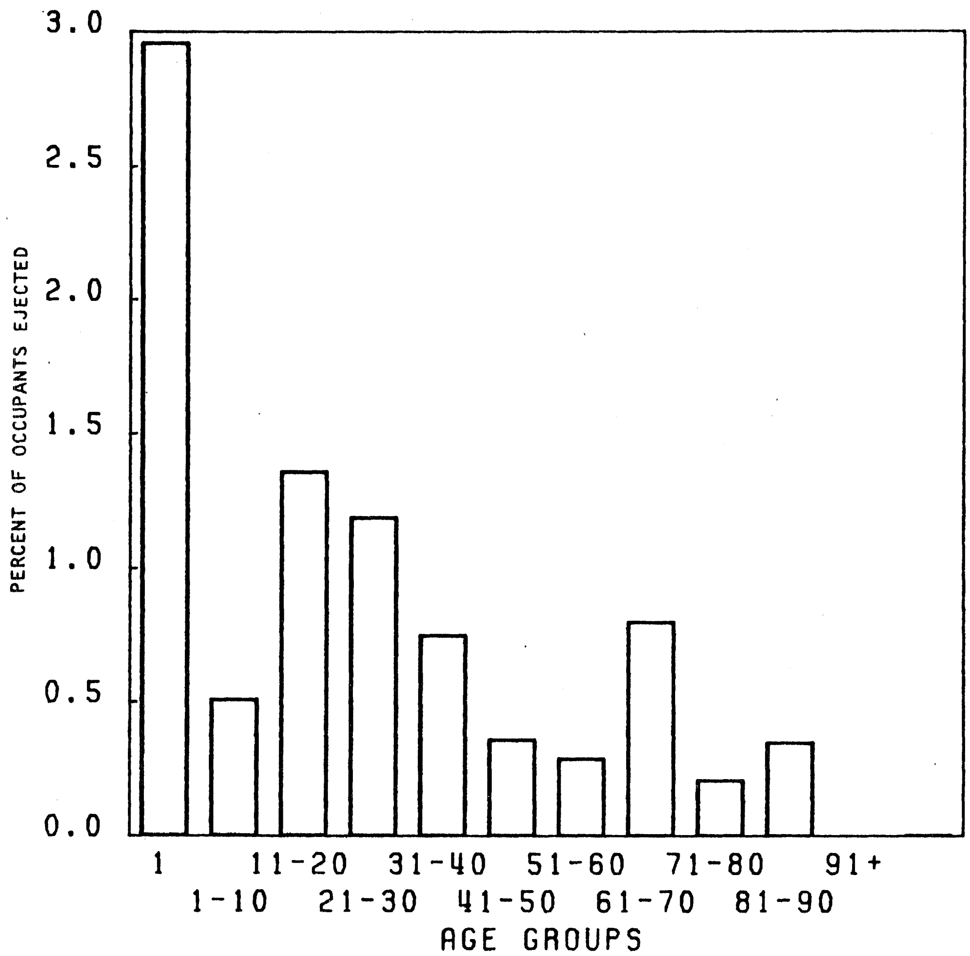


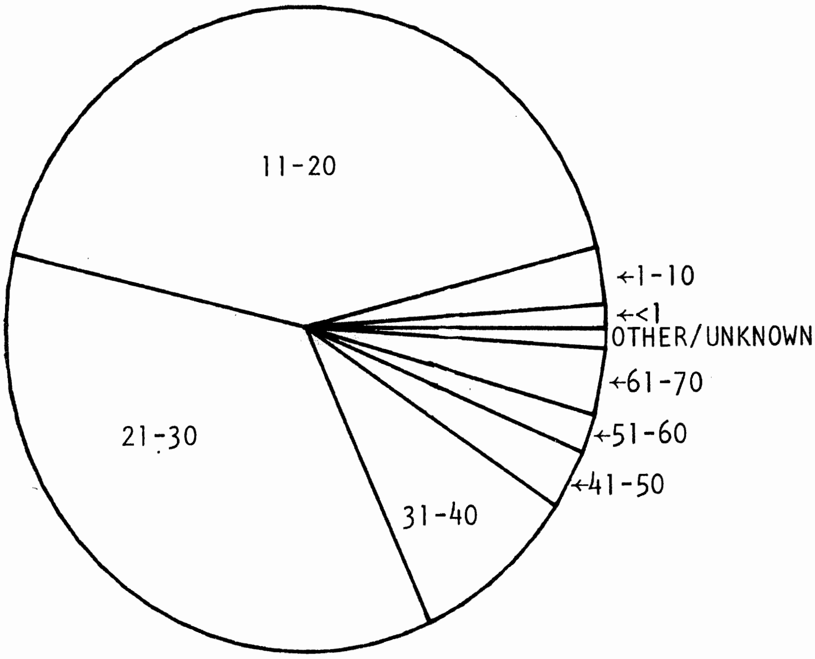
FIGURE 2
Ejection Rate by 10-year Age Groups

types of areas where those teams were investigating accidents. Rural areas showed a much higher incidence of ejection-type accidents than did urban areas. In rural areas, the driver was reported as ejected in 2.4% of the towed passenger cars as compared with 0.6% of the urban towed passenger car accident involvements.

A difference was found in rate of ejection by road condition. In accidents where the road was dry, 1.1% of the drivers of passenger cars were ejected. This rate is similar to that of wet roads (0.9%), but higher than the rates for icy and snowy roads (0.8% and 0.5%, respectively).

The ejection rate by roadway functional classification did not vary dramatically except in one case. A driver was ejected from a passenger car in 0.8% of the accidents on both arterial and minor arterial roads. For expressways this rate was 0.9%, for local streets or roads, 1.0%, and for collectors, 1.1%. On freeways though, the rate was 1.6%. In

NUMBER OF EJECTED OCCUPANTS: 10-YEAR AGE GROUPS
NCSS 27 MONTH WEIGHTED DATA



NUMBER OF NON-EJECTED OCCUPANTS: 10-YEAR AGE GROUPS

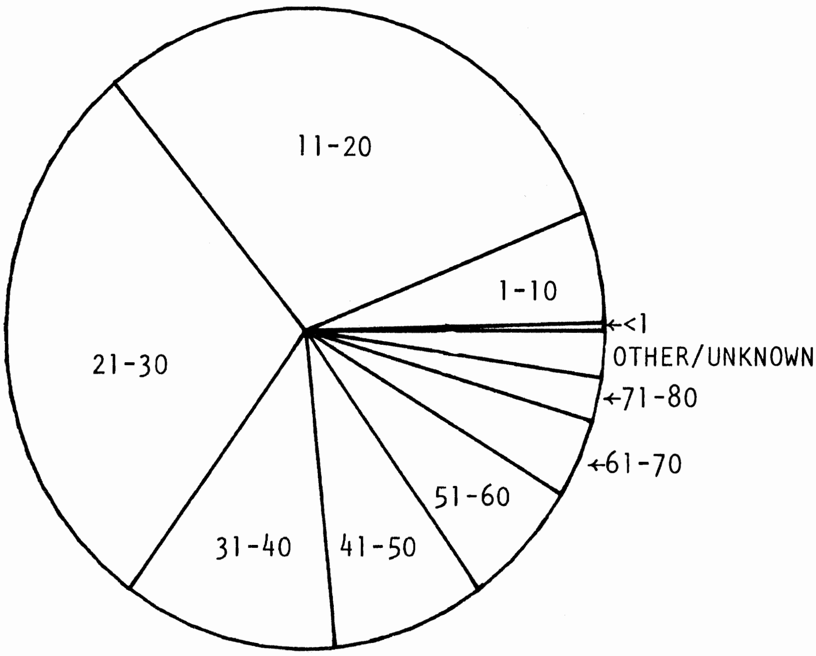


FIGURE 3
Age Groups of Ejected and Non-ejected Occupants

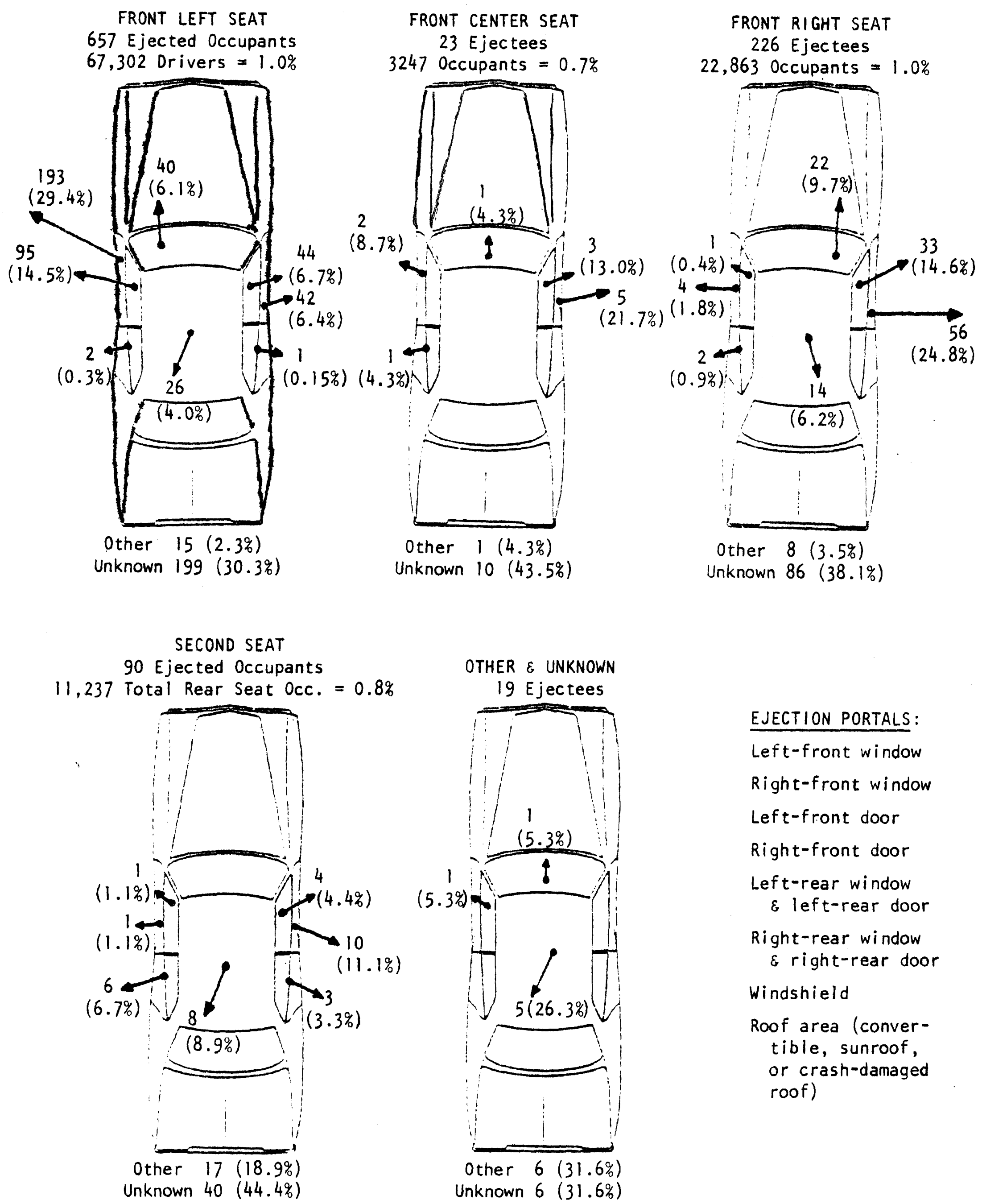


FIGURE 4
Seat Position and Ejection Portal
NCSS 27-Month (Weighted) Data
(Percent by Portal for Each Seat Position)

NCSS, freeways were described as an "expressway with full control of access." Expressways differ from this in that they do not have "full or partial control of access and generally with grade separations at major intersections."[16] Ejections were found to be most likely to occur on a road with either no intersection (1.5%) or at a 3-leg intersection (1.8% of these intersection accidents featured the ejection of a driver from a passenger car). The occurrence of ejection for other types of intersections are as follows; 3-leg T, 0.4%, 4-leg cross,0.4%, 4-leg oblique, 0.5%, and multi-leg, 0.2%.

If looked at from the standpoint of when ejection took place by month or time of year, those times when it would be colder exhibited the lowest ejection rates. As the weather warms, so ejection seems to increase. The months of July and September showed the highest rate of ejection, three times that of January. This factor was included in the multivariate analysis of Section 2.

Ejection Portal, or the occupant's avenue of ejection from the car, is further detailed in Table 7. Table 7 shows a substantial difference between large and small cars and the rate of driver ejection through windows and doors. Small cars are defined here as compacts and anything smaller, and large cars are defined as intermediates and anything larger. The total rate of ejection is higher for small cars, though the rate of ejection through doors is similar to that of the large cars. The rate of ejection through windows, though, is dramatically different.

A comparison of ejection rate through front doors, front door windows, and windshields by passenger car model year groupings (Table 8) shows a marked reduction in door ejections for "newer" cars. This trend has been noted in other studies. The door ejection rate reduction by a factor of two coincides with the development of improved door latches and outside door handles.

Table 9 displays the frequency of ejection (partial, complete, etc.) by the status of door opening in the crash. All model year cars are included, but the table presents ejection data from the left-front

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[16] Coding Manual and Definition for National Crash Severity Study, CALSPAN Field Services. 1977.

TABLE 7
Ejection Portal and Car Size (Drivers Only)
NCSS 27-Month (Weighted Data)

	Number of Cars (Drivers)	Ejections			
		Door	Window	Other	Total
Small Cars	31,602 (100%)	132 (0.418)*	108 (0.342)	152 (0.481)	392 (0.01240)
Large Cars	33,797 (100%)	107 (0.317)	31 (0.092)	86 (0.254)	224 (0.663)

*Numbers in parentheses indicate the percentage of drivers in each category.

seat position (driver) only. Of particular interest is the fact that 32.7% of the complete ejections take place without any door opening at all, and that the left-front door opens about one-and-one-half times as often as the right-front door, perhaps because of more frequent loading of the driver door. Note also that the fact that a door opened does not necessarily mean that the driver exited through that portal. Actual ejection frequencies by occupant seat location were shown in Figure 4. For example, Figure 4 indicates that there were 193 drivers ejected though the left-front door as compared with at least 223 left-front door openings (in cars with ejection) shown in Table 9. Finally, there were a large number of door openings without ejection as shown in the first column of Table 9.

Passenger car occupants in the front seat are most likely to be ejected from either a window or a door closest to their seated position, then the opposite door or window, and finally the windshield. A modest proportion of rear-seat occupants was coded as ejected through the roof area. Ejection portal is reported as "unknown" for a large number of ejectees. This problem was due in part to the codes available to the investigator. If, for example, it was known that a driver was ejected from the left side of the car, but it was not known whether the ejection was through the door or the window, or through an open or a closed

TABLE 8
Ejection Portal and Car Model Year (Drivers Only)
NCSS 27-Month (Weighted) Data*

Model Year	Number of Cars (Drivers)	Ejection Portal**					Total Ejections
		LF Window	RF Window	LF Door	RF Door	Windshield	
1974-78	25,608 (100%)	39 (0.152)	18 (0.070)	60 (0.234)	7 (0.027)	11 (0.043)	135 (0.527)
1969-73	28,684 (100%)	37 (0.129)	20 (0.070)	69 (0.241)	16 (0.056)	19 (0.066)	161 (0.561)
1964-68	11,403 (100%)	18 (0.158)	6 (0.053)	58 (0.509)	18 (0.158)	6 (0.053)	106 (0.930)
01-1963	1,554 (100%)	1 (0.064)	0 (0.0)	7 (0.450)	4 (0.257)	4 (0.257)	16 (0.01030)
Total (Average)	67,249	95 (0.141)	44 (0.065)	194 (0.288)	45 (0.067)	40 (0.059)	418 (0.622)

*Numbers in parentheses indicate the percentage of all drivers in each category for each model year group.

**"Other" and "Unknown Portal" cases are deleted from this table.

TABLE 9
Ejection Status versus Door Opening (Driver Only)
NCSS 27-Month (Weighted) Data

Door Opened	No Ejection	Complete Ejection	Partial Ejection	Trapped	Other MD	Unknown if Ejected	Total
No Door Opening	50,180 76.8%	162 32.7%	78 48.7%	262 54.7%	12	442 36.6%	51,136
Left Front	1289 2.0%	176 35.6%	30 18.8%	80 16.7%	2	109 9.0%	1686
Right Front	926 1.4%	55 11.1%	22 13.7%	32 6.7%	1	50 4.1%	1086
Left Rear	75 0.1%	3 0.6%	0 0%	1 0.2%	0	2 0.2%	81
Right Rear	62 0.1%	1 0.2%	1 0.69%	1 0.2%	0	1 0.2%	66
Left Front + Right Front	158 0.2%	44 8.9%	10 6.3%	37 7.7%	3	24 2.0%	276
Left Front + Left Rear	45 0.1%	3 0.6%	2 1.2%	2 0.4%	0	2 0.2%	54
Right Front + Right Rear	20 0.0%	1 0.2%	0 0.0%	2 0.4%	0	1 0.1%	24
Other Combinations	100 0.2%	9 1.8%	2 1.2%	11 2.3%	0	8 0.7%	130
Unknown If Opened	12,943 19.1%	41 8.3%	15 9.4%	51 10.6%	1	568 47.1%	13,169
Total	65,348 100%	495 100%	160 100%	479 100%	19 100%	1207 100%	67,708

window, ejection portal would be coded "unknown." Had a code been available for use that would have indicated the general area of ejection, much data would have been preserved.

The relationship between CDC clock direction (direction of impact force) and ejection may be seen in Figure 5. "Unknown if ejected" cases have not been included in this figure. A review of NCSS cases from various teams and time periods revealed that almost all "unknown if ejected" cases should have been coded "no ejection." A clock direction of 00, or non-horizontal force, exhibits the highest ejection rate. Non-horizontal force impacts most often involved rollovers, long identified as the collision type most likely to produce ejection. Frontal impacts with clock directions of 12, 11, and 01 all produce similar ejection rates; 0.6%, 0.5%, and 0.5%, respectively. Side impacts (force directions of 2-4 and 8-10 o'clock) produce higher ejection rates than the frontal impacts.

Numbers in parentheses indicate the percent of occupants ejected for each impact direction shown, i.e., for 3:00 impacts, 2.6% of all occupants were ejected.

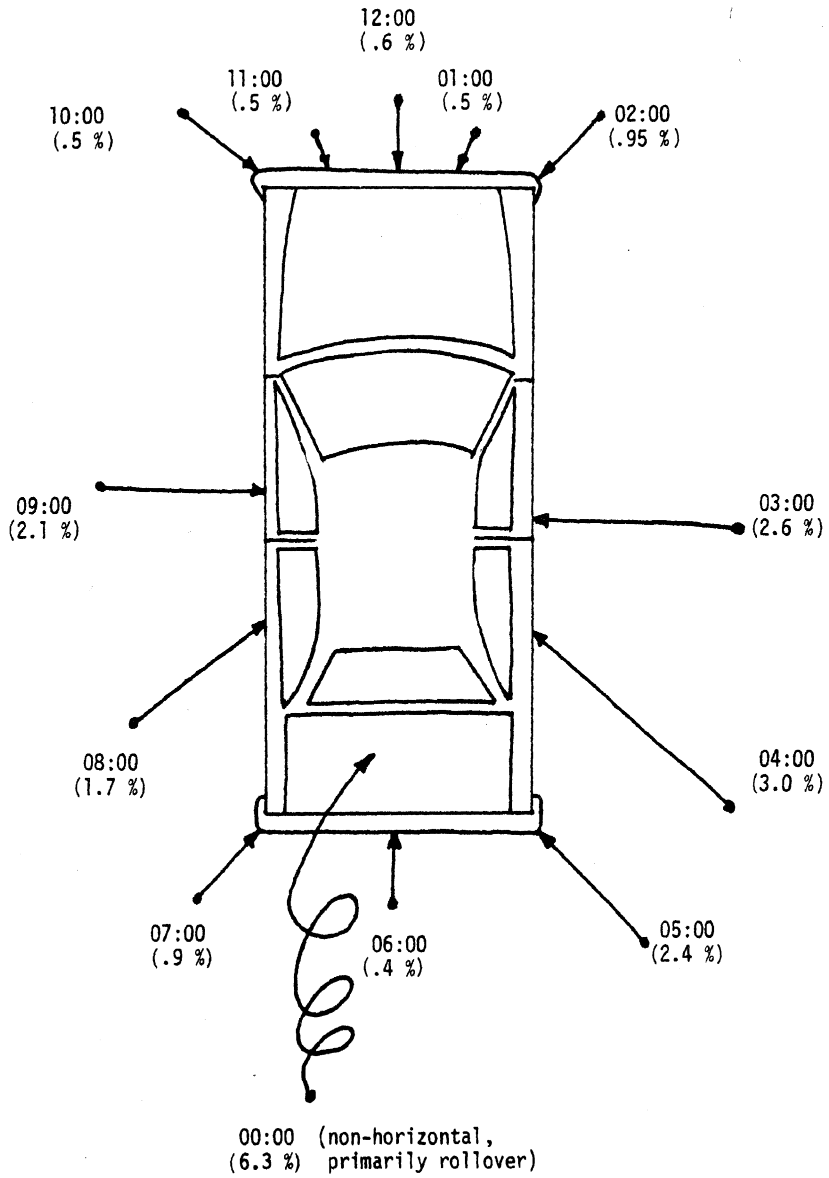

FIGURE 5
Direction of Force Association with Ejection
NCSS 27-month (Weighted) Data

5.0 CASE REVIEWS

The NCSS data contained four accident cases in which belted occupants were reported completely ejected from their vehicles. An initial closer look at the data set showed that there were three complete ejections: two occupants who were wearing lap belts only, and one occupant who was using a passive shoulder belt. The fourth case was the partial ejection of an occupant wearing both lap belt and upper torso restraint.

These four cases were reviewed in more detail and the results of this review are presented here.

The first case involved a 1972 Cadillac that struck a 1973 Pinto station wagon. The driver of the Pinto had been coded as having been wearing his lap belt only and being completely ejected. In the NCSS data forms there are provisions for three separate responses to the question of restraint use: the police officer's opinion, the response of the occupant when interviewed, and the opinion of the investigator considering the first two responses and any other information available to him (such as evidence found upon inspection of the car). In this particular case, there was an apparent miscoding. When interviewed by the accident investigator, the Pinto driver stated that he was not using any restraint system. The official police accident report made no mention of any belt use. Within the hard copy of the case no evidence was found, other than the investigator's having marked "lap belts used," that would indicate that the belts were being worn.

The second case involved a 1970 Mercury Cougar, driven by a 30 year-old male, that ran off the road and struck two separate objects. In the forms in the original case, restraint usage was coded as follows: police, lap only; interview, none; investigator, lap and upper torso. Partial ejection was coded, though no evidence of this was found, except in the portion of the "Human" form where the ejection response is located. The Cougar driver sustained three injuries; a contused right shoulder, from contact with the windshield, a contused forehead, from contact with the steering wheel, and chest contusions also from contacting the steering wheel. No mention was made of how partial ejection happened, or what portion of the driver's body was partially ejected. The only conclusion available as to restraint use would be based on the driver interview, and he reported that he was not using any restraint. If the driver was partially ejected, no information was included in the case, and there was apparently no injury associated with the partial ejection. If he was not partially ejected, a coding mistake had been made.

In the third belted-ejection case, documentation as to ejection and belt usage was included. A 1964 Ford Galaxie four-door struck a fixed object with its front end. Two additional impacts also occurred. The CDCs were as follows; 01RBES1, 11LYAW3, and 02FREW3. The 24 year-old male driver was completely ejected through the right-front door. He was found outside the car with his lap belts still around him. The floor-anchorage points were reported as being quite rusty, and they gave way when the lap belts were loaded by the driver at impact. He contacted the glove box area of the instrument panel, resulting in an open fracture of his left femur, and also contacted the right-front door interior panel. Contact with the door panel resulted in his fracturing his right humerus and his right wrist prior to exiting the vehicle through the right-front door. Both the left-front and the right-front doors were coded as having opened. No information was available as to whether the lap belts were original equipment or aftermarket devices or who may have installed them. The driver was hospitalized for 24 days and was reported to have still been having difficulty with transitory radial nerve palsy at the time this case had been submitted (1978).

The fourth belted-ejection case involved a 1978 Volkswagen Rabbit 2-door, equipped with VW passive upper torso restraints. Besides being included in the NCSS data set, this accident was also documented in a Calspan ACRS report, number 79-2, also numbered ZM-5864-V.

On a rural, four-lane highway, covered with snow and ice, a 1974 Dodge Dart Custom 4-door sedan struck the 1978 Rabbit. The two cars had been approaching one another from opposite directions when the Rabbit driver apparently lost control and came across the center line of the highway and began rotating counter-clockwise. When struck in the right side by the Dart, the Rabbit had rotated to an impact configuration just beyond a point perpendicular to the Dodge. The impact speed of the Dart was calculated to be 51.9 miles per hour, and the impact speed of the VW calculated to be 40.4 miles per hour. The Dart proceeded, after impact, in the same direction and general course as before impact. The Rabbit was spun dramatically, by impact forces, in a clockwise rotation.

The 33 year-old male driver of the Rabbit was ejected through the rear hatchback following the violent spinning of the VW as it and the Dodge ceased engagement. He sustained multiple skull fractures from contacting the Rabbit's backlight header, and coding indicated that he was fatally injured prior to his ejection. The driver of the Dart sustained one AIS level 4 injury, one AIS-3 injury, and 3 other injuries at AIS-2 or less. A conclusion presented in the in-depth report of this accident was that the VW driver would not have been ejected had he been wearing a conventional 3-point restraint. It was reported that he had slipped under the VW passive upper torso restraint when the seat-back rotated rearward and that, as he moved toward the rear of the vehicle, his feet had caught and pulled the lower portion of the padded instrument panel toward the rear of the car.

6.0 MATCHED PAIR COMPARISON

The following section presents information obtained from a "Matched Pair" subset of NCSS. With the relatively large number of cases in NCSS and the detailed information reported, it was possible to look at ejection and non-ejection of passenger car occupants under the same circumstances. Initially the data were scanned to include only vehicles with at least one ejected occupant. This group was further reduced to include only those vehicles with two front-seat occupants. From this data set came those accidents where one vehicle had two, and only two, occupants, at least one of whom was ejected. A direct comparison may be made between ejected and non-ejected occupants of the same vehicle. Other comparisons, such as ejected drivers versus ejected right-front seat passengers, are also included in this section.

Figure 6 compares the treatment levels (or degree of injury) of 40 right-front seat passengers and drivers who were both ejected from the same car. Injury was not reported on the AIS scale for all occupants in this data set, and therefore severity of injury by type of medical treatment (a rather complete record in the NCSS data) was employed. Thus the point in the upper left hand corner of the graph represents a passenger car for which the ejected driver was hospitalized overnight with the ejected right-front seat passenger neither treated nor transported to a medical facility (i.e., injured only slightly or not at all). The distributions are quite symmetrical, with drivers having only slightly more severe injury (seriousness of treatment) than their passenger counterparts from the same vehicle.

Figure 7 shows the NCSS Classification (level of treatment) of ejectees and non-ejectees of the same vehicle. The NCSS data set contained 74 cases in which a vehicle was occupied by two, and only two, front-seat occupants, and in which one was ejected and the other not ejected. Clearly, ejected occupants were injured more seriously (required a higher level of treatment) than those who were not ejected. Though many of the ejected and non-ejected persons in the same car had

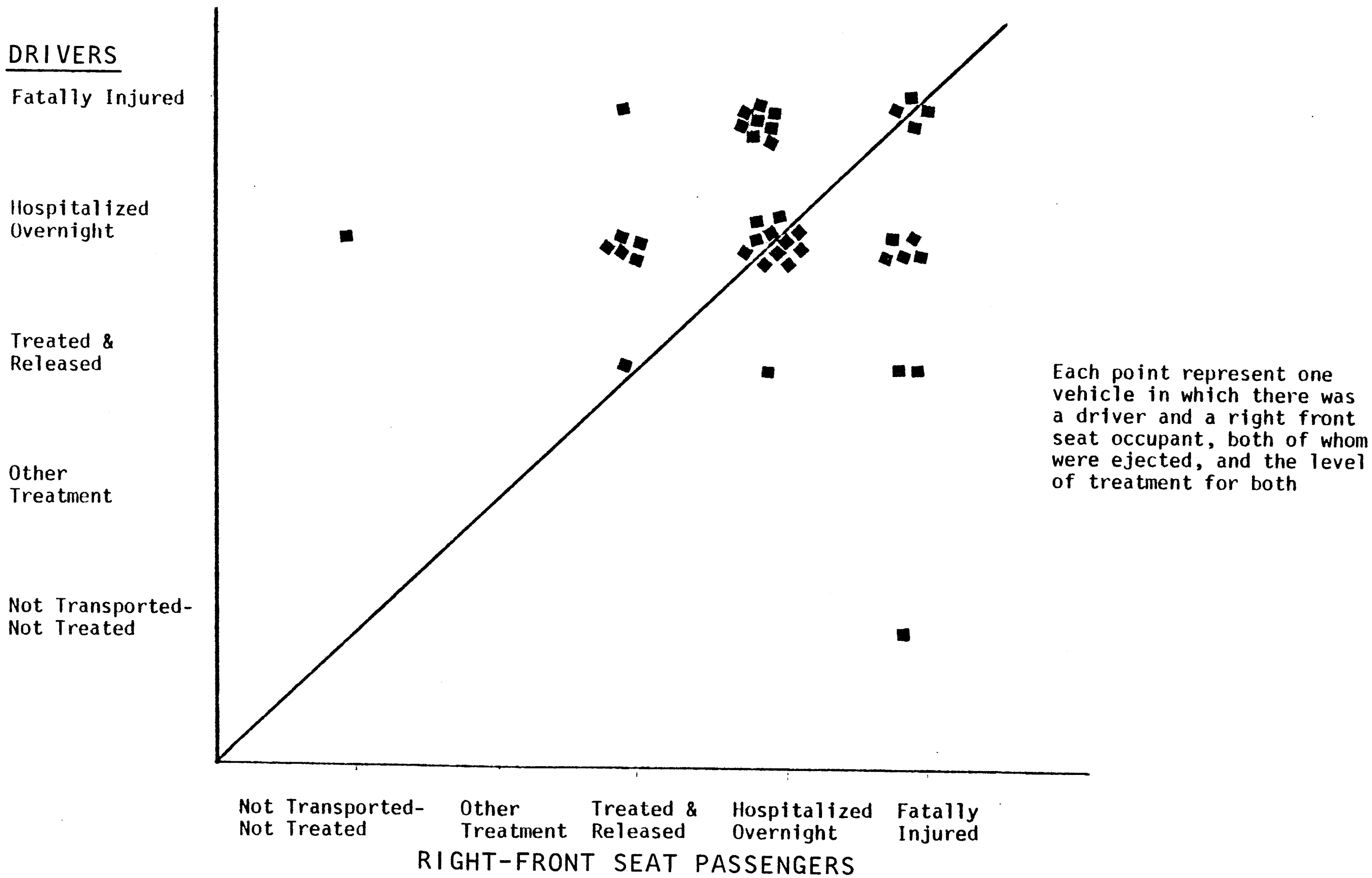

FIGURE 6
NCSS Classification of Ejected Drivers and Right-Front Seat Passengers of Same Passenger Car

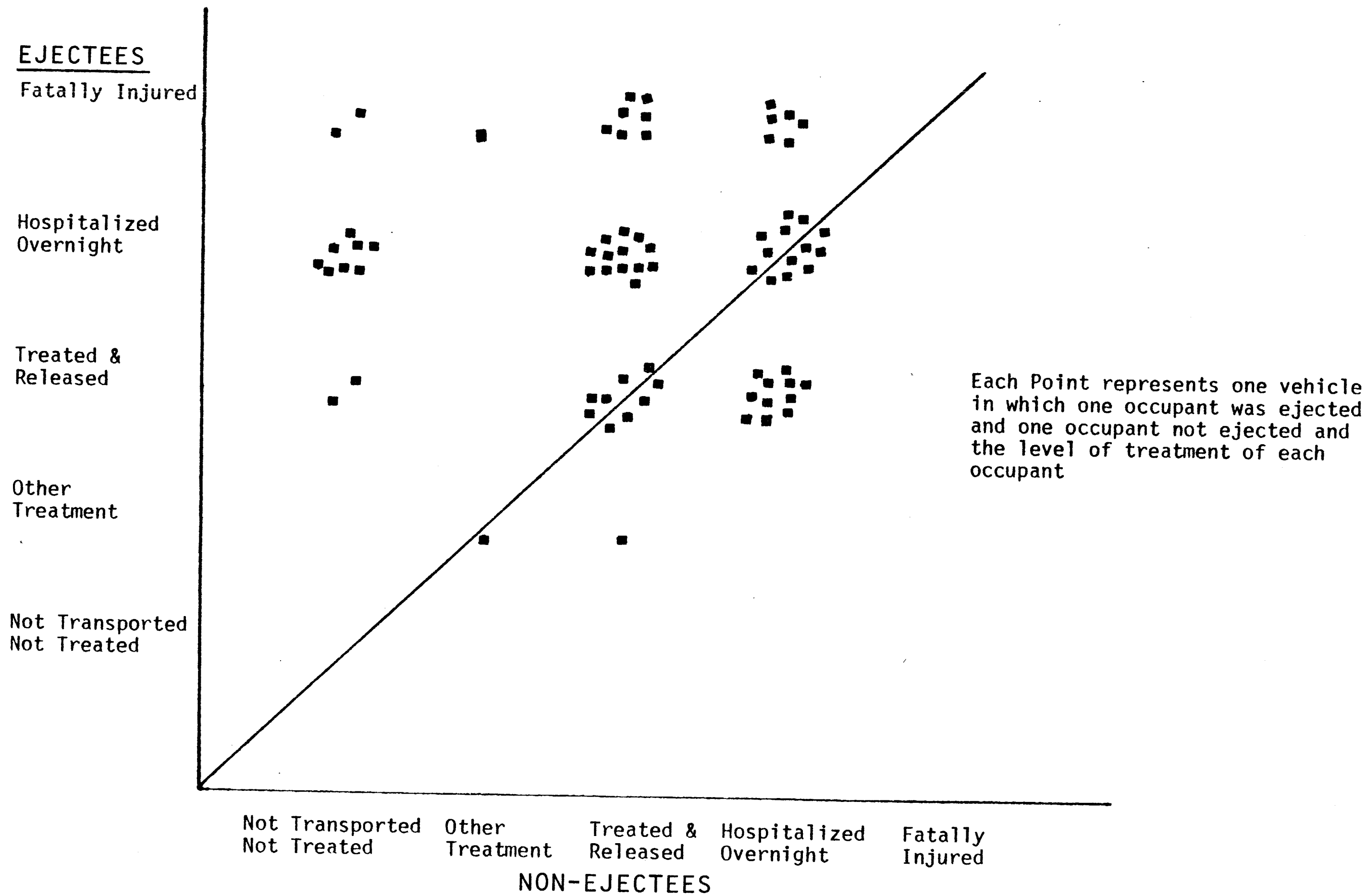

FIGURE 7
NCSS Classification of Ejectees and Non-Ejectees of Same Vehicle

equal levels of treatment (those cases lying along the 45° line), and some non-ejected occupants required more serious treatment, no non-ejected occupant in the matched pair set was fatally injured, while 16 of those ejected were. Other data support the conclusion that one is more likely to be seriously injured if ejected than if not ejected. This matched pair comparison indicates that this is true for occupants of the same crashed vehicle.

APPENDIX A

Comments on Case Reviews

In the process of reviewing the original case materials from the NCSS program a number of problems of interpretation occurred. In most cases the hard copy materials contained valuable information which could not be fully coded into the computerized files because of the specific coding conventions used for NCSS. The primary purpose of this appendix is to present information on these matters which may be of value in planning and conducting future data acquisition programs.

From the 74 NCSS cases in which one occupant was ejected and the other occupant not ejected, 11 cases involving a fatal ejection are the basis for this review. In six of the cases it was the driver who had been ejected. The other five ejected occupants were right-front-seat passengers. None of the ejected drivers or passengers was coded as having used restraints.

Contacts Producing Injury

All 11 ejected occupants were coded as having contacted the door or some component of the door such as the interior door panel, arm rest, or window winder handle. Occupant contact points were unknown or missing for five of the non-ejected occupants (including one who was reported not injured). In five of the six cases where this information was reported, a door was coded as having been contacted by the non-ejected occupant. Though in many instances there were other interior contact points for both the ejected and non-ejected occupants, in these five cases both the occupants of the vehicle contacted the door nearest to them, though not simultaneously. This type of occupant movement would be typical of a multi-impact accident, a rollover, or a crash in which a vehicle underwent some type of dramatic change in direction.

Ejection Portals

In all 11 cases the ejected person left the vehicle through a portal on his, or her, side of that vehicle. Six occupants were ejected through a front door window opening, closed or open, and the other five through a front door opening. In some cases the door was no longer attached to the vehicle. In other cases the door was intact, but open. It was judged that each of the ejected occupants would have avoided complete ejection had they been using lap belts and upper torso restraints, although partial ejection might still have occurred.

Accident Configurations and Cause

Eight of the eleven cases were single vehicle accidents. All eight involved rollover of the case vehicle. Of the three remaining cases, one involved a passenger car struck by a train, one was a passenger car that was struck in the side by another car (with subsequent impacts with a pole and a tree), and the last case involved a passenger car that struck a construction barrier, a parked car, and finally a curb. In each case the collision that produced ejection featured violent movement of the vehicle and its occupants. In four of the rollover cases excessive speed was specifically noted in the case report.

A common factor was noticed in the 11 matched pair ejection cases, as in most all accidents, that is, that the accident probably could have been avoided had the driver, or drivers, exercised more caution. In all eleven cases either use of alcohol, excessive speed, loss of control, or improper lane useage were reported. Because of the purpose of the NCSS study, this kind of information was not encoded, buut can often be determined by reading the case material.

Injury Details

In two of the eleven matched pair cases, it was known only that the occupants sustained fatal injuries, but no further description was provided. In one of these two cases, it is likely that head injuries were incurred due to contact with the roof of the vehicle. In both instances, it was the driver who was ejected, and both contacted their respective left front doors either prior to or while being ejected through the door opening.

In the nine remaining cases, seven ejected occupants sustained head injuries. The two who did not (but for whom injury information was available) both sustained chest injuries. One of these was reported to have received chest injuries only and the other to have also sustained a neck injury. Injury severity comparisons for ejected and non-ejected occupants within the 11 selected cases using the Abbreviated Injury Scale (AIS) are not possible. In some of the 11 cases AIS is coded while in other cases level of treatment such as "Treated and Released" or "Admitted to Hospital" are the only indicators of injury severity. For the fatally injured occupants, the only information provided was that they were "killed". Most often this was because no autopsy was performed and the only injury information provided in the case came from a coroner's report. Any information, such as what body area was injured, or a description such as "crushed skull", that would come from a coroner would appear only in the hard copy of the case. Such information was not coded for NCSS, as a coroner's report was considered unsubstantiated medical data. This difficulty will be discussed more at length later.

Neck injury was cited in five of the eleven cases for the ejected occupant. In four of these instances, the neck injury accompanied a head injury. The fifth case was a combination chest injury and neck injury. Non-ejected occupants were more likely to sustain injuries of the extremities, the back, and the face. tended to sustain head and neck injuries.

Included as Table 10 is a chart showing the information available for the eleven selected cases. Each line represents one vehicle and gives the collision configuration for that vehicle, the CDC (Collision Deformation Classification) for the impact that produced ejection, and injury and other information for the ejected and non-ejected occupants. Injury severity is given as AIS when available, otherwise as medical treatment level. Occupant contact points are listed, though they may not necessarily be for the injuries that are noted. In only one case were restraints used by an occupant, and this occurrence is reported.

Coding Conventions and Problems

Examination of specific NCSS case reports provided an opportunity not only to get more detailed information regarding ejection, but also to compare the material within a case report with the computerized data

TABLE 10

Selected Information About Ejected and Non-Ejected Occupants in the Matched-Pair Review

VEHICLE/ ACCIDENT		EJECTED OCCUPANT						NON-EJECTED OCCUPANT				
Type	CDC	Ejection Portal	Seat Position	Injury Severity	Restraint Use	Body Region	Contact Point	Seat Position	Injury Severity	Restraint Use	Body Region	Contact Point
Rollover	00TDH0-3	LF Window	Driver	Fatal	No	Chest	LF Door	RF	T&R(B)	No	Unknown	RF Door Instrument Panel
Struck Pole after being struck by car	11FZEW1	LF Door	Driver	Fatal	No	Chest	LF Door	RF	Not Injured (0)	No	NA	NA
Curb after barrier and car	02FRWN-1	RF Door	RF	Fatal	No	Head, Neck	Tire	Driver	T&R(1)	No	Head, Neck	Unk.
Train (2 impacts)	990000-0	RF Window	RF	Fatal	No	Head	Ground, R.Door	Driver	Unk.(1)	No	Head, Face, Knee	Steering Wheel Instrument Panel
Rollover	00TDH0-3	RF Door (Door off)	RF	Fatal	No	Head, Neck, Unsp. Multiple Fractures	Unknown	Driver	(3)	No	Ribs, Head	Unknown
Rollover	00TYH0-3	RF Window	RF	Fatal	No	Head, Neck, Face	Ground, A- Pillar	Driver	T&R(1)	No	Face, Back	Unknown
Multiple Rollover	990000-0	LF Door	Driver	Fatal	No	Neck, Chest	Ground, L.Door	RF	(3)	No	Thigh, Arm, Extrem.	Steering Wheel Door Panel
Rollover (Four quarter rolls)	990000-0	LF Window	Driver	Fatal	No	Head, Neck	LF Window Frame	RF	(2)	No	Ribs, Upper Extrem.	RF Door Panel
Undercarriage, pole, then Rollover	00TYH0-4	RF Window	RF	Fatal	No	Head	Ground or Car	Driver	(1)	No	Face, Unknown 1.Shoulder	Unknown

VEHICLE/ ACCIDENT		EJECTED OCCUPANT						NON-EJECTED OCCUPANT				
Type	CDC	Ejection Portal	Seat Position	Injury Severity	Restraint Use	Body Region	Contact Point	Seat Position	Injury Severity	Restraint Use	Body Region	Contact Point
Rollover	990000-0	LF Window	Driver	Fatal	No	Head	A-Pillar	RF	(1)	Lap & Upper Torso	Upper Extrem.	Door
Rollover	00TDH0-3	LF Door	Driver	Fatal	No	Unknown Probably Head	Roof, Door Panel	RF	T&R(1)	No	Neck, Back, Right Arm	Door Panel Seatback

file. Often some level of detail was lost in the coding process. The reason for this data loss was not always the same. For example, often some degree of injury information could be found in the "hard copy" of a case but not transferred to the coded material of the case because of the NCSS coding conventions.

At times during the course of the NCSS, injury information provided by the non-fatally injured occupant in an interview was treated in a different manner. Throughout most of the project, only medically documented injury information could be coded. As of March, 1978, minor injuries as described by an interviewee could be coded, if they were in addition to information supplied by an accepted coding source such as a discharge summary.

The effect of these instructions was to keep coded injury data in the NCSS file "clean" in that they would all be obtained from a medical source. This convention works well until one looks at cases where data is missing because a medical report was not available or, in the case of the 11 ejection case reports, no autopsy was performed.

The National Accident Sampling System (NASS) has made provisions to improve on this problem. Injuries are coded with priority given to accepted medical sources. If injury information is available only from a coroner or an interviewee, it may still be coded. Another variable is included that gives the source of the injury information, such as an autopsy report, an emergency room report, or an interview. Not only is the injury information that might have been lost in NCSS cases retained (because it would not have been coded and digitized in NCSS) but confidence in the data may be assessed because of knowledge of the source of the data.

Sources of Injury Contact Information

When injury information was available in a NCSS case in a coded form, "source of injury", or what an occupant may have contacted to cause that injury, was also coded. Some problems were noted with this variable. If an occupant remained in a vehicle it was usually easier to ascertain what contacted portion of the vehicle interior may have been associated with a particular injury than it would be for an ejected occupant. Given that one has a certain amount of knowledge of the vehicle's movement during the crash, one also has a good idea of the occupants movement within the vehicle. If the occupant sustains injuries while in the vehicle, while exiting the vehicle, and after exiting the vehicle, associating damaged, or contacted, portions of the vehicle interior becomes more complex. In the injury coding in a NCSS case, only one injury source (occupant contact) could be coded. This variable was evidently coded for the most likely contact, and it would sometimes have been more informative to have had an option of recording several contacts for a particular injury. During the course of the matched pair review, injury sources and contact points were examined and most often found to be plausible as coded, though often another source might have been just as plausible.

CDC Coding

In analyzing the digital NCSS file a slight problem exists in regards to CDC and ejection. This is not so much a problem in the sense of the NCSS data itself, but in the approach for correlating CDC and ejection. For each vehicle in a NCSS case up to two CDCs could be coded. The impact number within the accident sequence would be associated with a given CDC. The total number of impacts for each vehicle would also be coded. The convention for coding the two CDCs was to use the two with the highest severity (Delta V if CRASH runs were made) or the two that produced the most damage to the vehicle. Though it may not have occurred often, it is possible that the impact that produced ejection would not be coded. In one of the 11 matched pair accidents this was the case. A passenger car was travelling in an urban area and struck a construction barrier. It then continued down the road where it struck a parked car. The impact with the parked car tore the right front door off the vehicle later was the exit portal for the occupant. The car then continued further down the road where it yawed and rotated counter-clockwise. At this time the right front passenger was probably hanging on to components in the interior to keep from "falling out". As the car rotated, the right front passenger was ejected. He moved forward, in the direction the vehicle was travelling, struck the ground, and was then struck by the car he had been riding in as it struck a curb. In this accident no CDC was written for the car/curb/passenger impact, and hence the CDC information available for the case was not directly associated with the ejection.

The variable "Ejection Area" also presented some problems in light of the detailed case review. Twenty-eight separate codes were used to identify specific areas of ejection. An "other" code was included, as were codes for "missing data", "unknown ejection area", and "unknown if ejected". The twenty eight specific codes were not unique areas. For example, Left Front Window, as an individual area, had three different code values. One was used if the window had been open, one if it had been closed and damaged, and the third if it had been unknown if the window was open or not. As specific as the codes were, they still did not cover some possibilities. If the investigator knew the specific area of ejection the available codes worked well, but often one would not know if an occupant had been ejected through a door or a window, even though it might be known, or reasonably presumed, that the general area of ejection was the left front. If the investigator could not come to a decision, the only choice would be "unknown ejection area". If the investigator did decide, but with hesitation, it is quite possible that the wrong choice was made. Had a code for general area of ejection, such as left front door--and/or--window been available, some lost data would have been retained and usefulness of this variable improved.

Restraints

In all eleven matched pair cases, it was judged that use of available restraints would have prevented ejection. In some cases partial ejection might still have been possible (flailing arms, heads, or torsos) but the likelihood of a fatal injury would have been dramatically reduced. In three cases that featured a good deal of occupant compartment intrusion, it might still have been possible that the occupant would have been severely injured even had he been restrained. We believe, however, that the severity of injury for these three occupants would have been less had they remained in their respective vehicles.

In taking a close look at how ejection was precipitated in these matched pair cases, one recurring factor was noted. Ejection seemed more likely to be associated with violent or dramatic movement, or directional change, of a vehicle, if this movement were not along the longitudinal axis of the car. This is obvious in rollover accidents, but is also apparent in other crashes. In the three cases involving more than one vehicle, the cars underwent dramatic change in direction. The path the ejected occupant would follow tended to take two forms. Either they would head directly toward a door or window opening, and exit through that opening, or they would move about in the interior striking this object or that and then "find" a portal for ejection. The difference between these two path types seemed to be whether the occupant was ejected initially or after coming in contact with a number of interior components. The movement of the occupants could also be described as violent, or with dramatic changes in direction, particularly in cases where they contacted a number of interior surfaces prior to ejection.

The 11 matched pair cases found in the NCSS data presented an opportunity to make direct comparisons, in a number of areas, between ejected and non-ejected occupants in the same crashes. The dramatic disparity in injury severity between those occupants who are ejected and those who remain in the car is apparent.

Being able to review actual case reports or "hard copy" is important in any study in order to have a better understanding of the coding of variables. The detailed review of the 11 fatal ejection case reports provided an opportunity to make comparisons in a number of areas regarding the NCSS data. In addition, various factors related to ejected and non-ejected occupants of the same vehicle were compared. Of particular benefit in the NCSS cases were the extensive notes and annotations. Not only did these notes provide additional information regarding cases, but helped point out both strengths and weaknesses with coded variables.

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