Evaluation of Effectiveness of Door Locks on Pre-1956 and Post-1955 Automobiles

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UNTIL the last decade it was widely accepted as a "fact" that in an automobile accident occupants who were thrown from the car were safer than those who remained inside. Indeed, the connotation of "thrown clear" was that the ejectee would otherwise have been killed. Although such incidents have been documented, a 1954 Automotive Crash Injury Research (ACIR) report (*1*) showed that they were the exception rather than the rule. The ACIR study found that most ejections occurred when automobile doors opened under impact conditions and that door opening was both a frequent and hazardous event: in injury-producing automobile accidents one or both front doors opened in about 44 percent of the cars, and, contrary to general opinion, occupants who were hurled through these doors were often thrown clear—to eternity, not to safety.

A later ACIR study (*2*) sought to determine more precisely the consequence of door opening in terms of occupant ejection and injury and to estimate the potential reduction in fatal injuries if ejection could be completely prevented. About 13 percent of the occupants of cars in which injury occurred were completely ejected through open doors. Among these ejected occupants the frequency of fatality was 12.1 percent; among nonejected occupants, 2.5 percent. Thus, risk of fatality was five times greater for ejected than for nonejected occupants. At certain speeds and in certain accidents—rollovers, for example—this difference in injury risk was as much as 20 to 1. Since 1954 the frequency of door opening, ejection, and injury among ejectees and nonejectees in pre-1956 cars has been examined a number of times, and each time these findings have been confirmed.

In another phase of the same study it was estimated that preventing ejection of the occupants could reduce the frequency of fatality in injury-producing accidents by about 25 percent. It was also calculated that such a reduction could produce a potential saving of approximately 5,500 lives annually. Subsequent ACIR studies examined the effectiveness of two methods of preventing ejection—seat belts and safety door locks.

Seat belts have been available to motorists for some time. Although the effectiveness of this device had been demonstrated in early Crash Injury Research studies of aircraft accidents (*3*), confirmation of these findings in automobile accidents was deemed essential. As early as 1956 analysis of a small sample of accidents in which occupants of the cars had used seat belts indicated a substantial reduction in dangerous and fatal injuries when seat belts were worn.

In 1960, using a larger and more cohesive sample, the effectiveness of seat belts was examined again in a joint ACIR-California study (*4*). The use of belts reduced major and fatal injuries by about 35 percent, and possibly two-thirds of this reduction resulted from the control of occupant ejection. It was also apparent that educating motorists, first to buy seat belts and then to use them, was in itself a major task:

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approximately 3 percent of the 54,000 accident-involved vehicles in the California data were equipped with belts, and only about one-third of the occupants to whom belts were available used them (*5*).

From the occupant's viewpoint another, and simpler, method of reducing ejection is, in effect, to seal off those apertures through which people are most often ejected—the automobile doors. One advantage of this method is that it requires no unusual action on the part of the automobile occupant, only the accepted routine of closing and locking a door. However, while keeping doors closed can prevent ejection of the occupants, it cannot provide the additional protection against unrestrained motion within the car which is afforded by the seat belt.

In 1956 the manufacturers of American automobiles introduced modified safety door locks in an effort to reduce door opening and thus to curb occupant ejection. Although the door locks of individual manufacturers differed, all had one feature in common, some sort of "positive stop" designed to prevent the latch and striker from becoming disengaged when impact forces twisted and distorted the car body or door frame. Figure 1 is a simple illustration of the basic principle underlying this positive stop.

Laboratory tests, as well as test crashes and rollovers conducted by various automobile manufacturers on their test tracks, demonstrated that the new door locks were superior in holding power to the old door locks. Valuable as the analysis of such laboratory tests and test crashes may be, however, these tests do have their limitations. For example, it is difficult to reproduce certain accident conditions, such as rollovers, on the test track so that the results can be precisely repeated for further study, or to translate damage to anthropomorphic dummies into potential injury to human beings. The ultimate test of any new device is still its performance under actual operating conditions, and the true test of the new door locks must be their performance in actual crashes on the highways.

It is therefore the purpose of this report to evaluate the performance of modified safety door locks in 1956 and later model automobiles and to provide an estimate of their effectiveness in reducing the frequency of door opening, occupant ejection, and dangerous or fatal injury in injury-producing accidents. In arriving at this estimate, the answers were also obtained to two pertinent and closely related questions concerning door opening and occupant injury: (*a*) What is the potential reduction in dangerous and fatal injuries if no doors had opened? (*b*) How much of this potential reduction has been realized through use of the modified door locks?

Definitions

Door Opening: Refers only to doors which opened after impact to another part of the car. Doors that were struck and opened or that were torn off were not included.

Complete Ejection: Includes only those persons who were thrown completely out of an open automobile door upon or after impact.

"Other" Ejection: Includes persons hanging from or partly out of a door, persons who toppled from a car after it came to rest following an accident, and persons thrown through convertible tops (top up or down) or windows or through portions of the car torn open on impact.

Highest Impact Speed: Speed at which the fastest moving vehicle in a multiple vehicle accident impacted; the impact speed in single vehicle accidents.

Area of Impact: Portion of a car which struck a vehicle or object or was struck by another vehicle.

Fatal Injury: Injury causing death within 24 hours subsequent to accident.

Dangerous Injury: Injury which threatens life; victim placed on the "critical" list during the 24-hour period subsequent to the accident.

Nondangerous Injury: Injury which does not threaten survival but is more than minor; includes most fractures and severe lacerations.

Minor Injury: Lacerations, bruises, contusions.

Basic Data

Data examined in this study were drawn from the ACIR interstate program of rural injury-producing accidents and consist of information on 14,135 automobiles in each of which at least one occupant was injured. These cars carried 31,855 occupants.

Only American-made automobiles were studied and only 38 cars were "compacts." Since the purpose of the study was to evaluate the effectiveness of door locks in 1956 and subsequent models of automobiles, the cars were divided into two groups according to the period of manufacture—before 1956 and after 1955. A total of 8,606 pre-1956 cars containing 19,430 occupants and 5,529 post-1955 cars containing 12,425 occupants were studied.

Rationale

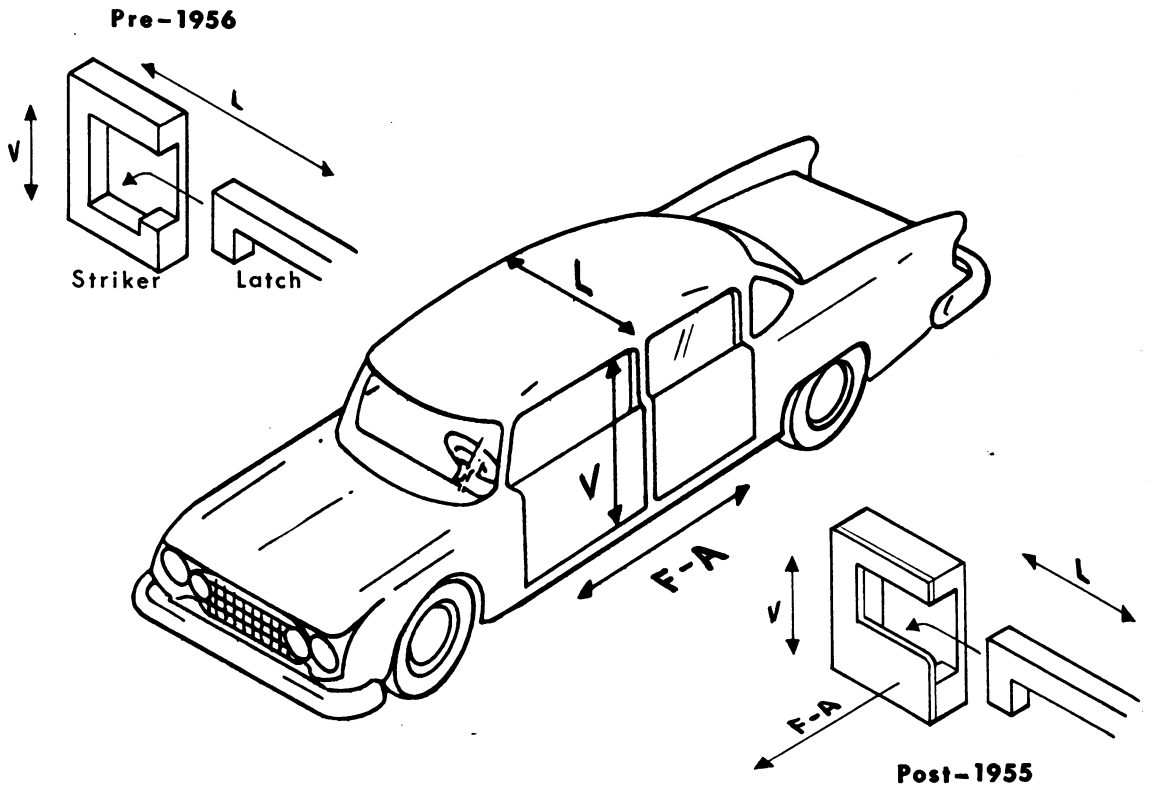
The rationale of this paper is based on the door opening-ejection-injury relationships described earlier and is therefore stated in terms of three closely related hypotheses. These hypotheses, assuming similar accident conditions for both pre-1956 and post-1955 automobiles, are:

- If the door locks in post-1955 automobiles are an improvement over the locks in pre-1956 cars, then the frequency of door opening among post-1955 cars should be lower than among pre-1956 cars.
- If the frequency of door opening in later model cars is reduced, then for post-1955 cars the frequency of complete occupant ejection through doors should also be lower than in pre-1956 automobiles.
- If fewer occupants are ejected from the more recent model cars, then the frequency of dangerous and fatal injuries among occupants of these automobiles should be lower than among occupants of the pre-1956 automobiles. (The shift of ejected occupants from the relatively high-risk ejection category into the relatively low-risk nonejection category should reduce the frequency of dangerous and fatal injuries.)

Methods and Procedures

Examination of the data in this study involved two major analytic procedures.

Figure 1. Simplified sketch illustrating basic principle of modified door locks



NOTE: Pre-1956 locks resisted forces in two directions, vertical (V) and lateral (L). Post-1955 locks resist forces in three directions—vertical, lateral, and fore and aft (F–A)—through addition of a metal stop, or lip.

First, in order to provide an overall perspective and to demonstrate the relationships between door opening, occupant ejection, and dangerous and fatal injuries, data on pre-1956 and post-1955 automobiles were compared, using the gross ACIR data described above—without the use of any controls.

Second, a more detailed examination of each of the three factors was performed under "controlled" accident conditions, using the method of "expectancies." Controls were employed to insure the comparability of accident circumstances and to provide information concerning the effectiveness of the new door locks in specified accident situations. In using the method of expectancies, it was simply assumed that if the new locks were not an improvement over the old, then, under the same accident conditions, the risk of door opening, occupant ejection, and dangerous or fatal injury in the later models would remain the same as it was in pre-1956 cars.

Throughout this study, in order to examine two-door and four-door cars on a comparable basis, door opening has been measured in terms of the frequency of one or both front doors opening. This presentation is confined to the major topics described in the first procedure. The detailed report on door lock effectiveness (*6*), containing additional information on methods, procedures, and findings, is available upon request.

Analysis of the gross data from the study provides a comprehensive view of the effects of door lock changes on door opening, occupant ejection, and injury and shows the relationship between these three factors. Since a gross comparison of pre-1956 and post-1955 automobiles would be meaningless unless accident conditions for the two groups of cars were essentially the same, cars of both eras were initially compared with respect to the distributions of a number of accident factors—speed, type of accident, seated position of occupants, and so on—which could conceivably influence the findings. Examination of these distributions also aided in the selection and grouping of the accident factors used as "controls" in the more detailed sections of the study.

In examining these distributions it was ascertained, for example, that the average number of occupants per car for both pre-1956 and post-1955 automobiles was nearly identical (2.26 and 2.25 respectively), that the distribution of these occupants according to seated position was the same in cars of both eras, and that the distributions of pre-1956 and post-1955 automobiles were similar with respect to the highest impact speed, although the later model cars were involved in slightly more "high speed" accidents than the older cars.

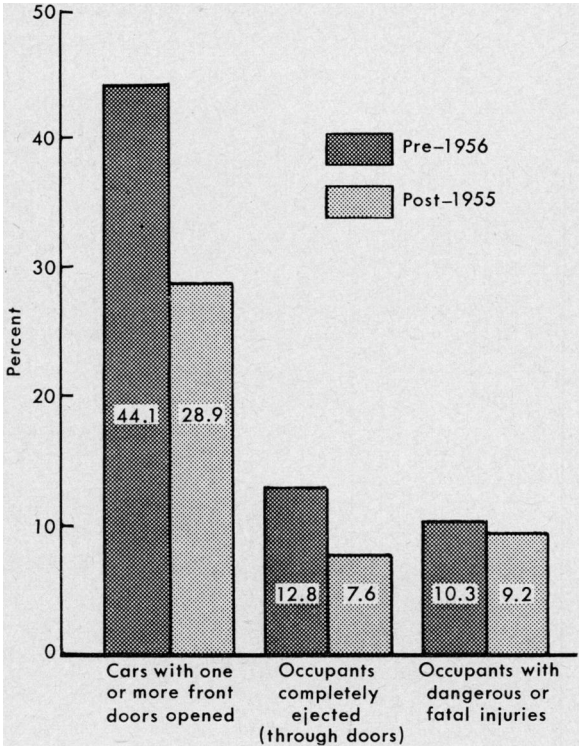
A similar comparison with respect to the principal area of impact also revealed few differences between the two groups of cars, although the later models were involved in a slightly smaller number of "lateral" force accidents and somewhat more "rear" and "miscellaneous" accidents. Despite the fact that occasional minor differences were found, accident circumstances for the two groups of cars appeared to be generally similar and, if anything, the later model cars were in a slightly larger number of severe accidents.

Findings

Over a period of years little, if any, change in the frequency of door opening, occupant ejection, and dangerous or fatal injury was observed among pre-1956 automobiles (*1*, *2*, *7*, *8*). In the present study, examination of accident circumstances, such as speed and accident type, indicated that these conditions were fairly comparable for both pre-1956 and later model cars. The examination of gross ACIR data—all injury-producing accidents reported by participating States—should therefore provide some perspective concerning the relative frequency of door opening, occupant ejection, and injury in pre-1956 and post-1955 automobiles. The comparative frequencies of all three events are illustrated for both groups of cars in figure 2.

Figure 2 shows that among the recent model cars there was a substantial reduction in the frequencies of door opening, occupant ejection, and dangerous or fatal injuries. Examination of the data under controlled conditions in the detailed report shows that these reductions were 32.84 percent for door opening, 39.62 percent for occupant ejection, and 11.57 percent for dangerous-fatal injuries. All reductions were statistically significant.

Figure 2. Frequency of opening of one or both front doors, occupant ejection, and dangerous or fatal injury, pre-1956 versus post-1955 automobiles



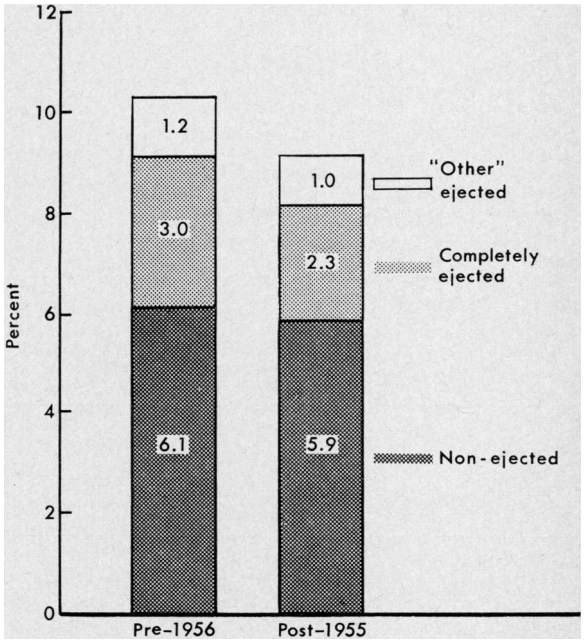
The distribution of dangerous or fatal injuries, according to ejection status of the occupants, is shown in figure 3. The reduction in percentage of dangerous and fatal injuries among occupants of the later model cars was largely due, as hypothesized, to a decrease in the percentage of ejected and dangerously or fatally injured occupants. Also, there was some reduction in these injuries among occupants in the "other" ejection category. Injury to nonejected occupants remained essentially the same.

One interesting phenomenon that appeared as a result of the door opening-ejection-injury change is worth mentioning: despite the fact that fewer occupants were ejected from post-1955 automobiles, a higher proportion of these ejected occupants sustained dangerous or fatal injuries than did occupants ejected from pre-1956 cars (table).

Since fewer occupants were ejected from post-1955 cars (fig. 2) and since occupants of these cars sustained fewer dangerous or fatal injuries due to the reduction in ejections (fig. 3), this phenomenon would appear to indicate that much of the reduction in number of ejections occurred under conditions of low accident severity. Examination of the data under controlled conditions confirmed this indication. Thus, those occupants who were ejected from post-1955 cars were subjected to more severe accident conditions than those ejected from pre-1956 cars and, as a result, sustained more severe injuries. It is likely that, as number of ejections is further reduced, through better door locks or the use of seat belts, the injury risk associated with ejection will continue to increase. For example, if all ejections occurred at speeds above 90 m.p.h., then it is probable that most ejectees would be killed and the difference in injury risk between all nonejected occupants and all ejected occupants would be enormous.

In the earlier study of ejection (*2*) it was calculated that if no ejection occurred the potential reduction in fatalities would be about 25 percent. This potential injury reduction was checked and essentially confirmed in the present study, in which the potential reduction for

Figure 3. Percentage of occupants sustaining dangerous and fatal injuries, according to ejection status, pre-1956 and post-1955 automobiles



dangerous-fatal injuries was estimated to be about 27 percent (*6*). It was further calculated that the modified safety door locks had achieved 31.95 percent of the potential injury reduction by reducing the frequency of ejection. If it is assumed that the same potential reduction would apply for fatality, then the number of lives saved as a result of redesigned door locks can be calculated. The assumption is reasonable in view of the fact that the frequencies of dangerous and fatal injuries are similar and have remained similar over a period of years (*8*), and that accident conditions which produce fatality produce a similar proportion of dangerous injuries.

In the ejection study, it was calculated that 20,528 of the approximately 40,000 persons killed in automobile accidents each year were occupants of automobiles involved in rural accidents, and that 3,150 were occupants of cars involved in urban accidents. Since the ACIR sample is primarily rural, the calculated potential reduction of 25 percent was applied to the occupants in the rural group and a lesser reduction (10 percent) was applied to the less severe urban accidents. In all, the potential saving in lives, if no ejection occurred, was estimated to be approximately 5,500 annually.

Using 5,500 as a base, it was estimated that if all cars were equipped with modified safety locks approximately 1,800 lives, 0.3195 × 5,500, might be saved annually. At the present time, when roughly 40 or 50 percent of all American cars are equipped with these locks, this saving amounts to perhaps 800 lives.

Change in percentage of dangerous or fatal injuries, according to ejection status of occupants and car model year

Ejection status	Car model year		Percent change
	Pre-1956	Post-1955	
Ejection:			
Complete	23.2	30.5	+31.5
Other [1]	23.2	32.0	+37.9
Not ejected	5.9	5.4	−8.5

[1] Persons hanging from or partly out of a door, persons who toppled from a car after it came to rest following an accident, and persons thrown through convertible tops (top up or down), windows, or portions of the car torn open on impact.

Discussion

Calculation of the injury reduction achieved by modified door locks logically brings up the question, If new door locks are so effective, why isn't there a dramatic decrease in automobile fatalities? The answer is, of course, that many factors other than door opening contribute to these deaths, and that a decrease in deaths due to one factor may be offset by an increase due to another, or to a number of others. For example, the effectiveness of door locks could conceivably be offset by changes in speed, automobile or highway design, traffic congestion, or almost innumerable other variables. The important fact is that when pre-1956 and post-1955 cars were compared under similar accident conditions, the later models showed an improvement with respect to door opening, occupant ejection, and injury.

Another question which is raised rather frequently, chiefly because detailed information on damaged door locks is not readily available, is concerned with the possibility that automobile doors may be inadvertently opened from within as a result of occupants grabbing for a handhold or flailing about in a collision. Since there is some evidence that this happens occasionally—several cases are documented in ACIR files—the basic question becomes one of frequency: How often does this type of door opening occur? Although available data cannot provide a precise and detailed answer to this question, efforts are currently underway to obtain additional information on lock damage, and study results will be reported in future papers.

It was stated earlier that the present report represents, in a sense, the culmination of a cycle of research and design change which was initiated some years ago with the statement of a safety problem: the risk of injury is heightened when occupants are ejected through automobile doors. A design change, modified safety door locks, was effected, and, later, an estimate was made of the potential reduction in injuries if no ejection occurred. Finally, the effectiveness of the design solution was evaluated in terms of door opening and occupant ejection, and it was estimated that approximately 32 percent of the potential injury reduction had been achieved. An injury reduction of this magni-

tude represents a major safety achievement, and yet there is evidence, if estimates of potential injury reduction are anywhere near accurate, that prevention of door opening still represents the area in which automotive redesign can accomplish the greatest reduction in injuries.

With respect to door locks, the cycle of research and redesign is not completed. In fact, several automobile manufacturers introduced new door locks on 1961 and 1962 model cars, thus initiating a new phase in the cycle.

Future papers will attempt to evaluate further safety improvements in order to demonstrate, if such demonstration is still needed, that a continuing cycle of research and design change can provide safer cars for the American motorist.

Summary

American automobiles manufactured after 1955 with modified safety door locks were compared with older model cars in order to determine the effectiveness of the new locks.

Data on 14,135 American-made automobiles in which at least one occupant had been injured were drawn from Cornell University's Automotive Crash Injury Research (ACIR) interstate program of rural injury-producing accidents. These cars had carried 31,855 occupants. For purposes of comparison, the data were divided according to year of manufacture of the cars, 8,606 before 1956 and 5,529 after 1955.

Pre-1956 cars were compared with post-1955 cars under similar conditions of highest impact speed in the accident, principal area of impact, and body style, in order to determine whether the frequency of one or both front doors opening, of occupant ejection, and of dangerous or fatal injury had changed. Some of the principal findings were:

1. The frequency of door opening was reduced 32.84 percent among post-1955 cars.

2. The frequency of occupant ejection was reduced 39.62 percent among occupants of post-1955 cars.

3. The frequency of dangerous and fatal injuries among all occupants of post-1955 cars was reduced 11.57 percent.

4. The previous estimate, made in 1958, that complete prevention of ejections by means of a "perfect" door lock could reduce fatalities by approximately 25 percent was essentially confirmed, using a combination of figures for dangerous and fatal injuries.

5. It was estimated that the modified safety door locks in later model cars had achieved about 32 percent of the potential injury reduction, if no doors opened.

Based on the earlier estimate that 5,500 lives might be saved if "perfect" door locks were installed in all cars, it was calculated that if all the cars on the highways had been post-1955 models with modified safety door locks, a saving of approximately 1,800 lives annually might have resulted. Assuming the present proportion of cars with modified safety locks to be about 40 or 50 percent, this saving at the present time amounts to about 800 lives.

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