Ziegler

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COMFORT AND CONVENIENCE ANALYSIS OF ADVANCED RESTRAINT SYSTEMS

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16. Abstract

Five restraint systems were evaluated in terms of comfort and convenience by ten subjects. Statistical analysis of particular questions and system comparisons (supplemented with subject and questioner comments) uncovered potential problems with individual system characteristics and provided overall system rankings. The standard lap and shoulder belt system (1974 Chevrolet Impala) was found to be more acceptable than the advanced systems. Several aspects of the systems caused difficulties or confusion, but the single-loop "window-shade" feature most frequently produced problems.

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Finally, appreciation is offered to Mr. Peter Ziegler (ODPR, NHTSA) for his many helpful suggestions during the development of the test methods and writing of this report.

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I. INTRODUCTION

There are numerous reports describing the life saving effects of wearing seat belts. Despite overwhelming statistics favoring seat belt usage, many individuals do not utilize the restraint systems in their cars. The primary explanations of non-usage are the discomfort and inconvenience factors involved in wearing seat belts. Therefore, one objective of seat belt research should be to obtain more user acceptable restraints.

The objectives of this report are to evaluate certain aspects of comfort and convenience of several new seat belt designs and to compare the test installations as complete systems. A typical 1974 restraint system is also included for comparison with industry standards. The test vehicles were available for only one and a half weeks. This short total testing period plus a lengthy evaluation time for each subject resulted in a small subject population (10). It is important to determine the presence of problem areas; therefore, a wide range of subject sizes was utilized. This led to an atypical subject population.

The questionnaire and data analysis techniques in this report were adopted with only slight modifications from those presented by Man Factors, Inc. (DOT HS-801 277). The use of similar techniques allows direct comparison of the two reports, and the Man Factors procedures seem to be well designed. Question areas included donning of the seat belt system, mobility and comfort in the system, doffing the seat belt system, and exiting from the seat belt system. Questions concerning different aspects of seat belt usage served to point out particular problem areas of the individual restraint systems. Additional input to the discussion of potential problem areas was obtained by subject and questioner comments that were recorded during the test. Overall ranking of the subjects acceptance of the different systems was obtained by overall results of the individual questions, pair comparison analysis, and subject ranking of the systems.

II. TEST METHODS

A total of five (5) cars were evaluated in this test program. The restraint systems ranged from a standard active type to a fully passive one. The cars (restraint systems) were lableled A, B, C, D, and E. Because all results and discussions refer to the identification scheme described below and shown in Figures 1 - 5, knowledge of the letter designation is essential to understanding the report.

Car No. A shown in Figure 1 was an AMC Hornet with a modified active restraint system. The lap belt and shoulder belt were part of a continuous loop of webbing, with a single retractor reel located in the door. A special one way slip ring provided a constant lap belt tension while allowing the shoulder harness to move and permitting movement within the car. This restraint system also had what has been termed a "window shade" adjustment of the shoulder belt tension. A small forward motion of the upper torso allowed slack to form in the shoulder restraint, but a larger motion of the upper torso initiated a retraction force that pulled the shoulder harness snugly against the chest. The shoulder restraint was locked by a vehicle sensitive emergency locking system. The final feature of this belt system was a door actuated retraction of the entire belt system. When the inside door handle was pulled, the "window shade" catch was released initiating retraction to the storage position.

Car No. B was a 1974 Chevrolet Impala. It had two restraint system take-up reels. An automatic locking retractor was used for the lap belt while a vehicle sensitive emergency locking retractor was used for the shoulder restraint. A single latch plate contained connections for both shoulder and lap belt into a single buckle. Shoulder belt position was guided by a ring attached to the headrest. This restraint system is illustrated in Figure 2.

Car No. C was a 1975 Cadillac Seville with a single loop webbing system (see Figure 3). This system was generally similar to that in Car No. A. The only differences were that the belt storage and retraction were located in the "B" pillar and the door activated

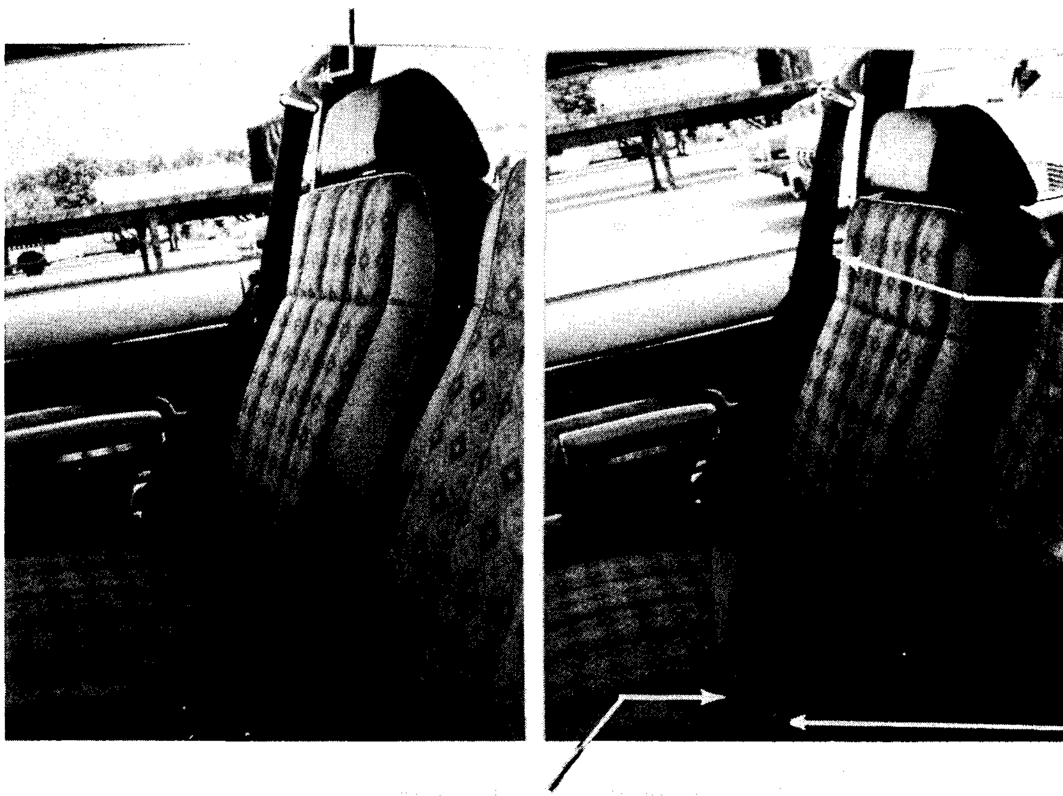


FIGURE 1 - Car No. A - Active Restraint in AMC Hornet

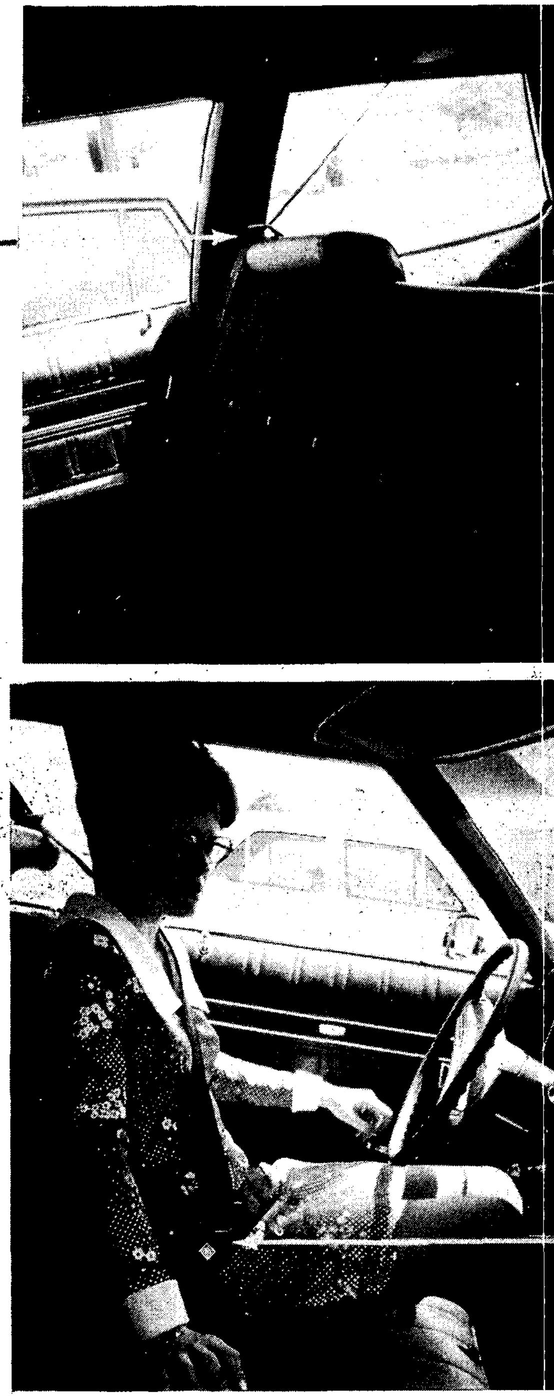


FIGURE 2 Car No. B - Standard Three-Point Restraint in Chevrolet Impala

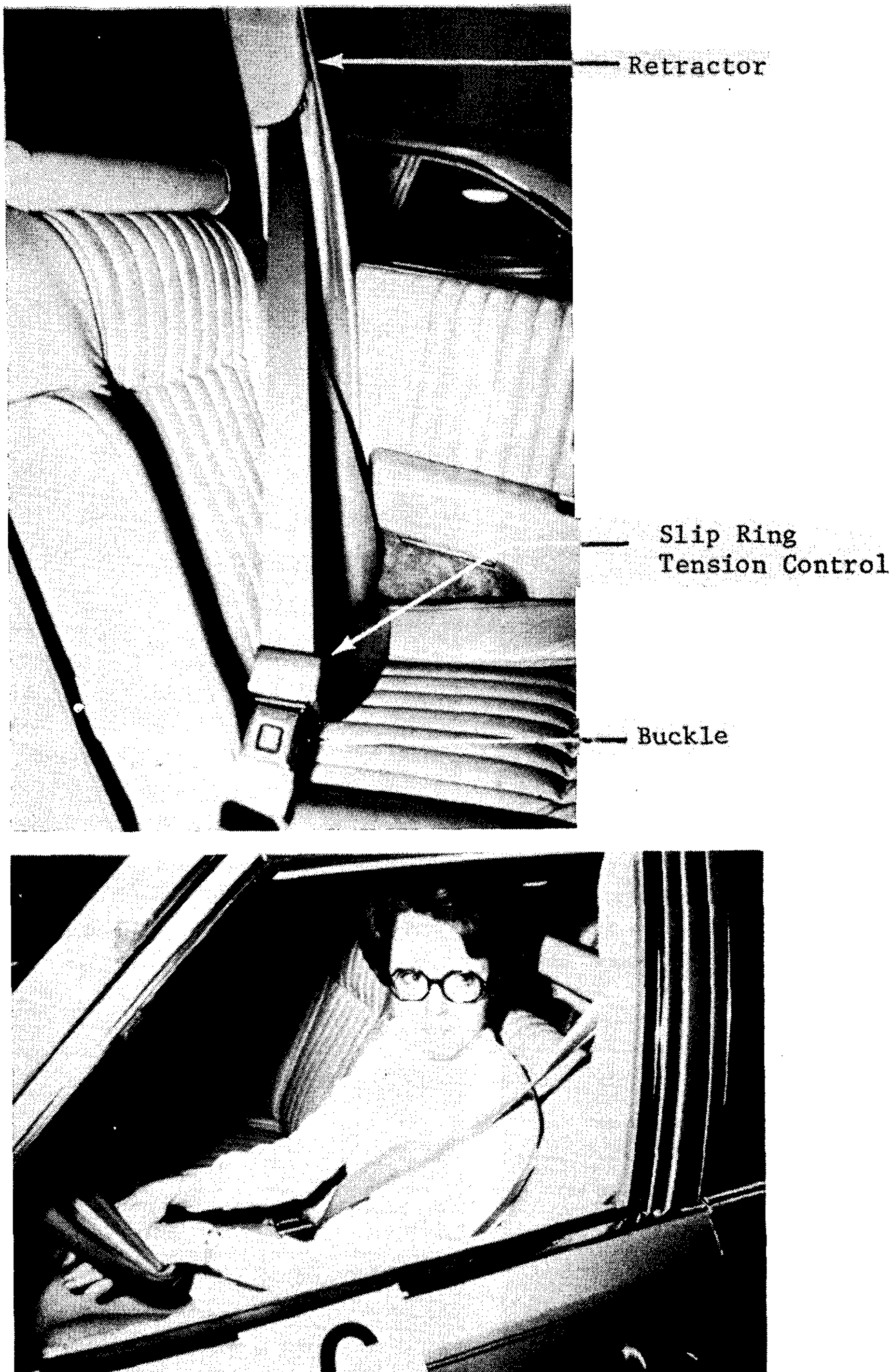


FIGURE 3 Car No. C - Active Restraint in Cadillac Seville

retraction was effected by releasing a physical contact in the door jam. Although not easily observed from external appearances, the belt tension was found to have a significant effect on comfort and convenience ratings by the subjects. The car No. C was observed to have a higher spring tension when using the "window shade" effect, as compared to Car No. A.

Car No. D was an AMC Hornet with a fully passive restraint system. This system had no lap belt. Lower limb movement was restrained by two energy absorbing knee bumpers placed a few inches in front of the legs of the driver and passenger. Figure 4 displays the belt system which automatically positioned the shoulder belt in approximately a normal driving position. The shoulder belt take-up reel was again located in the front door panel. This car had an emergency locking shoulder belt system, and the "window shade" adjusting feature was set to a light tension.

Car No. E was an AMC Hornet with a semi-passive restraint system. This system required only the removal of a ring holding the webbing on the door in order to have the take-up reel pull the lap and shoulder belt system into an approximately normal position. The take-up reel was located in a center console. A slip-ring allowed automatic adjustment of the belt loop between the lap and shoulder portions of the webbing. This system incorporated emergency car sensitive locking for the entire webbing. This restraint system is shown in Figure 5.

The basic test protocol consisted of an indoctrination discussion, a multi-trial questionnaire with periodic comparisons between two restraint systems, and finally, an overall ranking of the seat belt systems by the subject. It was difficult to determine how much, if any, training or trial usage should be given to the subject. All subjects were somewhat familiar (not necessarily frequent users) with lap and shoulder restraints, so no practice maneuvers were considered necessary for the test plan. The subject was first asked to

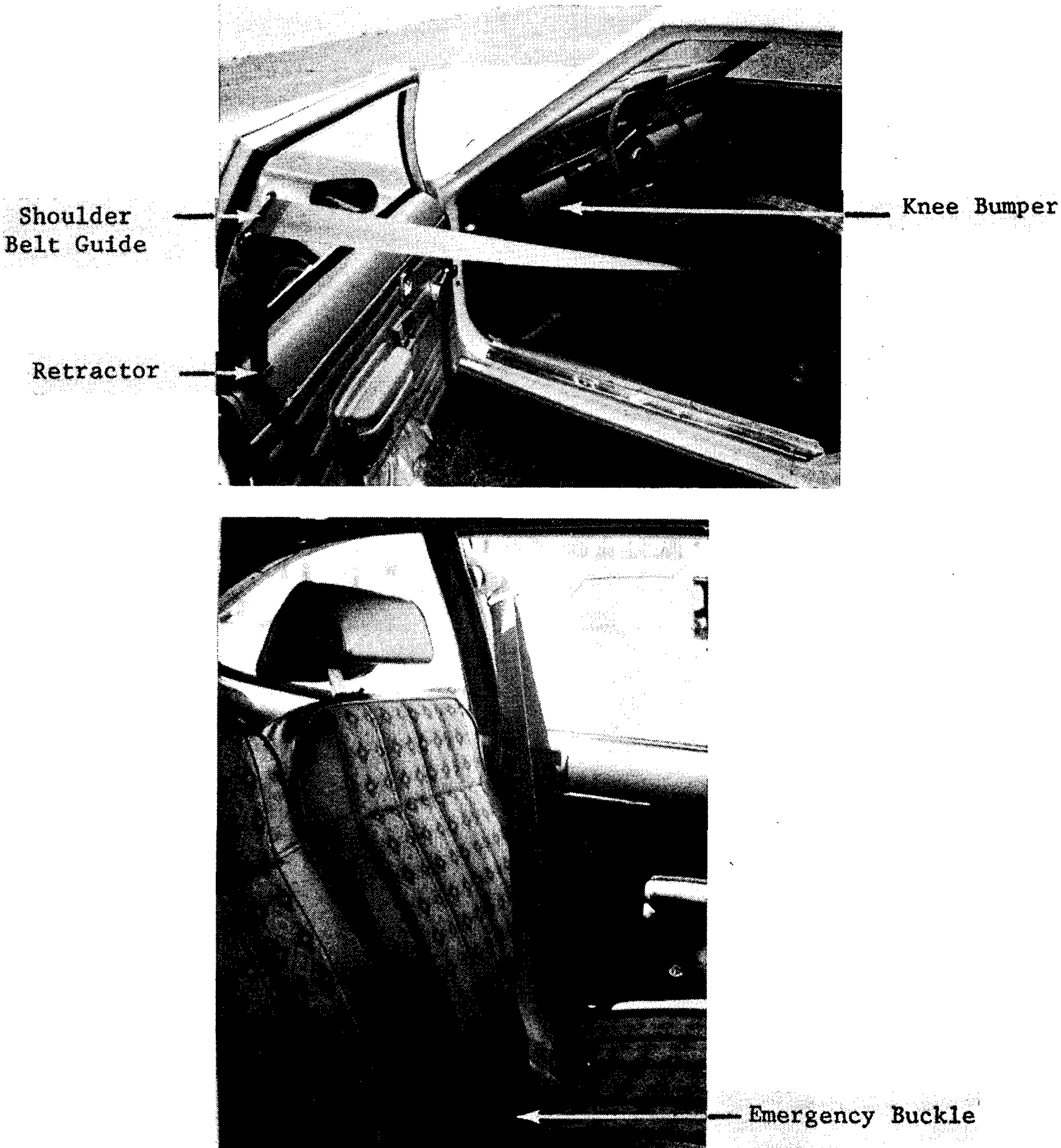


FIGURE 4 Car No. D - Fully Passive Restraint in AMC Hornet

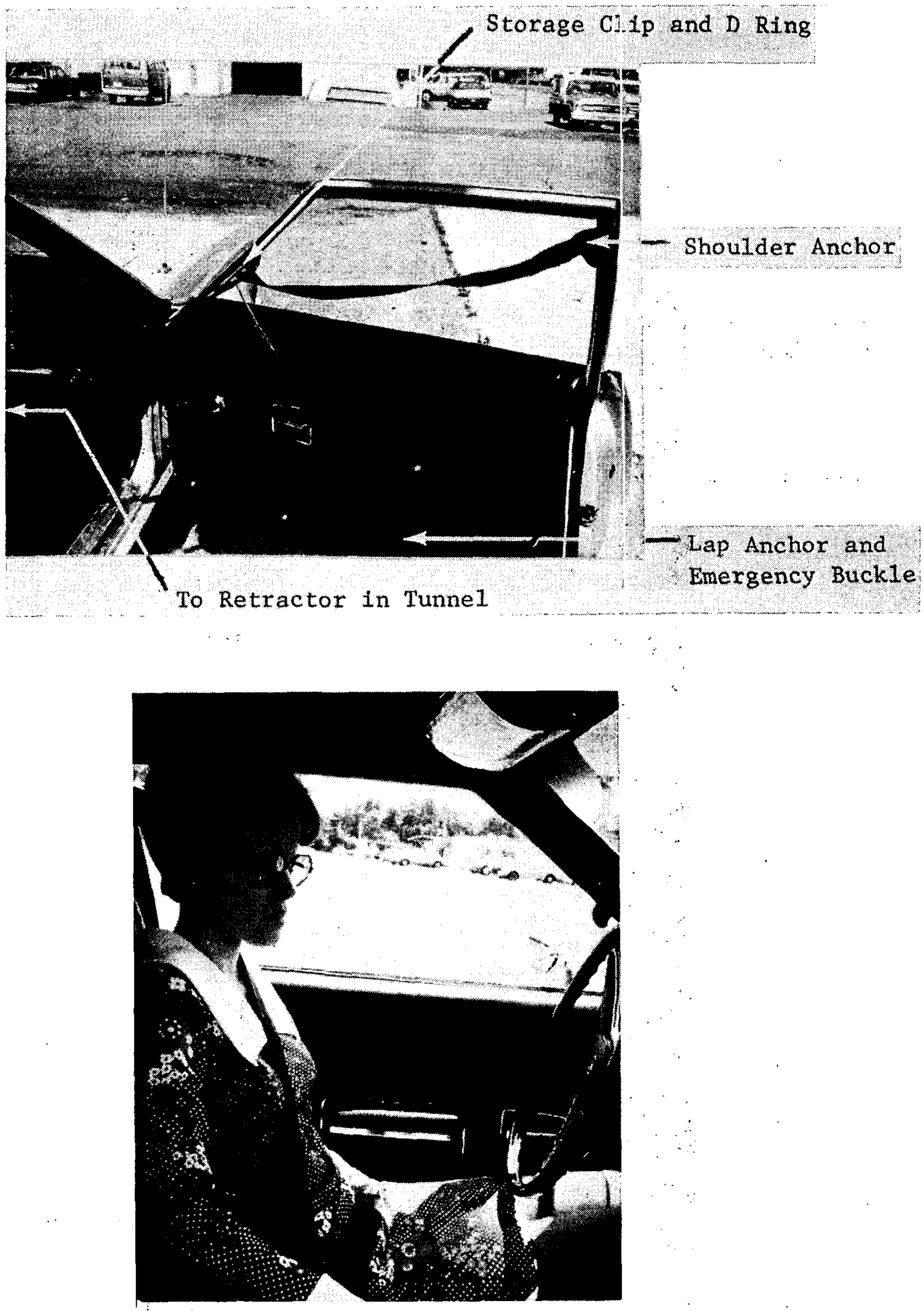


FIGURE 5 Car No. E - Semipassive Restraint in AMC Hornet

read an information sheet (shown in Appendix A) which explained the basic purpose of the research. Then the questioner read a detailed description (see Appendix A) and answered any questions. A card explaining the zero (0) to three (3) response scale was placed on the dashboard of each car as a ready reminder for the subjects in answering the questions.

The questionnaire (see Appendix A) was based entirely on that utilized by Man Factors, Inc. (DOT HS-801 277). Several parenthetical statements indicate comments which were made to the subjects prior to asking the questions. It should be noted that certain questions are applicable only to active restraint systems, while others are applicable only to passive restraint systems. While correspondingly numbered questions cover similar aspects of belt usage, a direct numerical comparison between active and passive systems where different questions were asked may not be proper. Therefore, in later analysis, for these questions, active and passive have been treated separately.

Two aspects of the new types of restraint system, presented some difficulties which were not precisely covered in the questionnaires. The "window shade" effect often required readjustment after inside the car maneuvers, and the subjects were unsure if this condition was a part of the test or if adjustment was permitted. On these occasions, the subject was assured that we were looking for his subjective evaluation of comfort and convenience features, and that he should readjust as he would under normal driving conditions. The second problem area concerned utilization of the door operated retraction of the seat belt system. The questionnaire provided for removal of the seat belt system and exiting from the car as separate stages. Therefore, the tendency for one to want to store the belt system utilizing the "window shade" retractor spring was one extra source of difficulty and confusion.

One major modification was made to the test protocol that was used by Man Factors, Inc. Question Set #5, the Emergency Exit, was only performed after the subject had entered a given car for the last time. The only deviation from the rest of the test procedures, was in the case of a pregnant female subject and two other females who had great difficulty in adjusting the seats. The seat position was set to a comfortable position the first time in the car and no further seat adjustments with the belt systems were required of them.

One basic objective of comparing the cars one to the other required that each car be compared with all of the others. This meant that for five test cars, each subject must compare it with four others. The resulting total indicated that there were 10 pair comparisons to be made, and the subject answered all questions 20 times. Figure 6 shows the ordering of the pairs for each of the 10 subjects. In general, this procedure randomized the order of entry into the cars and the order of the comparisons. Upon completion of the entire series of questions and pair comparisons, each subject was requested to rank from best to worst the seat belt systems as far as comfort and convenience was concerned.

These 10 subjects represented somewhat of a cross section of anatomical sizes for both male and female subjects. The only missing subject size was that of a very tall female. A physical description of the standing height and approximate weight were obtained by requesting this information from the subjects, and an erect seated height was obtained by anthropometric measurement. These data are given in Figure 7.

TEST SCHEDULE

Subject	Pair Ordering									
1	AB	CD	EA	BC	DE	CA	DB	EC	AD	BE
2	EB	DA	CE	BD	AC	ED	CB	AE	DC	BA
3	BC	DE	AB	CD	EA	DB	EC	AD	BE	CA
4	AC	EB	DA	CE	BD	AE	DC	BA	ED	CB
5	CD	EA	BC	DE	AB	EC	AD	BE	CA	DB
6	DB	AC	EB	DA	CE	AB	DE	CB	AE	DC
7	DE	AB	CD	EA	BC	AD	BE	CA	DB	ED
8	CE	BD	AC	EB	DA	CB	AE	DC	BA	ED
9	EA	BC	DE	AB	CD	BE	CA	DB	ED	AD
10	DA	CE	BD	AC	EB	DC	BA	ED	CB	AE

FIGURE 6 Test Schedule for Ordering of Subject Comparison of Restraint Systems

TEST SUBJECTS

I.D.#	Sex	Erect Seated Height (in.)	Standing Height (in.)	Weight (lbs.)
1	Female	32.5	61	109
2	Female	33.9	63	145
3	Female	34.3	67	123
4	Female	33.9	65.5	155*
5	Female	32.3	65	114
6	Male	38.9	75	195
7	Male	36.9	70	228
8	Male	34.6	65	125
9	Male	34.9	70	165
10	Male	36.9	73.5	225

*7 months pregnant

FIGURE 7 List of Subject Anthropometric Data

III. ANALYSIS METHODS

This study is designed to provide a statistically sound comparison, based on comfort and convenience factors, among the several protective systems of interest and also to highlight significant problem areas. The method was first used under contract DOT HS-801277 to compare another group of systems. It was chosen for the present study to permit some degree of cross comparison, and because it is a generally sound approach.

However, the contractor's report left many gaps in the description of the analysis, and considerable effort was expended in filling in the voids. Therefore, so there will be no doubt about the analytical procedures, the following description is more detailed than might otherwise be necessary.

The data gathering procedure, as described in the previous section, permits three different evaluations of the systems based on different data. First, the questionnaire provides a detailed statistical description of each system and a means for discriminating between them based on various comfort and convenience aspects. Second, the pair-by-pair comparison provides a fairly sensitive overall preference ranking. The final overall ranking comes from the simultaneous five system ranking evaluation and reflects the summary preferences of the subjects after they had evaluated each system individually a number of times. The analytical basis and processed statistics for each of these comparisons are covered in the following paragraphs.

The basic experimental design was a three way factorial design with replications. The appropriate datum point model is

$$X_{ijku} = m_o + c_i + q_j + s_k + (cq)_{ij} + (cs)_{ik} + (qs)_{jk} + (cqs)_{ijk} + r_{ijku}$$

where the symbols have the following definitions:

- X_{ijku} - measurement for cars i, subjects j, questions k, trials u
- m_o - overall mean
- c_i - "cars effect"
- q_j - "question effect"
- s_k - "subject effect"
- $(cq)_{ij}$, $(cs)_{ik}$, $(qs)_{jk}$, $(cqs)_{ijk}$ - interaction effects
- r_{ijku} - random effect in each cell

In the analysis of the factorial design, the cars and questions were treated as fixed factors (i.e. as the total population of these factors and not as a sample from a larger population). The subjects, however, were treated as a random variable. It is true that the subjects were selected more to represent extreme characteristics than to be a random sample, but it was felt that this factor was more properly treated as random (though possibly biased). The repeated evaluations of the pair-to-pair comparisons provided the replications within each cell and a measure of the sampling error.

Based on the above model, the analysis of variance is given in Figure 8. Note that for our data i, j, K and u have dimensions 5, 25, 10, and 4 respectively. The theoretical variance which each mean sum of squares estimates and the critical F value at a 1/2% confidence level have been included to clarify the analysis.

Figure 8 shows that there are significant differences among the seat belt systems (the cars effect), and further, that these differences are not consistent over all questions (the cars and questions interaction effect). In order to identify the specific system and question differences, the system by question means were computed and analyzed further. (These means are given in Figure 9 of the next section.)

Tukey's Highest Significant Difference method of comparing a group of means was used in this next analysis phase. Of the several approaches proposed by various authors, this is the most conservative[1]. That is, it detects a significant difference least often.

The method assumes a group of samples drawn from populations having the same standard deviation and then tests for significant differences among their means. If the samples come from the same population (i.e., no significant difference exists) the differences in the means will be

[1] Wine, R. Towell, "Statistics for Scientists and Engineers"

ANALYSIS OF VARIANCE SUMMARY

Sum of Squares Source	Variance Estimated by Mean Sq.	Degree of Freedom	Mean Square	F	F.005
Subjects (S)	$\sigma^2 + cqn\,\sigma_S^2$	9	15.99		
Cars (C)	$\sigma^2 + qn\,\sigma_{CS}^2 + \frac{qsn}{(c-1)} \sum (c_i)^2$	4	8.974	5.42	4.47
CXS	$\sigma^2 + qn\,\sigma_{cs}^2$	36	1.655		
Questions (Q)	$\sigma^2 + cn\,\sigma_{QS}^2 + \frac{csn}{(q-1)} \sum (q_j)^2$	24	9.087	3.00	2.00
QXS	$\sigma^2 + cn\,\sigma_{QS}^2$	216	3.031		
CXQ	$\sigma^2 + n\,\sigma_{CQS}^2 + \frac{sn}{(c-1)(q-1)} \sum\sum ((cq)_{ij})^2$	96	2.322	4.80	1.40
CXQXS	$\sigma^2 + n\,\sigma_{CQS}^2$	864	.484		
Error	σ^2	3750	.2597		

FIGURE 8

MEAN SCORES FOR EACH QUESTION

--- SET NO.1 ---

Question	1	2	3	4	5	6
System A	.225	.350	1.300	.100	.575	.500
B	.150	.075	.125	.025	.025	.550
C	.275	.500	1.175	0	.400	.450
D	.275	.350	-	.325	.550	.700
E	.125	.200	.050	.325	.075	.700

--- SET NO. 2 ---

Question	1	2	3	4	5	6	7	8	9	10	11
System A	1.050	.500	.225	.325	1.600	.650	.625	.525	.425	.325	.200
B	.725	.175	.575	.075	.375	.900	.025	.475	.075	.225	.150
C	1.375	.650	.375	.200	.725	.675	.275	.350	.325	.375	.225
D	.325	.175	.225	.250	.950	.525	.225	.450	.150	.100	-
E	.400	.450	.375	.100	.500	1.075	.125	.650	.175	.425	.200

	--- SET NO. 3 ---				--- SET NO. 4 ---		--- SET NO. 5 ---	
Question	1	2	3	4	1	2	1	2
System A	.025	.150	.325	.900	.075	.100	.900	.800
B	.075	.125	.075	.150	.025	.025	.600	.700
C	.050	.075	.375	.850	.025	0	1.000	.600
D	.325	.175	.500	-	.600	.150	.500	1.700
E	.350	.075	.025	-	.100	0	.300	2.700

LEGEND: A - Active Hornet
B - Standard Impala
C - Active Seville
D - Passive Hornet
E - Semipassive Hornet

FIGURE 9

distributed according to a known distribution. The given differences are compared against the maximum expected from this distribution.

These Studentized Range values are available in standardized tabular form in most statistical texts. They are functions of confidence level, number of means being compared, and number of degrees of freedom of the standard deviation.

The standard deviation is usually available as an estimate from an analysis of variance of the data. The criterion or test range is then the product of the standard deviation and the Studentized Range value.

For our data, Figure 8 shows that for the overall system means, the variance of the means (from the "cars" line) is

$$\text{variance} = \frac{1}{(c-1)} \sum (c_i)^2 + \frac{1}{s} \sigma_{cs}^2 + \frac{1}{qsn} \sigma^2$$

since we are testing for significance of the first term, the sum of the last two terms make up the square of the standard deviation needed for the range test. The estimate of this quantity can be obtained directly by dividing the mean square for (C x S) by the product of the q, s, and dimensions.

$$\sigma_{TEST} = \sqrt{\frac{1.655}{(25)(10)(4)}} = .04068$$

with 36 degrees of freedom. Then multiplying this standard deviation by the Studentized Range for five means and 36 degrees of freedom, to obtain the test range, we have

Test Range = .04068 x St. Range (5, 36),

giving

Test Range, 1% level = .04068 x 4.98 = .203

Test Range, 5% level = .04068 x 4.06 = .165

These ranges will be used for interpretation in the next section.

In a similar way, the (C x Q x S) mean square is used to find the standard deviation for individual questions as follows:

$$\sigma_{TEST} = \sqrt{\frac{.4840}{(10)(4)}} = .110$$

with 864 degrees of freedom.

In treating the individual questions we will need ranges for groups of means having two, three, and five members because of the distinction between active and passive questions.

Then at the 1% level,

Test Range (2, 864) = .110 x 3.64 = .400

Test Range (3, 864) = .110 x 4.12 = .453

Test Range (5, 864) = .110 x 4.60 = .506

and at the 5% level,

Test Range (2, 864) - .110 x 2.77 = .305

Test Range (3, 864) = .110 x 3.31 = .364

Test Range (5, 864) = .110 x 3.86 = .425

The use of the same standard deviation to compare all questions is an approximation based on the distributions of all questions having the same variance. While this is not strictly true, computing separate ranges for each question produced only minor variations in interpretations and did not warrant the additional complexity.

The pair-by-pair preference data were processed by simply counting the number of times each system was preffered over another system. The five systems were then ranked from best to worst by highest to lowest score.

The five system preference ranking data were used to compute "mean positions". That is, a value of 1 to 5 was assigned to each system for each subject corresponding to its position in the ranking, and then an average of these values was computed.

IV. RESULTS

Before proceeding with a detailed discussion of results, some general observations should be made to place these data in perspective and orient them with the earlier Man Factors study. First, both studies are based on posing a problem and then determining its degree; and so, the natural emphasis is on the bad points of the systems with little opportunity to bring out the good points. The reader should remember this test structure and should not prematurely conclude that he is faced with a group of bad systems, some of which are just worse than others.

Second, unlike the Man Factors study, no system in this study was chosen as possibly representing an undesirable design. Each system is considered by someone to be superior to at least the less desirable ones of the Man Factors group. The smaller spread of the present results is compatible with this situation.

Third, the standard three-point Impala (B) of this study was selected to be essentially identical to one of the better systems of the Man Factors study. It received a better (lower) score in this study. Whether this is due to the difference in the subject sample or to its different relative position in the results of the two studies is not clear. While a quantitative multiplier cannot be justified, it may be appropriate to mentally calibrate the current scores upward somewhat in comparing the two studies.

A. Comparison by Characteristics

Much of the succeeding discussion is based on applying the analytical procedures of the preceding section to the mean scores of Figure 9. In addition, we will also consider any mean score of 1.0 or greater to represent a problem. This is at the "minor problem" level, but for a question to have a mean value at or above this threshold, most subjects must have considered it a problem of some degree.

Figure 10 combines the problem identification and the results of applying Tukey's H.S.D. technique in an easily interpretable form. For each question, the systems are in order from left to right according to increasing mean score. Where active and passive had different questions, the two subgroups are displayed on successive lines while maintaining relative left to right order. Any system with a problem (score of 1.0 or more) is enclosed in parentheses. Any systems whose mean values are not significantly different at the 1% confidence level (differ by less than .506) are underlined by the same line. If a comparison at the .5% confidence level is desired, the appropriate test ranges from page 17 may be applied to the data of Figure 9, but only minor changes will result. To illustrate the mechanics of interpreting Figure 10, it may be well to consider a few examples. Thus, for question 1-1, no system is significantly different from the others. For question 1-3, systems A and C have problems, B is better than C or A, C is not different from A, and the question didn't apply to D. For question 2-7, B is better than A, but no other pairs are different.

The first question set dealt with entering the car and donning the protective system.. Entering the passive and semipassive systems (D and E) seemed easy for this group of subjects, though individuals with poorer coordination might have more difficulty. One or two subjects remarked on the maze of webbing in E, and one female subject felt that she would need to use here forearm to guide the belt in D and that this might be a little inconvenient with something in her hand. Another asked, "Where would I put the groceries?" Figure 11 shows normal entry into the semipassive system.

Though it appeared to the tester that retrieving the latch plate was producing some unusual contortions in A and C (active Hornet and Seville), no subject remarked on this and questions 1-1 and 1-2 showed no statistically significant difference from the other systems. In fact, system D (passive Hornet) had as high a score as A and C, probably because of the minor confusion of finding no latch plate at all. See Figure 12.

The subjects didn't appear to differentiate between the actions of extending the webbing and securing the buckle. Therefore, questions

1-3 and 1-5 should be considered together. It appeared that 1-5 was given relatively better scores because the subjects felt they had already complained on questions 1-3. In any event, the active Hornet and Seville (A and C) had a definite problem associated with positioning and buckling the latch plate and were significantly worse than the other systems. As illustrated in Figures 13 and 14, the subjects almost invariably used two hands in the process. They also had to readjust the latch plate each time they entered the car, since retraction changed the setting.

The standard Impala (B) may have had a slight advantage in this section because it was roomier and was a more familiar system, but one male did catch the latch plate in his pants pocket.

Systems For Which Differences Between Mean Scores
For Each Question Were or Were Not Significant*

SET NO. 1 (Asked after subject donned belt system)

(A) = Active System (P) = Passive System

1.	(A) Locating latchplate (P) Confusion on getting past belt on entry	B A C E D
2.	(A) Retrieving latchplate (P) Interference with entry	B A C E D
3.	(A) Extending webbing (P) Unhooking webbing	B (C)(A) E
4.	(A) Finding buckle (P) Harness dragging across chest	C B A D E
5.	(A) Securing buckle (P) Harness missing shoulder	B C A E D
6.	(A) (P) Straightening webbing	C A B D E

*System-identifying letters that are joined by underlining have mean scores that do not differ significantly; those not joined do differ significantly. Letters A through E enclosed in parenthsis indicate system on which a problem has been noted. Letters arranged best (lowest) on left to worst (highest) on right. Two lines are used where active and passive questions differ.

LEGEND: A - Active Hornet
B - Standard Impala
C - Active Seville
D - Passive Hornet
E - Semipassive Hornet

FIGURE 10

SET NO. 2 (Asked after subject has adjusted seat, reached for controls, and turned to look rearward)

For both Active and Passive Systems

1.	Interference with seat adjustment	D E B (A) (C)
2.	Interference with reach	B D E A C
3.	Obstruction of left rear view	A D C E B
4.	Limitation in turning for rear window view	B E C D A
5.	Failure of webbing to fit snugly	B E C D (A)
6.	Webbing touching neck or face	D A C B (E)
7.	Webbing falling off shoulder	B E D C A
8.	Harness crossing inboard chest (breast)	C D B A E
9.	Webbing exerting pressure on shoulder	B D E C A
10.	Webbing chafing across shoulder	D B A C E
11.	Lap belt riding up on stomach	B A E C

FIGURE 10 Con't

SET NO. 3 (Asked after subject doffed belt system)

1.	(A) Locating buckle	A C B
	(P) Doffing belt system	D E
2.	(A) Operating buckle release	C B A
	(P) Stowing (hooking) belt system	E D
3.	(A) Webbing hanging up on clothes, etc.	B C A
		E D
	(P) Webbing dragging across clothes, etc.	B C A
4.	(A) (P) Retraction and stowage complete	

SET NO. 4 (Asked after subject had exited from vehicle)

1.	(A) (P) Interference with exit	B C A E D
2.	(A) Belt system clearance of door	C B A
	(P) Hold door against belt tension	E D

SET NO. 5 (Asked after subject completed emergency exit from adjacent door and toward opposite door)

For both Active and Passive Systems

1.	Emergency exit from driver's door	E D B A (C)
2.	Emergency exit from opposite door	C B A (D) (E)

FIGURE 10 Con't

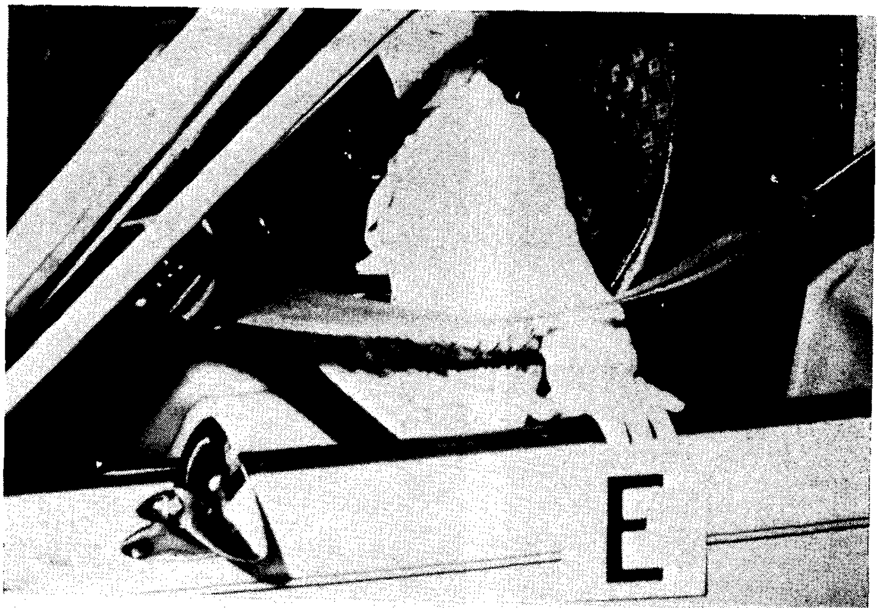


FIGURE 11 Normal Entry - Semipassive Hornet

FIGURE 12 Retrieving Latch Plate - Active Hornet

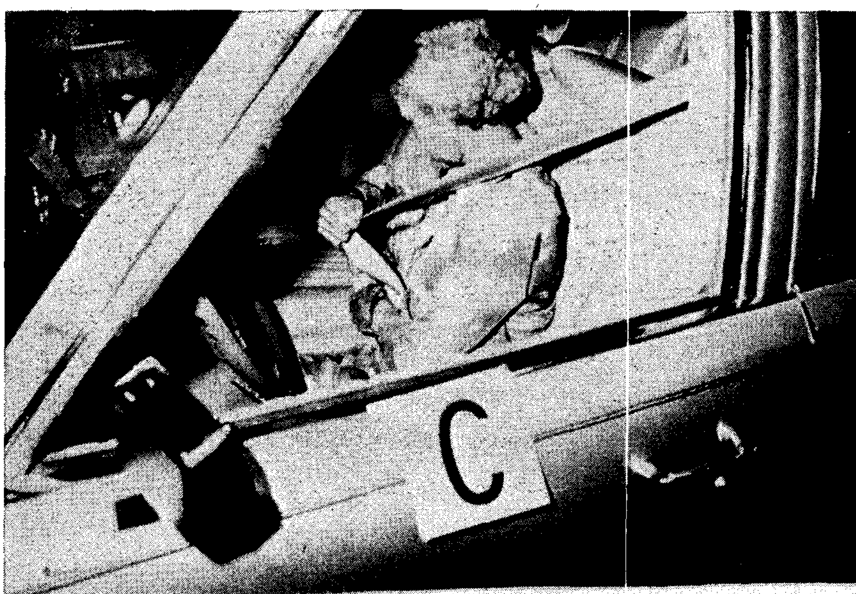


FIGURE 13 Positioning the Latch Plate - Active Seville

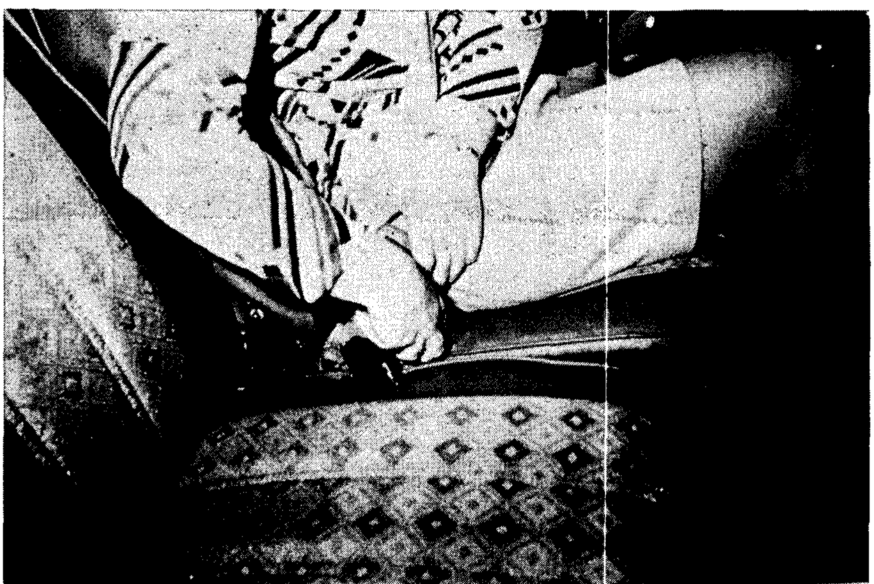


FIGURE 14 Positioning and Buckling the Latch Plate - Active Hornet

The second set of questions covered factors encountered while wearing the belt system. Mobility questions (2-1 through 2-4) showed significance only in seat adjustment where the active Hornet and Seville (A and C) were both significantly worse than the passive and semipassive (D and E), and both A and C had a problem. This result may not be entirely realistic because the test procedure required the belt to be fastened and then the seat to be moved. In the normal situation, the seat may already be in position or it would be adjusted before fastening the belt.

From the subjects' comments, the active Seville (C) slightly restricted reaching due to the heavier tension (Figure 15). The tester's observation showed the possibility of some minor problems in some systems such as obstruction of view to the left rear (Figure 16), chafing, and some physical limitation when looking right rear (Figure 17), and the belt falling off the shoulder in maneuvers in systems with the "window shade" (A, C, D). These points were not necessarily identified as important in either the statistics or the subjects' comments.

Those questions dealing with the fit of the shoulder belt (snugness, 2-5; falling off the shoulder, 2-7; pressure, 2-9) gave system A the worst score with a definite snugness problem. Systems C and D were next best ranking belts. All three of these systems have the "window shade" feature, but with somewhat different characteristics.

The features most pertinent to the subjects' responses to questions concerning fit appeared to have been the retractor tension and the balkiness of the "window shade" action. The active Hornet (A) had a moderate tension but the balkiest retractor, sometimes requiring a number of attempts to release the catch. The active Seville (C) had the most reliable retractor but the heaviest tension. The passive Hornet (D) had a moderately reliable retractor with the loosest tension.

Figures 18 and 20 show some of the situations encountered which probably relate to the "window shade". This feature is potentially quite sensitive from an acceptance standpoint, since it is not an externally obvious feature and is the only feature requiring periodical attention to readjust. During the test there was continual doubt as to the desirability and propriety of readjustment, even though great care was taken to explain the operating principles and philosophy. It

FIGURE 15 Reaching - Active Seville

FIGURE 16 Looking Left Rear - Passive Hornet

FIGURE 17 Looking Right Rear - Standard Impala

FIGURE 18 Belt Off Shoulder Looking to Rear - Passive Hornet

FIGURE 19 Loose Shoulder Belt - Passive Hornet

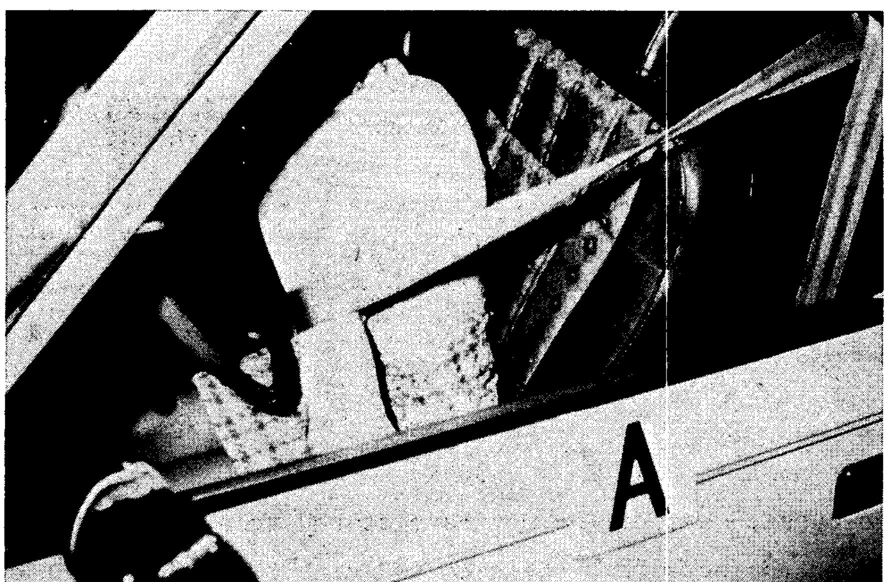


FIGURE 20 Belt Off Shoulder Looking to Rear - Active Hornet

seems reasonable to conclude that the feature will be a controversial one having its strong proponents and equally strong detractors. A smoothly functioning retractor appears a prime requirement for favorable acceptance.

In the questions concerning chafing or poor positioning (questions 2-6, 2-8, and 2-10), the semipassive Hornet (E) scored worst, having a real problem on question 6. The female subjects were more sensitive to this type of discomfort than the males were. At least one girl pointed out that collarless summer blouses and dresses provided especially bad chafing situations (Figure 21).

Question set three, dealing with normal storage and exit disclosed no particular problems. Question 3-1 showed the passive and semipassive hornets (D and E) with the worst scores in initiating the exit maneuver, probably reflecting some unfamiliarity with the passive and semipassive systems, as opposed to the more standard release requirements of the active systems. System E scored significantly better than D on questions 3-3 and 1-3, reflecting better fit and less interference. From this it would appear that the subjects differentiated chafing from fit and interference.

The active Seville and Hornet (C and A) are significantly worse than the standard Impala (B) on completeness of storage. This is related to the "window shade" feature and the fact that the test procedure required storage as a separate operation before opening the door and exiting. At any rate, the fact that the retractor did not operate created a variety of loose belt conditions including the belt catching on the armrest and under the seat. (The latter required some external assistance to free the occupant.) Some of these conditions are illustrated by Figures 22 and 24.

The passive system (D) may have scored relatively high in this set because the subjects felt the need to guide the belt with the right hand on exiting (Figure 25). One remarked that this could be inconvenient if one hand were needed for a purse or packages. This point is given greater weight by question 4-1 where system D is significantly worse than all three of the active systems on interference with exit.

In question set five, emergency exit from the left showed all of the active systems scoring worse than the passive or semipassive with

FIGURE 21 Chafing - Semipassive Hornet

FIGURE 22 Hand Assistance Required on Storage - Active Seville

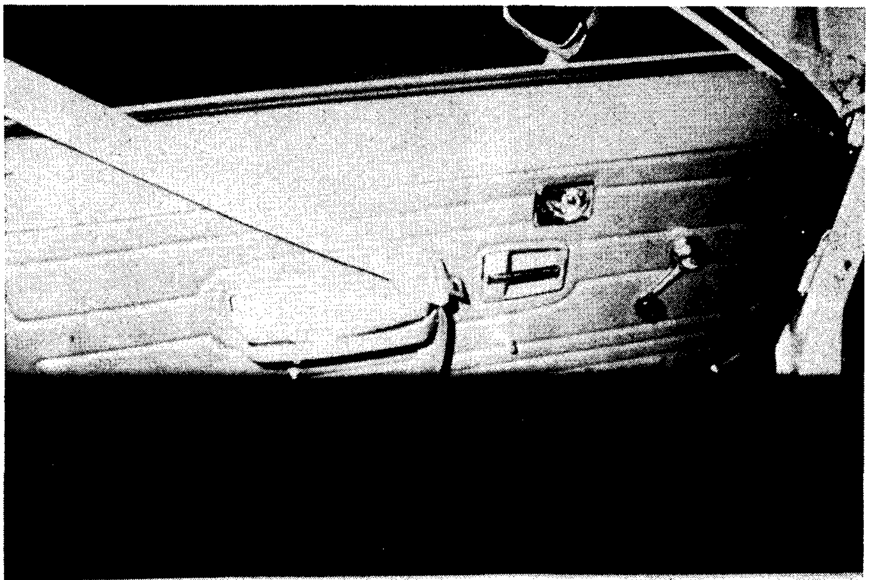


FIGURE 23 Belt Caught on Arm Rest - Active Hornet

FIGURE 24 Belt Caught Under Seat - Active Hornet

FIGURE 25 Hand Guiding Passive Belt - Passive Hornet

FIGURE 26 Right Side Emergency Exit - Semipassive Hornet

C just achieving problem status (possibly due to an unfamiliar door release design). However, systems D and E showed definite problems in a right side emergency exit. The scores for D and E were also each significantly different from all the rest. Figures 26 through 28 show some selected emergency exit situations.

The drivers side exit maneuver was timed and the average exit times are shown below.

System	A	B	C	D	E
Time to exit in seconds	5.3	5.5	5.7	3.8	5.1

As could be expected, the passive ans semipassive systems (D and E) required less time than the active systems because no unbuckling was required. System E should actually be closer to D (about 4.5 seconds), but one subject became confused and nearly 10 seconds were lost, looking for a buckle to release.

B. Overall Systems Comparison

The overall mean scores over all questions and all subjects are given in bar chart form in Figure 29. The systems have been ordered with the most desirable system at the left. The significance information has been obtained from these values by applying the test ranges computed in the analysis section. The significant range information indicates that at the 1% confidence level, the standard Impala (B) is better than the active Hornet (A), but no other pairs are significantly different. At the 5% confidence level, the Impala is better than the active Seville and Hornet (C and A), and the semipassive Hornet (E) is better than the active Hornet (A).

The overall ranking by the pair-to-pair comparison is shown in Figure 30 where the values are the number of times a system was preferred over its partner. The final ranking from the five system ordering data is given in Figure 31. Both figures are arranged with the most desirable system at the left.

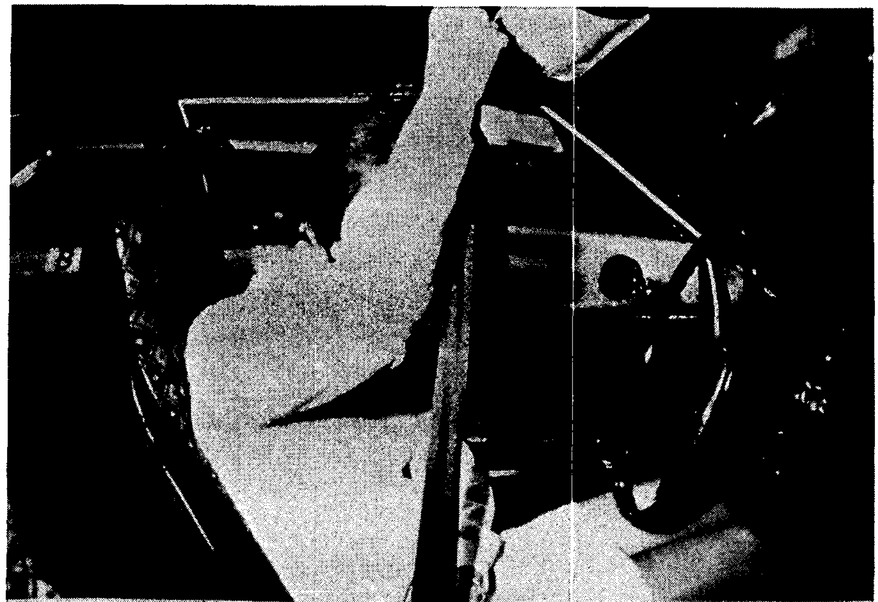
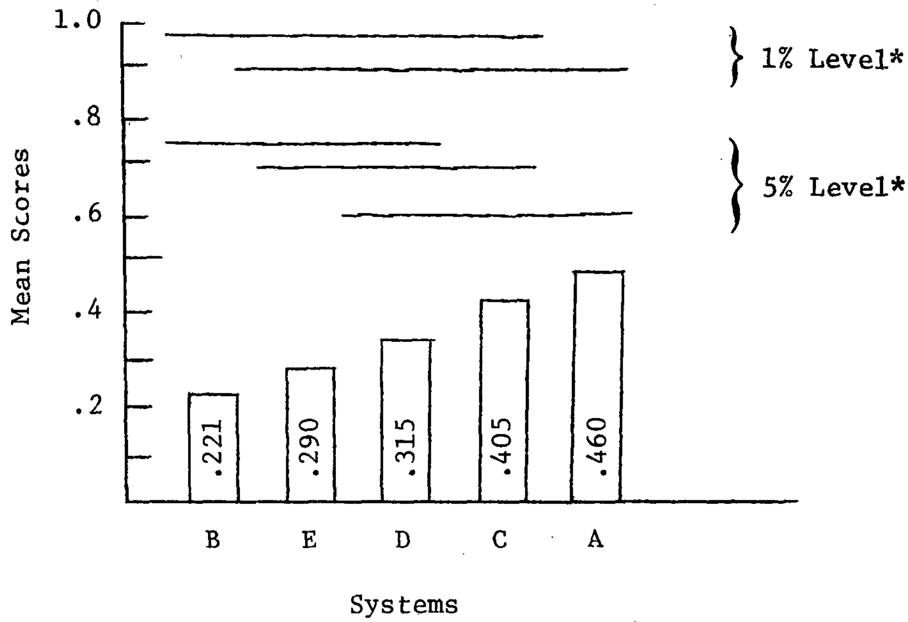


FIGURE 27 Right Side Emergency Exit - Semipassive Hornet

FIGURE 28 Left Side Emergency Exit - Passive Hornet

Overall Mean Scores For All Questions and All Subjects For Each System



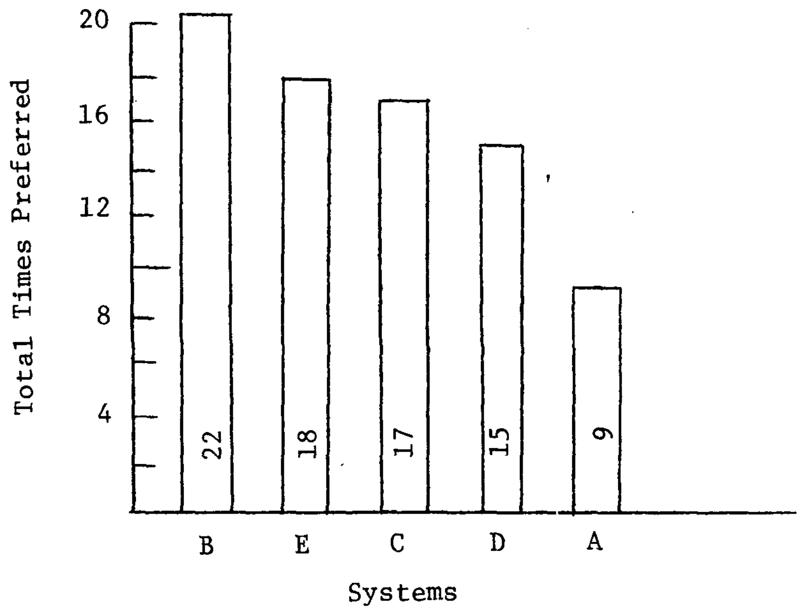
*Systems spanned by same line not significantly different.

Most desirable systems at left.

LEGEND: A - Active Hornet
B - Standard Impala
C - Active Seville
D - Passive Hornet
E - Semipassive Hornet

FIGURE 29

Total Number of Times Each System Was Preferred in Pair Comparison Tests

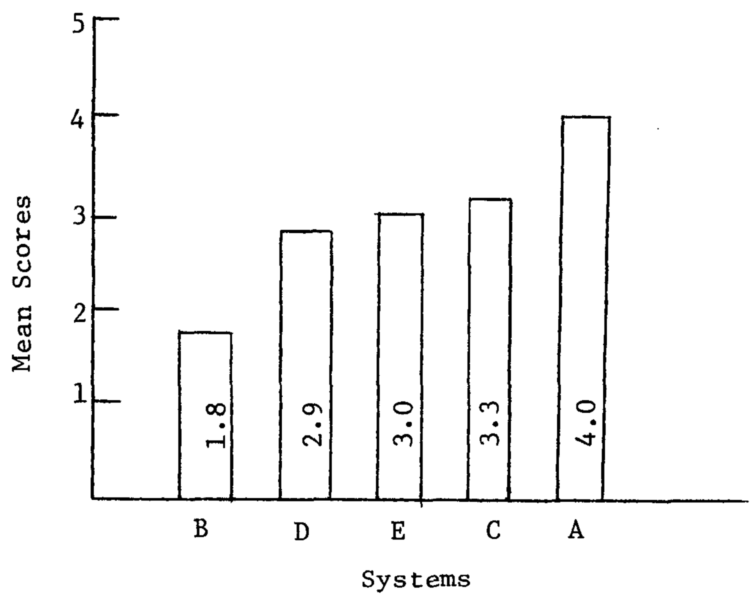


Most desirable system at left.

LEGEND: A - Active Hornet
B - Standard Impala
C - Active Seville
D - Passive Hornet
E - Semipassive Hornet

FIGURE 30

Means of Subject-Ascribed Ranks for Each of the Five Seat-Belt Systems



Most desirable system at left.

<u>LEGEND</u>: A - Active Hornet
B - Standard Impala
C - Active Seville
D - Passive Hornet
E - Semipassive Hornet

FIGURE 31

All three rankings agree that the standard Impala is the most preferred, and the active Hornet is the least preferred with the others closely grouped in between. The fact that the middle three are in different order in the three rankings is consistent with significant range test which could not distinguish them either.

It is worthwhile noting that one of the female subjects was 7 months pregnant. She experienced no problems of greater severity than did the other subjects. However, the shoulder belts rode above her left shoulder (didn't touch the shoulder) in all systems, and she remarked that system D was uncomfortable on her right breast. Figures 32 and 33 show views of this subject.

Figures 34 through 38 are included as representative "normal" situations showing a number of different subjects in various cars.

Since the design of the experiment required each system to be evaluated a number of times, there is the possibility that a learning effect exists in the data. To check this, the system averages for question sets 1 through 4 were computed separately for each successive trial as shown in Figure 39. System B, the most familiar system, showed essentially no learning effect. The other systems showed a trend toward decreasing score as more experience was gained, but without essentially altering the comparative results.

FIGURE 32 Pregnant Subject - Semipassive Hornet

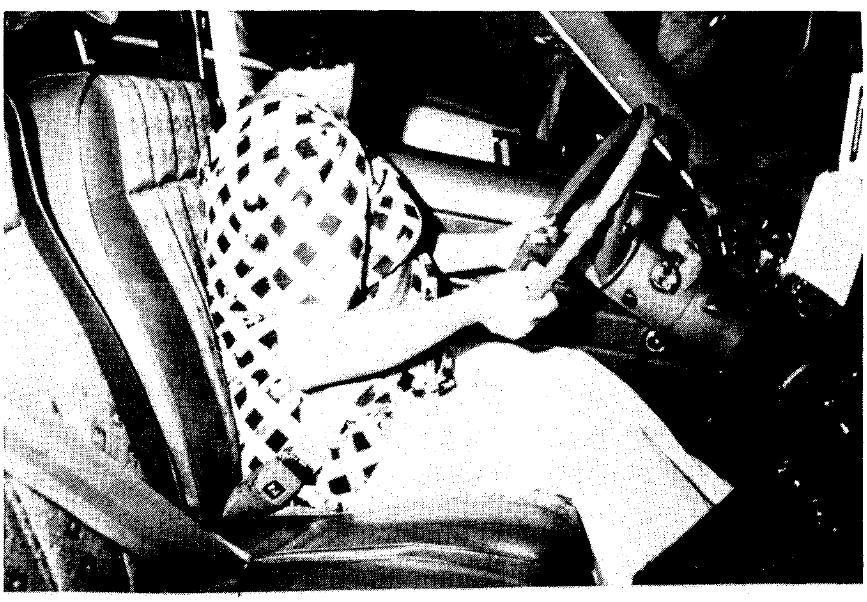


FIGURE 33 Pregnant Subject - Passive Hornet

FIGURE 34 Normal - Active Hornet

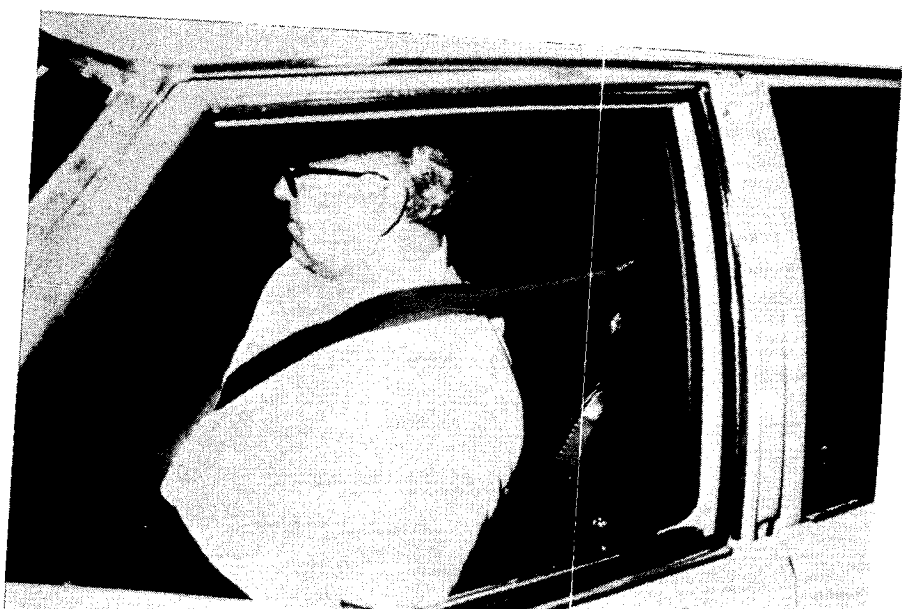


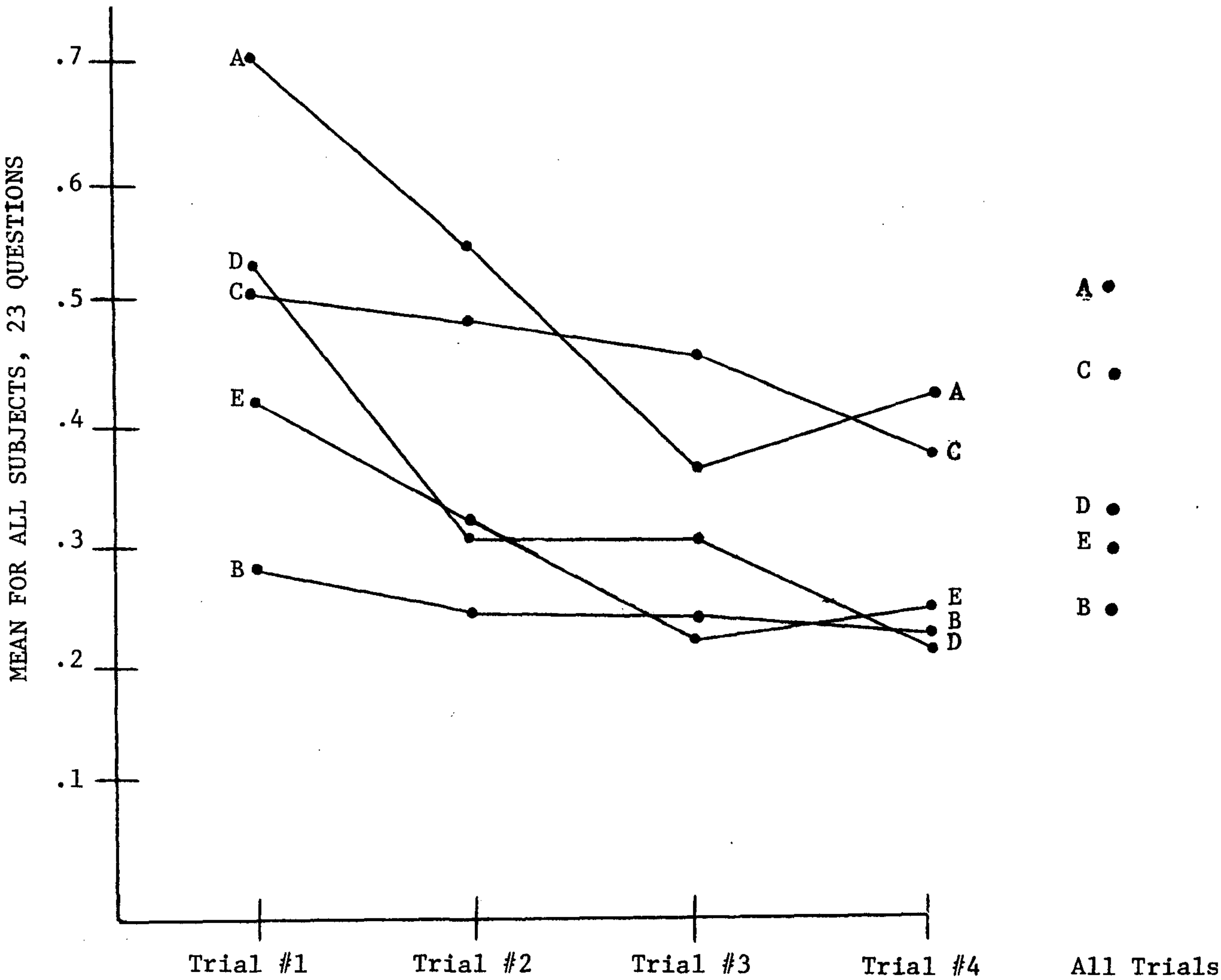
FIGURE 35 Normal - Standard Impala

FIGURE 36 Normal - Active Seville

FIGURE 37 Normal - Passive Hornet

FIGURE 38 Normal - Semipassive Hornet

Mean Scores for Successive Trials



LEGEND: A - Active Hornet
B - Standard Impala
C - Active Seville
D - Passive Hornet
E - Semipassive Hornet

FIGURE 39

V. SUMMARY AND CONCLUSIONS

A. System Configuration Summary

The short descriptions below are meant only to highlight a few features of each system for easy differentiation in the discussion that follows. The reader should refer to the first section of the report and to Figures 1 through 5 for more complete descriptions.

A - Active Hornet (single retractor in door, "window shade")

B - Standard Impala (1974 three-point)

C - Active Seville (single retractor in B-pillar, "window shade")

D - Passive Hornet (knee bolster, shoulder belt retractor in door, "window shade")

E - Semipassive Hornet (anchors in door, retractor in console)

B. Overall System Comparison

The questionnaire summary, the pair-by-pair preference ranking, and the overall order of preference ranking, all agreed that the standard Impala (B) was the most preferred and the active Hornet (A) was the least preferred. The other systems were closely grouped in between with the semipassive Hornet (E) chosen second best and the active Seville (C) chosen fourth best, two out of three times. See Figures 29, 30, and 31.

C. Comparison of Characteristics

The observations below are based on the comments of the subjects and the observations of the tester as well as the results of the questionnaire. A summary of problems (above the threshold level) identified by the questionnaire alone is given in Figure 40.

1. Extending the webbing (positioning the latch plate) scored as a definite problem for the two single retractor active systems (A and C). Most subjects used two hands and had to reposition the latch plate each time they entered the car.

2. As observed by the tester, entering the passive and semi-passive cars (D and E) appeared easy for these subjects and the questionnaire scores confirm this. However, remarks by some subjects indicated concern about the webbing interfering with entry and with access to the adjacent seat.

3. Seat adjustment was more difficult in the systems having fixed seat belt length after buckling (A, B, and C), with the active Seville (C) and the active Hornet (A) scoring as having definite problems.

4. The systems having the "window shade" feature (A, D, and C) scored worse than the others on snugness of fit, staying on the shoulder, and proper storage. Also, the systems with the balkiest retractors (A most balky, D next most balky, and C least) scored worse with A showing a definite problem and D just under the threshold. Combining these data with subject comments, it is reasonable to conclude that this feature will be a controversial one--particularly if the retractors are not well made.

5. The semipassive Hornet (E) produced the most chafing discomfort, scoring just over the problem threshold on discomfort to the face and neck.

6. While not reaching problem status, the passive Hornet (D) scored significantly worse on interference with exit, reflecting a need to push the belt away with the forearm.

7. The Active Seville (C) and the active Hornet (A) scored worse on emergency exit from driver's door with C just into the problem region.

8. The subjects found it nearly impossible to make an opposite side exit through the webbing of the semipassive Hornet (E) and nearly so for the passive hornet (D).

Identified Problems (Mean Score Above 1.0)

Set No.	Question No.	Problem	System	Mean Score
1	3	Difficulty in extending webbing	A	1.30
	3	Difficulty in extending webbing	C	1.18
2	1	Interference with seat adjustment	C	1.38
	1	Interference with seat adjustment	A	1.05
	5	Uncomfortable fit	A	1.60
	6	Webbing touched face or neck	E	1.08
5	1	Emergency exit from driver's door	C	1.00
	2	Emergency exit from opposite door	E	2.70
	2	Emergency exit from opposite door	D	1.70

FIGURE 40

D. Follow-up Investigation

A number of points were identified as important during this study but were not sufficiently illuminated by the data. Some of the areas needing further investigation are given below.

1. The subject sample of this study was chosen to display more or less extreme characteristics. If a truly representative acceptance indicator, rather than a problem indentifier, is desired, a larger and more randomly selected subject sample is needed.

2. Many of the features were new to the subjects and their proper reactions could have been obscured by unfamiliarity. Therefore, it would be desirable to conduct a study of the systems in use over an extended period.

3. A study incorporating a broader range of environmental conditions, particularly the effect of restrictive winter clothing, is needed.

4. How much the different car make and style affected the comparative restraint results is unknown. Therefore, in a complete investigation the various restraint configurations, perhaps along with a "most desirable feature" special configuration, should be studied in the same make and body style.

5. Particular features could be studies through a broader survey approach where the public at large (e.g. in shopping centers) could be asked a few questions aimed at evaluation of particular features. Candidates for this approach would include:

a) the "window shade" feature
b) the single retractor with locking lap belt
c) locking vs. non-locking lap belt vs. knee bolster
d) entry and exit with the passive and semipassive designs
e) retrieval of the latch plate

INFORMATION SHEET

Safety belt systems are being developed with a number of new design features. Some of these features, such as the manner in which the belt is buckled and the way it retracts, are designed to reduce the confusion, inconvenience, and discomfort that was associated with the use of safety belts in older model cars.

The purpose of this research project is to determine the extent to which these design objectives have or have not been achieved. Safety belts must be designed to accommodate the requirements of all sizes of people--large, medium, or small, We want to learn what you, a potential user of this system, think about it.

So, as you put on the safety belt, as you are wearing it, and as you take it off, please be thinking about any problems of confusion, inconvenience, and discomfort you encounter.

We are interested only in any problems you may experience while putting the safety belt on, while wearing it, and while taking it off.

Immediately following the test we will ask you some questions, and you will be able to tell us about your observations.

FIGURE 41 Statement to Be Read by Each Subject

APPENDIX A

TEST CONDUCTOR'S STATEMENT

A. We are going to be evaluating five different restraint systems.

B. You will sit in the car; operate the restraint systems as necessary, and at several stages I will ask you a few questions concerning your opinions about the restraint systems.

C. We will treat the cars in pairs, testing each one separately, and then comparing the second with the first.

D. Individual questions can be answered by using the numbers 0, 1, 2, or 3. "0" means no problems and "3" means serious difficulties. It is difficult to place a label on the intermediate values but the following Table might be helpful:

0 = no problem
1 = minor problem
2 = moderate problem
3 = serious problem

E. The only term that may be unfamiliar is "latch plate". This is the male part of the latch which is usually attached to the webbing and inserts into what is commonly called the buckle.

F. Several of the cars (A, C, and D) have the so called "window-shade" effect for the belt take-up system. With such a system a light forward motion of the upper torso relieves tension from the shoulder harness, but a longer forward motion of the torso will reduce the slack in the shoulder restraint. Demonstrate the use of this feature.

FIGURE 42 Statement Read to Each Subject

APPENDIX A

TEST SUBJECT ______________ VEHICLE ________________

QUESTIONS FOR EVALUATION OF SEAT BELT SYSTEMS

(0 = no problem, 1 = minor problem, 2 = moderate problem, 3 = serious problem)

Set #1

Questions to be asked of subject upon completion of belt-system donning.
(Open door; set down; but on belt system)

(For Standard System)

1.	Did you have any difficulty in locating the latchplate?	0	1	2	3
2.	Did you have any difficulty in retrieving the latchplate?	0	1	2	3
3.	Did you have any difficulty in extending the webbing?	0	1	2	3
4.	Did you have any difficulty in finding the buckle?	0	1	2	3
5.	Did you have any difficulty in securing the buckle?	0	1	2	3
6.	Did you have to straighten the webbing?	0	1	2	3

(For Passive System)

1.	Did you experience confusion on how to get past the webbing upon entering the vehicle?	0	1	2	3
2.	Did the belt system interfere with your entry into the vehicle or closing the door?	0	1	2	3
3.	Did you have any difficulty in unhooking the webbing?	0	1	2	3

FIGURE 43 Questionnaire for Evaluation of Seat Belt System

4.	Did the harness drag across your chest (breast)/clothing?.	0	1	2	3
5.	Did the harness miss your shoulder?	0	1	2	3
6.	Did you have to straighten the webbing?	0	1	2	3

Set #2

Questions to be asked after subject has: adjusted seat to rearmost, forward, and preferred positions; reaches for glove compartment and left vent handle; and turns to look toward left rear and out of rear window.

(For Standard and Passive Systems)

1.	Did the belt system interfere with the seat adjustment?	0	1	2	3
2.	Did the belt system interfere with your reach to the glove compartment, or with any controls?	0	1	2	3
3.	Did the shoulder harness obstruct your left rear view?	0	1	2	3
4.	Did the shoulder harness limit your turning to the right to look out the rear window?	0	1	2	3
5.	Did any part of the webbing system fail to achieve a snug fit?	0	1	2	3
6.	Did the webbing lay on or rub against your neck or face?	0	1	2	3
7.	Did the webbing fall off your shoulder?	0	1	2	3
8.	Did the shoulder harvess lay across your breast (or on the inboard side of your chest)?	0	1	2	3
9.	Was the webbing pressure on your shoulder comfortable?	0	1	2	3
10.	Did the webbing chafe across your shoulder?	0	1	2	3
11.	Did the lap belt ride up on your stomach?	0	1	2	3

FIGURE 43 Con't

Set #3

Questions to be asked of subject upon completion of belt-system doffing. (Unfasten belts; place in storage position; remain seated)

(For Standard System)

1. Did you have any difficulty in locating the buckle release?	0	1	2	3
2. Did you have any difficulty in operating the buckle release?	0	1	2	3
3. Did the webbing hang up on you, your clothes, or parts of the vehicle during retraction?	0	1	2	3
4. Was retraction and stowage complete?	0	1	2	3

(For Passive System)

1. Did you experience confusion on how to doff the belt system?	0	1	2	3
2. Did you have any difficulty in stowing (i.e., hooking) the belt system?	0	1	2	3
3. Did the belt drag across your chest (breast)/clothing?	0	1	2	3

Set #4

Questions to be asked after subject has exited from vehicle.

(For Standard System)

1. Did the belt system interfere with your exit?	0	1	2	3
2. Were all parts of the belt system clear of the door?	0	1	2	3

(For Passive System)

1. Did the belt system interfere with opening the door or exiting from the vehicle?	0	1	2	3
2. Did you have to hold the door against the tension of the belt?	0	1	2	3

FIGURE 43 Con't

APPENDIX A

Time required to make an emergency exit: _______________ seconds

---

Set #5 (Performed only last time a subject tests a given restraint system.)

Questions to be asked after subject has completed emergency exit from adjacent door and begun emergency exit toward opposite door.

(For Standard and Passive Systems)

1. Did you experience any difficulties in making an emergency exit from the door on the dirver's side?	0	1	2	3
2. Did you experience or can you imagine any difficulties in making an emergency exit from the opposite door?	0	1	2	3

Compared with

The Criterion Car (________________________)

The Comparison Car (________________________)

is:

Much Worse	Somewhat Worse	Slightly Worse	Same	Slightly Better	Somewhat Better	Much Better
3	2	1	0	1	2	3

FIGURE 43 Con't