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REAR COMPARED TO FRONT SEAT RESTRAINT SYSTEM EFFECTIVENESS IN PREVENTING FATALITIES

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ABSTRACT

This work was performed to present briefly the results of recently published estimates of restraint system effectiveness for rear seats of passenger cars, and to contrast these estimates with earlier estimates of restraint system effectiveness for front seats. The estimates were obtained by applying the double pair comparison method to data in the Fatal Accident Reporting System (FARS). The average effectiveness of rear lap belt restraints was estimated as (18 ± 9)%, compared to (41 ± 4)% for front lap/shoulder restraints. While the results indicate that effectiveness for rear lap belts is lower than for front lap/shoulder belts, the rear seat estimate suggests that there is a 39 in 40 chance that rear seat restraints reduce fatality probability.

INTRODUCTION

This work was performed to present briefly the results of recently published estimates of restraint system effectiveness for rear seats of passenger cars [1,2], and to contrast these estimates with earlier estimates of restraint system effectiveness for front seats [1,3,4]. The estimates were obtained by applying the double pair comparison method [1] to data in the Fatal Accident Reporting System (FARS) [5]; this is a computerized data file maintained by the National Highway Traffic Safety Administration giving detailed information on every traffic crash occurring in the United States since January 1, 1975, in which anyone was fatally injured.

The analyses were confined to occupants in the outboard seating positions (that is, passengers in the right rear, left rear, and right front seating positions, and drivers). There were insufficient data to examine center front or center rear seating positions.

The double pair comparison method

All the estimations use the double pair comparison method, which is described briefly below; complete technical details are given in [1].

The method focuses on two occupants, a "subject" occupant and an "other" occupant. The probabilities of a fatality to the subject occupant under two conditions, restrained and unrestrained, are compared. The other occupant essentially serves a normalizing, or exposure estimating, role.

The subject occupants used in this study are passengers in the right rear, left rear, and right front seating positions, and drivers. Occupants in any seat except that occupied by the specific subject being studied may be used as "other" occupants.

For simplicity, we describe the method below in terms of the right rear passenger as the subject occupant and the driver as the other occupant. Generalization to the other cases is obvious.

The method uses two sets of fatal crashes. The first set consists of crashes involving cars containing a restrained right rear passenger and an unrestrained driver, at least one of whom is killed. From the numbers of right rear passenger and driver fatalities, a restrained right rear passenger to unrestrained driver fatality ratio is calculated. From a second set of crashes involving cars containing unrestrained right rear passengers and unrestrained drivers, an unrestrained right rear passenger to unrestrained driver fatality ratio is similarly estimated. Under assumptions discussed in [1], dividing the first fatality ratio by the second gives the probability that a restrained right rear passenger is killed compared to the corresponding probability that an unrestrained right rear passenger is killed, averaged over the distribution of crashes that occur in actual traffic; this is the measure of restraint system effectiveness sought, and applies for the following definition of effectiveness. Effectiveness in preventing fatalities is the fraction (or percent) reduction in fatalities which would accrue to a presently unrestrained population if the population were to change to universal restraint use, all other factors remaining unchanged.

The other occupant in the double pair comparison, the unrestrained driver, does not directly enter into the result. Because of this key feature of the method, many separate estimates can be calculated by choosing a variety of other occupants; 12 such estimates were obtained for the rear seat investigation and 46 for the front seat investigation.

In the results section, all the required calculations to derive individual estimates of effectiveness and to combine many estimates to generate a more precise overall estimate are given in terms of one specific numerical example.

Data

All the estimates used Fatal Accident Reporting System (FARS) data [5]. As this data set contains information on fatal crashes only, the results apply exclusively to fatalities, and should not be generalized to other levels of injury. The analyses used only adult (16 years or older) occupants. Some additional details of the data used in the rear seat study [2] and the earlier performed front seat study [3] are summarized in Table 1. For the rear seat study, all model years were included, and any occupant coded as using any restraint was presumed to be using a lap belt. For the front seat study, only data for passenger cars model year 1974, or later, were included in the analysis; 1974 was the first model year for which manufacturers were required to equip all cars with integrated three-point lap/shoulder belts for the driver and right front passenger seating positions. All drivers or right front passengers in such cars coded in FARS as using any type of restraint are assumed to use this system. These assumptions regarding which restraint system was used were necessary because, due to coding problems in FARS, it is not possible to identify specifically which restraint system was used.

Note further that all the estimates assume that actual use, or non-use, of a restraint system is as coded in the FARS data. Any systematic errors in coding restraint use could, of course, generate systematic errors in effectiveness estimates.

Effectiveness is estimated essentially from the cases in which restraint use of subject occupant and other occupant differ. There is a strong tendency for restraint system use or non-use to be the same for different occupants of the same vehicle. Hence, sample sizes in the really important cells were even smaller than would arise if restraint system use were distributed randomly among occupants to generate the totals in Table 1. The sample sizes, which were different for each "subject" and "other" occupant pair, are given in [2] and [3].

Table 1. Summary of data.

Front or rear	FARS years	Model years	Subject occupant	Fatalities		Probable restraint system
				Restrained	Unrestrained	
Rear	1975 thru 1985	All	Right passenger	322	12 211	Lap belt only
			Left passenger	215	10 333	
Front	1975 thru 1983	≥1974	Right passenger	716	15 595	Lap/shoulder belt
			Driver	711	14 738	

RESULTS

All the equations required in this report are given in terms of a specific numerical example; for derivations, justifications, proofs and discussion of these equations, see [1], in which the equations were developed in terminology identical to that used here.

The specific example chosen uses the right rear passenger as the subject occupant, and the unrestrained driver as the other occupant. The raw fatality data for this case are given as the first of the six cases in Table 2. These

Table 2. Calculation of the effectiveness of restraint systems in preventing fatalities to right rear passengers. The fatality frequencies a, b, c, j, k, and l are defined in the text and extracted from the FARS data; all the other quantities are functions of these, as explained in the text.

Other occupant characteristics	First (upper) and second (lower) comparison data						R	E(%)	Error range (%)
	a j	b k	c l	d m	e n	r_1 r_2			
Unrestrained driver	22 3414	39 4802	9 1462	31 4876	48 6264	0.646 0.778	0.830	17.0	-7 to 36
Unrestrained right front passenger	20 2643	38 4245	8 1747	28 4390	46 5922	0.609 0.733	0.831	16.9	-8 to 36
Unrestrained left rear passenger	6 1666	17 1687	6 870	12 2536	23 2557	0.522 0.992	0.526	47.4	24 to 64
Restrained driver	80 184	63 116	30 44	110 228	93 160	1:183 1.425	0.830	17.0	-2 to 32
Restrained right front passenger	71 121	59 86	28 44	99 165	87 130	1.138 1.269	0.897	10.3	-11 to 28
Restrained left rear passenger	31 14	29 14	11 2	42 16	40 16	1.050 1.000	1.050	-5.0	-61 to 32
						Weighted average values	0.827	17.3	8 to 26

Estimated average restraint system effectiveness in preventing fatalities to right rear passengers = (17.3 ± 8.7)%

data show a = 22 restrained right rear passengers were killed travelling with unrestrained drivers who were not killed, b = 39 unrestrained drivers were killed travelling with restrained right rear passengers who were not killed, and there were c = 9 cases in which restrained right rear passengers and unrestrained drivers travelling together were both killed. From these values we compute the restrained right rear passenger to unrestrained driver ratio

$$r_1 = (a+c)/(b+c) = d/e = 31/48 = 0.646 . \qquad (1)$$

Similarly, the unrestrained right rear passenger to unrestrained driver ratio is given by

$$r_2 = (j+l)/(k+l) = m/n = 4876/6264 = 0.778 , \qquad (2)$$

where j, k, and l are defined as a, b and c, except that the subject occupant, the right rear passenger, is unrestrained.

The restrained to unrestrained fatality ratio for right front passengers is then given by

$$R = nd/me = r_1/r_2 = 0.830, \qquad (3)$$

or, expressed as a restraint system effectiveness in percent, E, given by

$$E = 100(1 - R) = 17.0\% . \qquad (4)$$

The error ranges in the estimates are calculated in terms of the standard error, σ, of the logarithm of R, which is given by

$$\Delta R = \pm R\sqrt{\sigma_\mu^2 + 1/n + 1/d + 1/m + 1/e} , \qquad (5)$$

where σ_μ is an estimate of the intrinsic uncertainty (analogous to a random instrumental error). As before [2-4], we take $\sigma_\mu = 0.1$; that is, we assume that even in the limit of very large samples, confounding effects limit the accuracy that can be obtained by an individual determination to about ± 10%.

The error bounds are then given as

$$E_{lower} = 100[1 - \exp(\log(R) + \sigma)] \tag{6}$$

and

$$E_{upper} = 100[1 - \exp(\log(R) - \sigma)]. \tag{7}$$

Eqns 6 and 7 are used in preference to the simpler assumption of a symmetric error, ΔE, in the effectiveness, given by

$$\Delta E = 100\, R\, \sigma\ . \tag{8}$$

This error estimate, which was used in the prior work [2-4], is derived by assuming that σ is small compared to unity [1]. This assumption was used only to present errors in convenient form -- it is not contained in any derivations. Eqns 6 and 7, which reflect that errors are in fact symmetric around the logarithm of R, rather than around R, is more appropriate when σ becomes large due to few data. The numerical values in the present example substituted in to eqns 6 and 7 give lower and upper error limits of -6.7% and 35.5%, respectively. Applying eqn 8 gives E = (17.0 ± 20.9)%.

The weighted average of the six values of R in Table 2, $\bar{R}$, is obtained as

$$\bar{R} = \exp[\Sigma w \times \log(R)/\Sigma w] \tag{9}$$

where the weight, w, is given by

$$w = (R/\Delta R)^2 \tag{10}$$

and the summation is over the six values of R. For the data in Table 2, $\bar{R}$ has the value 0.827, or an average restraint system effectiveness of 17.3%.

The error in the average value of $\bar{R}$, $\Delta\bar{R}$, is given by

$$\Delta\bar{R} = \bar{R}/\sqrt{\Sigma(R/\Delta R)^2} \qquad (11)$$

which, for the present case is 0.087, or 8.7%. For convenience, this rather than the upper and lower bound estimates also shown in Table 2, will be used. For small errors the difference is immaterial.

Thus, the data in Table 2 gave the following estimate of lap belt restraint system effectiveness for <u>right rear passengers:</u>

$$(17 \pm 9)\%. \qquad (12)$$

Applying the same procedures to data for the <u>left rear passenger</u> (see Table 2 of [2]) gave the following estimate of restraint system effectiveness for <u>left rear passengers:</u>

$$(19 \pm 10)\%. \qquad (13)$$

The estimates in eqns 12 and 13 give no indication that effectiveness is different in the two outboard rear seating positions. It is therefore appropriate to combine them to obtain a composite estimate, using eqn 9. However, because the data used for the left and right rear passenger estimates have some overlap and are accordingly not independent, it would be inappropriate to use eqn 9 to compute a composite error, as is discussed in [2,3]. Instead, the conservative choice of taking as the overall error the smaller of the errors for the left and right seating positons was made, without reducing it further to reflect the additional information from the other seating position.

Combining the estimates of eqns 12 and 13, and using the error in eqn 12, gives the estimate of effectiveness of lap belt restraint systems in preventing fatalities to <u>outboard rear seat occupants</u> as

$$(18 \pm 9)\%. \qquad (14)$$

The analyses for front seat occupants [3] was essentially similar to that described above for rear seat occupants, except larger quantities of data permitted disaggregation by occupant age. The results of the many additional estimates produced by such disaggregation were combined, using eqn. 9, to give the final estimates shown in Table 3. Note that, because of the substantially larger quantities of data for the front seat case, the errors are smaller than for the rear seat estimates, which are given again in Table 3 to facilitate comparison.

Table 3. Summary of the effectiveness of restraint systems in preventing fatalities.

	Driver or left passenger	Right passenger	Combined
Front	(42 ± 4)%	(39 ± 4)%	(41 ± 4)%
Rear	(19 ± 10)%	(17 ± 9)%	(18 ± 9)%

DISCUSSION

The combined result for the front seat occupants reflects weighting of the driver and front seat passenger estimates by occupancy rates for these seating positions. In [2] the (41 ± 4)% result is further combined with an estimate of (45 ± 5%) from NHTSA to give an overall estimate of (43 ± 3)%. That is, if all drivers and right front seat passengers not presently using the provided lap/shoulder belts were to become users, a 43% fatality reduction to this population would result provided all other factors remained the same.

From the combined rear result in Table 3, let us assume that actual rear restraint system effectiveness is estimated as 18%, with the estimate normally distributed around the actual value with a standard deviation of 9%. From the properties of the normal distribution, we can readily calculate the probability that the actual effectiveness has values in any chosen range. For example, the probability that the actual effectiveness is greater than 30% is 0.092. The probability that the actual value is positive is 0.977 (in contrast to a 0.023 probability that it is negative).

Given the uncertainties in obtaining the estimate of (18 ± 9)%, and the uncertainty surrounding the distribution of the error, the above probabilities are clearly very approximate. However, they do suggest the following conclusions:

- there is a 39 in 40 chance that rear lap belts decrease fatality likelihood

- there is a less than 1 in 10 chance that rear lap belts are more than 30% effective in preventing fatalities.

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