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IDENTIFICATION OF VARIABLES AFFECTING DRIVER SEATED POSITION

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16. Abstract

A sample population of 51 male and 57 female subjects ranging in age from 18 to 78 years was assembled and tested in six different vehicles for preferred seat positions under non-driving and driving conditions. Volunteer subjects were selected by age, stature, and weight criteria in order to match the U.S. adult population to the extent practical. Analysis of these data suggest that on a total sample basis there is little difference between seat positions selected under non-driving and driving condiitons, but that individuals may show significant differences. The small differences in group mean positions observed in this study may be due to a seat belt and/or an initial seat position factor. Post-drive seat position results were analyzed in a variety of ways to identify factors that may influence a person's preferred seat position.

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SUMMARY

A sample population of 51 male and 57 female subjects ranging in age from 18 to 78 years was assembled and tested in six different vehicles for preferred seat positions under non-driving and driving conditions. Subjects were selected by age, stature, and weight criteria to match the U.S. adult population. Analysis of the data collected in this study reveals the following:

1) On a total sample basis, the mean differences in seat positions selected under driving and non-driving conditions were less than .5 inch for all vehicles. While these mean differences are probably insignificant from a practical aspect, they were found to be statistically significant in many cases. Comparisons of seat positions selected under various test conditions suggest that these differences are primarily due to a seat belt and/or an initial position effect rather than the driving versus non-driving factor. The tendency is for people to select positions closer up when using seat belts or starting from an initial forward position.

2) Stature is the most significant anthropometric variable in determining preferred seat position, explaining approximately 30 to 60 percent of the seat position variance, depending on the vehicle seating configuration.

3) The relation between stature and seat position for the total population is non-linear. A linear regression of mid-range stature and seat position underestimates the close-up and far-back positions selected by population extremes.

4) A comparison of dimensionalized mean seat positions selected across the six vehicles used in this study reveals a complex interaction between pedal location and steering wheel location in determining preferred seat position. There is a surprisingly small range of distances from H-point to the lower steering wheel rim for the mean preferred seat positions in the vehicles tested.

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This study was supported by the Motor Vehicle Manufacturers Association (MVMA). The authors would like to express their appreciation to the members of the MVMA Human Factors Sub-Committee who assisted with the experimental design and the selection of test vehicles. Particularly noteworthy was the assistance of Dave C. Hammond of Ford Motor Company for the design of the subject selection matrix and assistance with statisical techniques, and Ronald W. Roe of General Motors for preparation of the vehicle dimensional data.

INTRODUCTION

The factors that determine a driver's selected seat position are not clearly understood. An investigation into these factors could most easily be conducted in a laboratory vehicle mock-up or at least in a static (non-moving) vehicle where vehicle features could be easily modified and measurements efficiently recorded. There is some question, however, as to whether people will position themselves in a non-driving situation as they would after having actually driven a vehicle. The purpose of this study was to measure the preferred seat positions of drivers in static and dynamic situations and to thereby:

1) determine if elected seating positions of drivers for static conditions are the same as those while actually driving, and

2) examine the effects of principal vehicle packaging factors and subject characteristics on the selection of seat positions.

METHODS

VEHICLES AND SUBJECTS

The six vehicles shown in Fig. 1 were selected for use in this study. These vehicles consist of three pairs of vehicles matched for similar G* scores (1), including two vans, two mid-size cars, and two compact cars. Table 1 lists these vehicles, their G scores, and seat track features. All vehicles are 1978 models except the Rabbit, which is a 1976 model. While the steering column tilt angle and seat back angle were adjustable in two of these vehicles, these were fixed to one position for this study (see Table B-1).

The final subject population consisted of 108 volunteers from the Ann Arbor area. Fifty-one (51) of these subjects were male and fifty-seven (57) were females. Ages ranged from 18 to 79 years. Figs. 2, 3, and 4 illustrate the age, stature, and weight distributions of these subjects. Tables 2 and 3 compare the stature and weight percentiles from the 1960-1962 Health Survey (2) and the 1974 HANES Survey (3) of the U.S. adult population. It is obviously impossible with such a small sample size to obtain a perfect match to the general population. Nonetheless, a good distribution of these three variables was achieved. If the comparisons between the 1974 HANES data and the 1960-1962 HEW data are realistic, then the males

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*The G score or general package factor is the principal factor which is highly correlated with the nine primary package variables which specify the driver workspace.

This study was reviewed by, and conducted under, standards established by the University of Michigan Medical Center, Committee to review Grants for Clinical Research and Investigation Involving Human Beings, and conforms to the guidelines of the Institutional Guide to Department of Health, Education and Welfare Policy on Protection of Human Subjects.

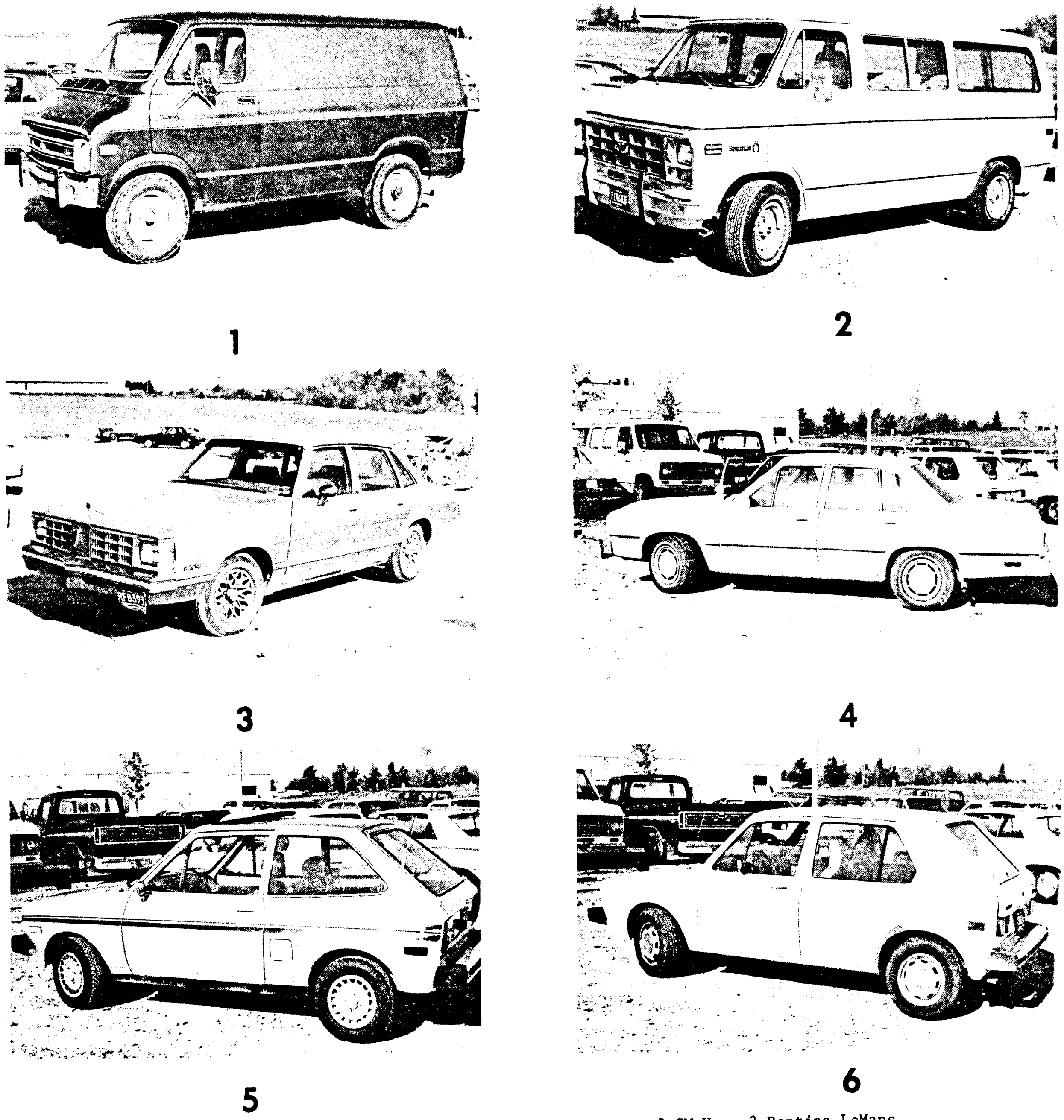

Fig. 1 - Vehicles used in study: 1-Dodge Van, 2-GM Van, 3-Pontiac LeMans, 4-Ford Fairmont, 5-Ford Fiesta, 6-VW Rabbit

Table 1 - List of Vehicles, G Scores, and Seat Track Features

Vehicle No.	Vehicle*	G Score	No. Detents	Horiz. Distance Between Detents (inches)	Total Horiz. Seat Travel (inches)
1	Dodge Van	.27	11	.50	5.0
2	GM Van	.14	11	.54	5.4
3	Pontiac LeMans	-.84	9	.84	6.7
4	Ford Fairmont	-.74	11	.55	5.5
5	Ford Fiesta	-.41	9	.6	4.8
6	VW Rabbit-4DR	-.36	10	.86	7.7

*All model years are 1978, except Rabbit which is 1976.

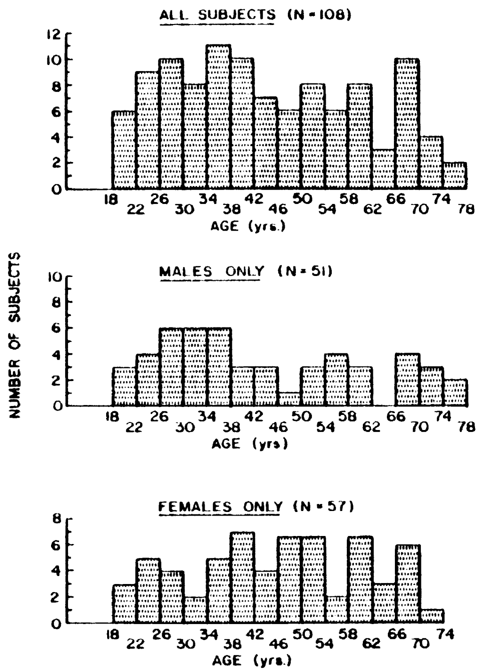

Fig. 2 - Age distributions of subjects

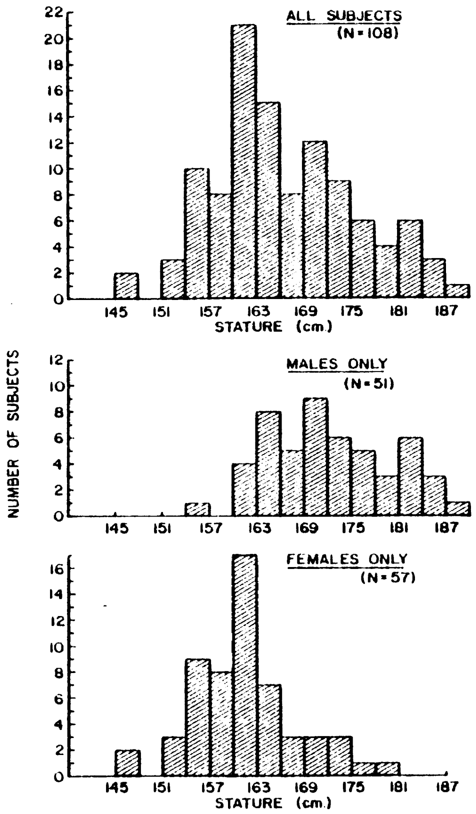

Fig. 3 - Stature distributions of subjects

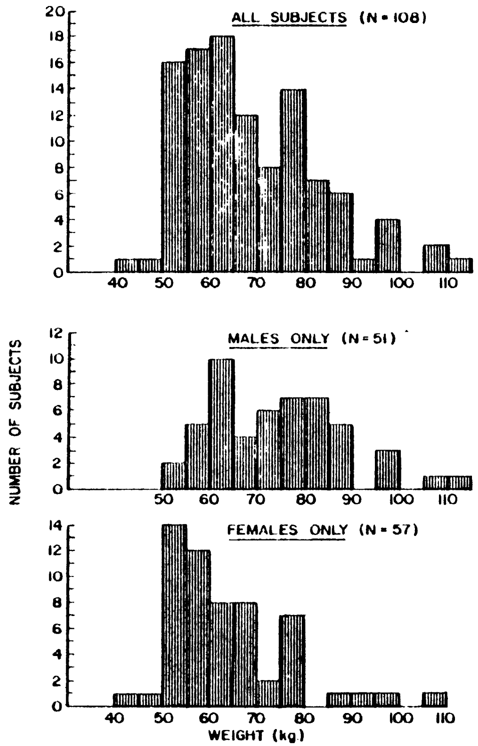

Fig. 4 - Weight distributions of subjects

Table 2 - Stature* Characteristics of Subjects Compared to Data from 1960-1962 Health Survey and 1974 HANES Survey

Data Source	Gender	N	Mean	Percentiles 5th	10th	50th	90th	95th
Subjects	Males	51	172.1	161.5	163.0	171.2	183.2	185.7
	Females	57	161.2	151.6	154.2	161.0	170.4	173.5
1974 HANES	Males	5260	175.3	163.5	166.4	175.3	184.4	186.9
	Females	8411	161.5	151.1	153.7	161.8	169.7	172.2
1960-62 HEW	Males	3091	173.2	161.5	163.8	173.5	182.4	184.9
	Females	3581	160.0	149.9	151.9	159.8	168.4	170.4

*Stature in centimeters

Table 3 - Weight* Characteristics of Subjects Compared to Data from 1960-1962 Health Survey and 1974 HANES Survey

Data Source	Gender	N	Mean	Percentiles 5th	10th	50th	90th	95th
Subjects	Males	51	74.8	56.9	59.8	74.6	89.8	97.6
	Females	57	63.7	50.5	52.5	60.2	78.4	92.0
1974 HANES	Males	5260	78.2	58.2	62.3	77.3	96.0	102.3
	Females	8411	65.0	47.3	50.0	62.3	84.1	92.3
1960-62 HEW	Males	3091	76.4	57.3	60.9	75.4	93.2	98.5
	Females	3581	64.5	47.3	50.4	62.3	82.7	90.4

*Weight in kilograms

of the sample population are somewhat lighter and shorter over the complete range of stature and weight than the U.S. population. The females match quite well to both the 1974 and 1960-1962 HANES data for stature and weight. The mean age of the sample population is 44 years (43.3 for males and 44.7 for females), which is probably somewhat greater than the mean age of licensed drivers (5).

While the primary concern in selecting subjects was to obtain a good distribution of age, stature, and weight, some attempt was also made to match the U.S. population proportions of age/stature and stature/weight groupings. The age range of 18-79 years was divided into four groups at years 30, 42, and 55. Stature was divided into five groups at the 20th, 40th, 60th and 80th percentiles for the 18-79 year population of males and females separately, and weight was divided into three groups at the 33rd and 66th percentiles for 18-79 year males and females. Using the 1960-1962 HEW data (5) and a computer program by Hammond (6), the proportions of the U.S. population in each age/stature and stature/weight grouping were computed for males and females. These proportions were then used to compute the ideal number of subjects per group, based on sample sizes of 50 males and 50 females. Tables A-1 through A-4 in Appendix A show the results of these computations and compare them with the actual numbers of subjects in each group. A perfect match is obviously impossible with such a small sample size and would be impractical for this preliminary investigation even if it was possible. A reasonable match has been achieved, however, and in only one group (tall, thin females) was no subject obtained. A weighting procedure can therefore be used on the data to proportion results to the primary age, stature, and weight characteristics of the general population.

TEST PROCEDURES

Subjects responding to advertisements in local papers and meeting the general height and age requirements of the subject selection criteria were scheduled for an initial visit in which they filled out a health questionnaire and signed a consent form. At this time the general purpose of the study was explained (i.e., to investigate where people position the seat), and the thirteen anthropometric measurements listed in Table 4 were taken. Measurements were taken on clothed subjects without shoes.

TABLE 4 - ANTHROPOMETRIC MEASUREMENTS

1. Weight
2. Stature
3. Erect Sitting Height
4. Normal Sitting Height
5. Eye Height (sitting erect)
6. Shoulder Height (sitting erect)
7. Knee Height (sitting)
8. Frontal Arm Reach (standing)
9. Buttock-Knee Length
10. Lower Arm Length
11. Shoulder-Elbow Length
12. Shoulder Breadth
13. Seat Breadth

When the subject pool was nearly completed, scheduling of the subjects for actual testing began. Subjects were run in groups of five or six when possible and two sessions (approximately three hours in duration) were scheduled each day. All sessions were completed over a two-month period during September and October when heavy garments would not be worn.

STATIC TESTS - At the beginning of a session the subjects were reinformed of the general purpose of the study and Part I of the instructions (Fig. 5) concerning the static (non-driving) tests was read. Subjects were not told at this time that they would also be driving the vehicles in a second test. For approximately the first half of testing the subjects were instructed to make four seat adjustments in each vehicle without the seat belts*, two from the seat full forward and two from the seat full rearward. The seat position for the initial trial (i.e., full forward or full rearward) was varied in different sessions. Subjects remained in the seat between trials while the investigator assisted in alternately moving the seat forward or rearward after each trial. The door was closed during each adjustment. The seat detent position, indicated by a simple pointer and scale attached to the seat and vehicle floor as shown in Fig. 6, was read by the investigator when the subject indicated he/she had found the best position. These detent values were recorded on data collection forms attached to clipboards which were assigned to each subject. Subjects were also instructed not to look at the seat position scales during or between tests.

Approximately halfway through the testing program two additional tests were added to the static measurements in which the subject adjusted to the most suitable seat position with the belts in place.** These two tests were made with the seat initially positioned in the full forward position.

DYNAMIC TESTS - When all subjects had completed the static tests Part II of the instructions (Fig. 7) was read, informing the subjects*** that they would now drive each of the vehicles over a specified course of approximately

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*The two vans had lap belts only. The Rabbit had a passive torso belt system and the three other vehicles had standard 3-point belt systems.

**It was not always possible for the subject to put the seat belt on in the full forward position or to keep the belts on during all of the seat adjustment maneuvers. The final position selected in these tests, however, was with the belts worn.

***Subjects who did not know how to drive cars with standard transmissions could not complete the dynamic tests in the Fiesta and Rabbit. In all, sixteen subjects (14 females and 2 males) were eliminated by this factor, leaving a sample size of 92 rather than 108 for the dynamic tests with these vehicles.

INSTRUCTIONS - PART I

In this study we are interested in where people position themselves when driving cars. You are going to participate in a series of tests in which six different vehicles will be used. While you are not going to drive these vehicles, we would ask you to imagine that you will drive and position the seat where you would like it.

You will adjust the seat in each car six times, twice from the seat full forward and twice from the seat full rearward without the seat belts on, and twice from the seat full forward with the seat belts on. After each adjustment, we will note your selected seat position using a scale attached to the floor or seat of the vehicle. Please do not look at the scale while you are adjusting the seat or when you are done with each adjustment. After each reading the seat will be repositioned at full rearward or full forward for the next trial. All seat adjustments must be made with the vehicle door closed.

Are there any questions?

Fig. 5 - Part I of Subject Instructions

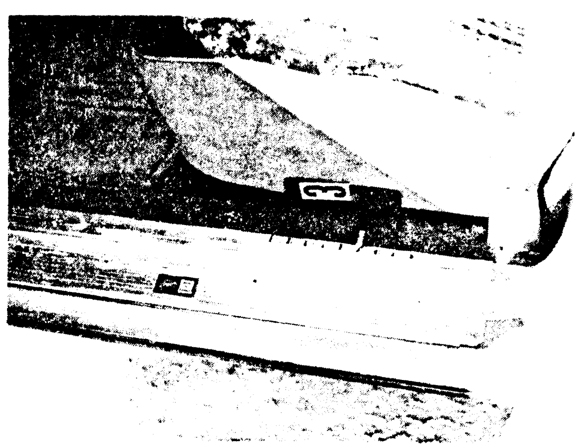

Fig. 6 - Scale and pointer on Pontiac LeMans for measuring seat positions.

four miles. During this drive they were to make as many seat adjustments as necessary but to return with the seat in their most preferred position for driving. Prior to entering a vehicle, the seat was always adjusted to the position farthest from the average of their selected static positions. Subjects were also instructed to wear the seat belts throughout these tests. Prior to the start of the drive, the investigator recorded the selected pre-drive seat position. Upon the subject's return from the drive the investigator recorded the post-drive or final selected seat position. At this time the subject filled out a vehicle evaluation form (Fig. 8) concerning his/her judgement of various vehicle features (e.g., location of steering wheel, location of pedals, seat angle, seat adjustment range, seat belt accommodation, etc.) in the vehicle just driven. Upon completing this questionnaire, the subject entered the next vehicle and repeated the procedure.

In both static and dynamic tests, the vehicles were assigned to subjects in a predetermined order that varied from session to session. Upon completion of the dynamic tests in all vehicles, the subjects filled out a final questionnaire (Fig. 9) concerning their driving habits, such as miles driven per year, types of vehicles usually driven, use of seat belts, and whether they would normally adjust the seat position in vehicles other than their own. In addition, subjects were asked to rank the vehicles they had driven by preference for seating accommodation.

Table 5 summarizes the different conditions under which seat positions were recorded and gives the abbreviated terms that will be used to refer to these conditions in the remainder of this report.

INSTRUCTIONS - PART II

Now we are going to ask you to drive each of the cars over a specified course shown on a map provided you.

The procedure is as follows: Get in the assigned car, close the door and fasten the seat belt, then adjust the seat position to where you want it for driving. When this is done, we will note the position you have selected and you may begin to drive the course shown on the map. In doing so you may adjust the seat position as many times as you wish. We ask, however, that you pull over to the side of the road or into a parking lot along the way and come to a full stop before adjusting the seat. When you are convinced that you have found the most suitable seat position for driving, you may continue back to HSRI without further stops. Upon returning we will note your final selected seat position. You will then park the vehicle and fill out a brief evaluation form provided on your clipboard before being assigned to another vehicle. Please take time to look at this form before driving the first vehicle.

In making the seat adjustments please do not look at the seat adjuster or scale. Be especially cautious of other traffic when stopping for making seat adjustments.

In driving the course, please drive carefully, obey all speed limits, signs, signals, etc.

Fig. 7 - Part II of Subject Instructions

TABLE 5 - SEAT POSITION VARIABLES

Abbreviated Term	Description
NBF	Average of 2 no-belt static positions from initial forward position
NBR	Average of 2 no-belt static positions from initial rearward position
NBM	Average of NBF and NBR positions
WBM	Average of 2 with-belt static positions from initial forward position
PRE	Pre-drive with-belt position
POST	Post-drive position (with belt)

In the final selected seat position, how did you feel about the following items?

	(1) Dodge Van	(2) Chevy Van	(3) Green Pontiac	(4) Ford Fairmont	(5) Fiesta	(6) Rabbit
*STEERING WHEEL LOCATION: 1 - too close 2 - acceptable 3 - too far away	___	___	___	___	___	___
TOP OF STEERING WHEEL RIM: 1 - too high, interferes with forward vision 2 - acceptable 3 - lower than necessary	___	___	___	___	___	___
BOTTOM OF STEERING WHEEL RIM: 1 - higher than necessary 2 - acceptable 3 - too low, interferes with leg	___	___	___	___	___	___
BRAKE PEDAL LOCATION: 1 - too close 2 - acceptable 3 - too far away	___	___	___	___	___	___
GAS PEDAL LOCATION: 1 - too close 2 - acceptable 3 - too far away	___	___	___	___	___	___
FOOT MOVEMENT BETWEEN: 1 - too much space 2 - acceptable 3 - too little space	___	___	___	___	___	___
STEERING WHEEL ANGLE: 1 - too flat (horizontal) 2 - acceptable 3 - too tilted (vertical)	___	___	___	___	___	___
FORWARD SEAT ADJUSTMENT: 1 - not enough 2 - acceptable 3 - more than needed	___	___	___	___	___	___
REARWARD SEAT ADJUSTMENT: 1 - not enough 2 - acceptable 3 - more than needed	___	___	___	___	___	___
SEAT BACK ANGLE: 1 - too upright 2 - acceptable 3 - too reclined	___	___	___	___	___	___
SEAT CUSHION LENGTH: 1 - too long 2 - acceptable 3 - too short	___	___	___	___	___	___
SEAT CUSHION HEIGHT FROM FLOOR: 1 - too low 2 - acceptable 3 - too high	___	___	___	___	___	___
SEAT WIDTH: 1 - too narrow 2 - acceptable 3 - too wide	___	___	___	___	___	___
ANGLE OF SEAT CUSHION: 1 - front too high 2 - acceptable 3 - front too low	___	___	___	___	___	___
SHOULDER HARNESS ACCOMODATION: (see next page for rating criteria)			___	___	___	___

Fig. 8 - Post-drive vehicle evaluation form

1. How many years have you been driving? ________

2. Approximately how many miles a year do you drive? _______

3. Which of the vehicles in these tests is most similar to the car you usually drive? (check one)

   1 - Dodge Van   3 - Pontiac   5 - Fiesta
   2 - Chevy Van   4 - Ford Fairmont   6 - Rabbit

   Kind of car you usually drive ____________

4. Please check which of the following types of vehicles you have driven for an hour or more in the last 5 years:

   1 - semi/heavy truck   5 - mid size car
   2 - pickup/light truck   6 - small car
   3 - van   7 - sports car
   4 - full size car

5. Have you driven a rental vehicle in the last 5 years?

   Yes ___ No ___

6. If yes, about how many times do you drive a rental vehicle per year? (please check)

   1 - less than 1   3 - 3-4
   2 - 1-2   4 - 5 or more

7. Do you (check one)

   1 - never   2 - seldom   3 - usually   4 - always

   adjust seat position when driving a vehicle other than your own?

8. Given your own choice, for a short drive such as the one you have just taken, would you use seat belts?

   1 - never   2 - sometimes   3 - always

9. Rank the six vehicles you have been sitting in for driving <u>position</u>.

   1 - (best) ______________________
   2 - ______________________
   3 - ______________________
   4 - ______________________
   5 - ______________________
   6 - ______________________

Fig. 9 - Final Questionnaire

DATA ANALYSIS - Data obtained from each subject, including seat positions by seat track detent for each trial, coded questionnaire responses, and anthropometric measurements, were keypunched and input to the Michigan Terminal Computer System (MTS). Statistical programs contained in the Michigan Interactive Data Analysis System (MIDAS) were used to perform statistical computations and tabulations, compare seat positions selected under different conditions, generate scatter plots and histograms, compute data percentiles, and perform linear regressions. A second set of statistical programs (OSIRIS) was used when it was desired to weight the data points to match the U.S. population by age/stature proportions.

Vehicle dimensional data were provided by the Motor Vehicle Manufacturers Association (MVMA). These dimensions were obtained using the SAE J826 H-point machine (7) and are summarized in Tables B-1 and B-2 of Appendix B. Using these dimensions, seat position data in detents were converted to distances of H-point from the accelerator heel point and vehicle steering wheel, thereby enabling comparisons of selected seat positions between vehicles.

RESULTS

GENERAL

The large volume of seat position measurement data, subject anthropometric data, and subject questionnaire results collected in this study is provided in raw form by subject and vehicle on magnetic tape and computer listings. This section of the report will present the primary results of statistical computations and graphical analyses on these raw data and will also provide some observations and conclusions in terms of the objectives outlined in the introduction. The procedures and computations discussed here are not intended to be all inclusive, and future analysis and data manipulation may be desired in terms of specific needs using the data provided on magnetic tape. Appendix C contains a summary of the vehicle evaluation and final questionnaire results which will be referred to throughout this discussion.

SELECTED SEAT POSITIONS

Fig. 10 illustrates the distributions of post-drive (POST) seat positions by detent selected by all subjects in the six vehicles. One fact is immediately apparent. Except possibly for the Le Mans, the seat positions are not normally distributed. If, however, one removes the subjects who selected the first and last detents of each vehicle, the remaining censored distributions appear to be more normally distributed within the limitations of the sample sizes. The total distribution for each vehicle then differs from a normal distribution primarily by the "piling-up" of subjects at the first and last detents, resulting from the limited seat track travel. Similar shaped distributions of selected seat positions were found for the

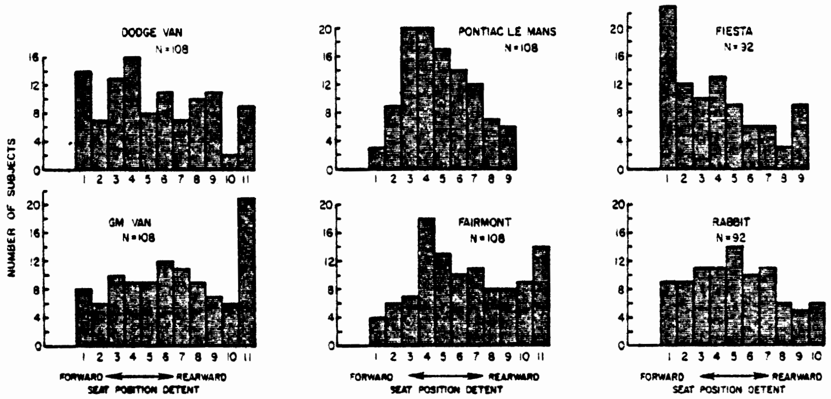

Fig. 10 - **Distribution of post-drive (POST) seat positions for all subjects**

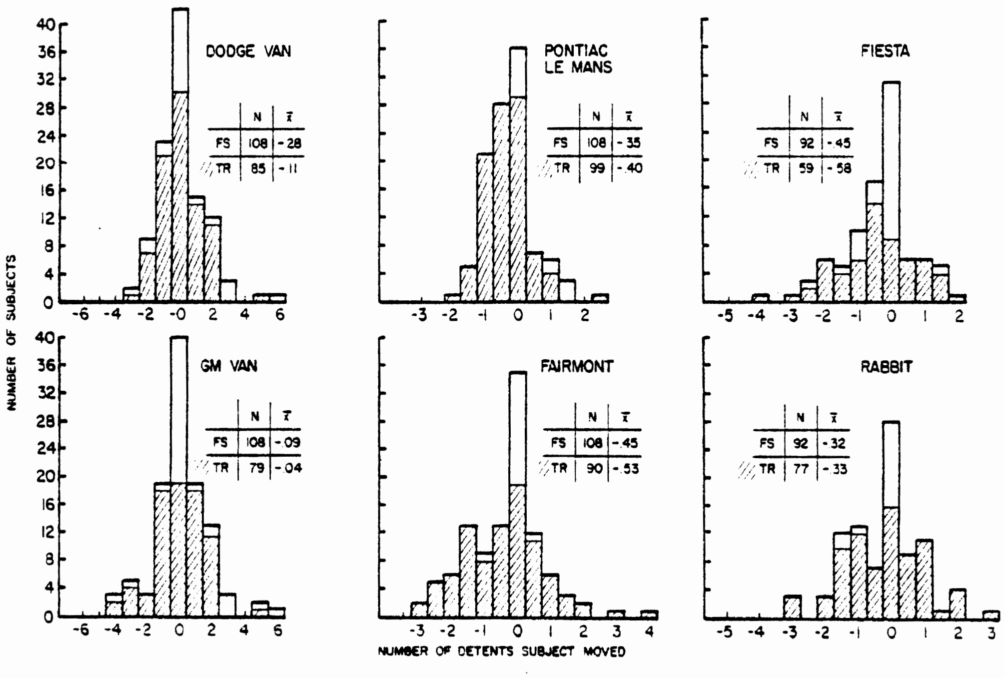

Fig. 11 - Distributions of POST-NBM differences. Unshaded histograms for all subjects. Shaded portions for sample population truncated by excluding subjects at end detents.

no-belt static positions (NBM), the with-belt static positions (WBM), and the pre-drive (PRE) positions.

COMPARISONS OF STATIC AND DYNAMIC RESULTS

VISUAL OBSERVATIONS - The unshaded histograms in Fig. 11 illustrate subject differences between the POST selected position and the mean of the no-belt selected positions (NBM) for each vehicle (DIF=POST-NBM). Several observations can be made from these distributions of differences. It is seen first of all that for some subjects significant shifts in selected seat position occurred between the static no-belt positions and the post-drive position. It is also seen, however, that these differences are nearly normally distributed about a mean difference that is relatively small in each case. In fact, these distributions differ from a normal distribution primarily by the large central peak at POST-NBM of zero. By eliminating those subjects who selected the first or last detent in POST positions, the shaded histograms results where the central peak is markedly reduced. Thus, these "no change" subjects are seen to be primarily those who selected either the full forward or full rearward detent. Attempts to distinguish the forward movers (negative differences) from the rearward movers (positive differences) in terms of subject driving experience, habits, etc., (i.e., final questionnaire information) revealed only the tendency for persons who sit close-up in the static tests to shift rearward after driving, and vice versa.

The inserts in Fig. 11 illustrate that while the mean value of the difference is small for each vehicle (generally less than .5 detent) it is always negative for both the full sample and censored distributions, illustrating that, in the mean, there is a slight tendency for subjects to more forward after driving. Yet one must conclude that these mean differences are insignificant from a practical viewpoint (i.e., 1/2 detent is less than .5 inch for all vehicles) and that, for a reasonable sample size, the average static seat position is essentially the same as the average dynamic position. Caution must be used, however, when looking at individuals, since substantial differences can occur.

STATISTICAL COMPARISONS - Despite the fact that these mean differences are small from a practical aspect, several statistical tests were used to test the hypothesis that the mean differences between selected seat positions under two conditions (e.g., NBM and POST, NBM and WBM) are zero. Paired t-tests were run for the full sample size, the sample of subjects resulting from censoring the POST distributions as previously described, and the sample of subjects resulting from elimination of those subjects on each vehicle who indicated a desire for more or less seat travel on the post-drive questionnaire (items 12 and 13 of Table C-1 of Appendix C).* The non-parametric Wilcoxon matched-pair rank sum statistical test was also used to test the null hypothesis that the distribution of the difference is symmetric about zero. While minor differences appeared between the results of these different tests, the overall results were essentially the same.

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*This attempt to normalize the distributions by using only the "contented" subjects did not eliminate as many "end" persons as desired and, in fact, occasionally eliminated a mid-track person. Some improvement in normalizing the distribution was obtained if subjects who indicated a desire for more seat travel on <u>any</u> vehicle were eliminated from all vehicles. Perhaps the questionnaire responses were unreliable. It is also possible that many persons were <u>content</u> to move the seat as far forward or rearward as possible, but would have moved it further if more travel had been available.

Tables D-1 through D-6 in Appendix D summarize these test results for the full sample paired t-tests showing the sample size, the mean difference, the standard deviation, and the significance (signif. < .05 indicates a significant difference at the .05 level). The sample size for comparisons with WBM is reduced, since only about half the subjects performed these with-belt static tests. Table 6 summarizes these results for all vehicles.

The observations that can be made from Table 6 are subtle but interesting. It will be noted that for all vehicles except the vans, the mean differences between no-belt static positions (NBM) and the post-drive (POST) positions are significantly different from zero. Thus one might at first suspect a statistically significant (though practically insignificant) difference between static and dynamic selected seat positions. On further observation, however, it can be seen that the vehicles generally show significant differences between the NBM position and any other with-belt position (i.e., PRE, WBM, and POST). Also, it is seen that with-belt positions, in comparison with each other, generally show relatively few cases of significant differences. Thus, it appears that the NBM-POST differences may be due to the seat belt influence rather than a static versus dynamic factor.

It is also observed, however, that there is a significant difference between the no-belt static positions starting with the seat full forward (NBF) and full rearward (NBR) for all vehicles, but that there are no significant differences between NBF and WBM positions. Since NBF and WBM positions were both from the seat initially full forward, these results suggest that the initial seat position may be an important factor. The fact that three vehicles show a significant difference between NBF and POST

Table 6 - Summary of Paired T-Test Results

Test*	Vehicles with Signif. Diff. at .05 Level	Vehicles with Mean Diff. >.5 Detent	Signs of Mean Diff.	Tendency
NBM-WBM	Le Mans Fairmont Fiesta Rabbit	None	All positive	WBM forward
NBM-PRE	Dodge Van Le Mans Fairmont Fiesta Rabbit	Fairmont	All positive	PRE forward
NBM-POST	Le Mans Fairmont Fiesta Rabbit	None	5 positive	POST forward
NBF-NBR	All vehicles	None	All negative	NFB forward
NBF-WBM	None	None	4 positive	
NBF-POST	Le Mans Fairmont Fiesta	None	4 positive	
WBM-PRE	None	None	4 negative	
WBM-POST	Fiesta	None	4 negative	
PRE-POST	Dodge Van GM Van	None	5 negative	POST rearward

*See Table 5 for definitions.

while only one shows a significant difference between WBM and POST suggests that the initial position effect accounts for only a portion of the difference between NBM and POST, the remaining factor being the seat belt. There appears, then, to be a tendency for persons to select positions further forward when wearing the shoulder belts or when starting from a forward position.

It can also be observed from these results that the vans tend to follow a somewhat different pattern than the other four vehicles. They do now show significant differences between NBM and POST positions, and they are the only vehicles with significant differences between PRE and POST positions. These observations have two possible explanations. From Tables D-1 through D-6 it is seen that the variances of the differences tend to be larger for the vans than the other vehicles, resulting in less sensitive tests for statistical significance. These larger variances are perhaps a consequence of the unfamiliarity of most of the subjects with van type vehicles, which resulted in more searching, less certainty, and therefore less repeatability on selected seat positions (only 4.4% of subjects drove van type vehicles). It is also seen that the actual mean differences between seat positions under the different test conditions tend to be smaller for the vans. This may be explained by the fact that the vans only had lap belts and therefore the shoulder belt factor previously hypothesized may not have had a significant influence in these vehicles. The significant differences between PRE and POST positions for the vans may also reflect the subject uncertainty in selecting a seat position prior to actually driving these vehicles.

SEAT POSITION, ANTHROPOMETRY, AND OTHER FACTORS

Stepwise regression analysis was used to study the effect of subject anthropometric measures on POST seat positions. Since subjects sitting at either the first or last detents may not have been at the position of their choice had further seat travel been available, they were again eliminated from the sample size for this analysis. The resulting distributions, while truncated normal at best, contain only those subjects who were not limited in their seat selection.

As one might expect, stature was the primary anthropometric variable to fall out of this analysis, explaining between .32 and .62 of the variance in POST seat position distributions, as shown in Table 7. Inclusion of other anthropometric measures such as weight, sitting height, arm reach, etc., added little to the amount of variance explained by stature alone. Fig. 12 shows a plot of percent variance explained by stature against vehicle G score. This suggests that the lower the vehicle G score, the more important is subject size in determining seat position. When one considers that the G score is an indication of the "truckiness" of the occupant seating (i.e., the higher the G score, the more upright is the occupant) this finding is not surprising.

Other observations made from analysis of variance and covariance on seat positions from various subject groupings are that:

1) Males and females are homogeneous in terms of selected seat positions for the vans and mid-sized cars when adjustments for height and weight are made.

2) Females tend to sit closer than similar sized males in the Fiesta and Rabbit.

3) Age does not add significantly to predictive ability although there is a slight tendency for younger people to sit farther away and for older people to sit closer.

Other attempts to explain seat position variation from information on subject driving habits such as miles/year and size of subjects' own vehicles, using multivariate nominal scale analysis, revealed no significant factors.

TABLE 7 - PERCENT OF POST SEAT POSITION VARIANCE EXPLAINED BY STATURE FOR SUBJECTS SITTING WITHIN END DETENTS

Vehicle	N	Percent Explained
Dodge Van	85	.32
GM Van	79	.28
Le Mans	99	.62
Fairmont	90	.45
Fiesta	59	.42
Rabbit	77	.54

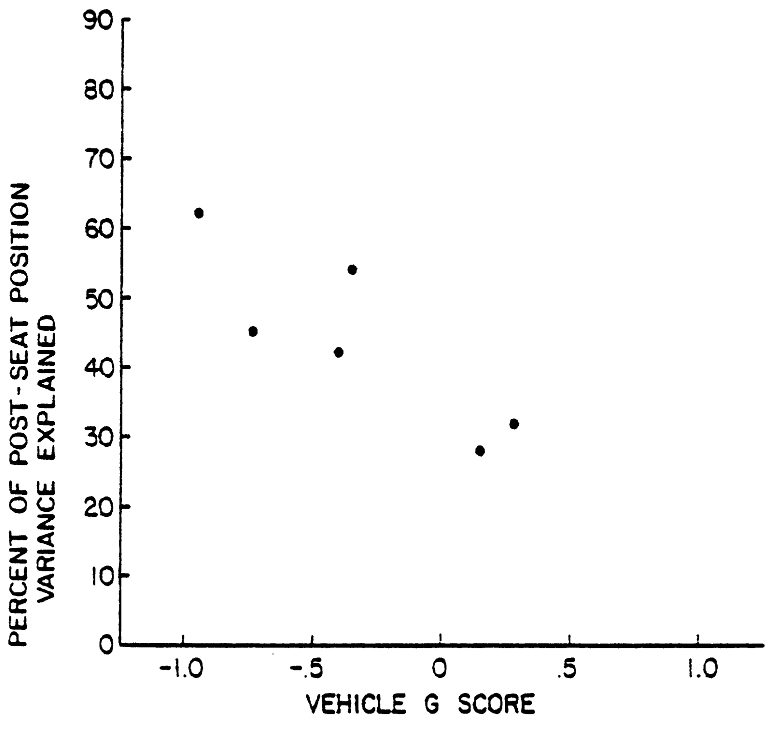

Fig. 12 - Percent of post seat position variance explained by stature plotted against vehicle G score.

DIMENSIONALIZED SEAT POSITION DATA

In order to present seat position results in a more meaningful way and to compare seat positions between vehicles, the detent numbers recorded during testing were converted to vehicle dimensional data using the information shown in Table B-1. Fig. 13 shows the four dimensions calculated and used in the remainder of this report. These include:

1) HHH - the horizontal distance from the H-point to accelerator heel point,

2) DHH - the diagonal distance from H-point to accelerator heel point,

3) HCH - the horizontal distance from H-point to the center of the steering wheel,

4) HLH - the horizontal distance from H-point to the lower rim of the steering wheel.

Table 8 shows these dimensionalized seat positions corresponding to the detent positions in each of the vehicles.

STATURE AND SEAT POSITION

As previously indicated, there is a fairly good relation between stature and seat position, especially for vehicles with low G scores. It is tempting, therefore, to use stature as a predictor of seat travel range for population extremes. Fig. 14 shows scatter plots for POST seat position versus stature for the six vehicles along with the linear regression lines for the full sample of subjects* (solid line) and the

*Since 16 subjects (14 female and 2 male) did not drive the Fiesta and Rabbit, only 92 POST seat positions were obtained for these vehicles. In order for the full sample of 108 subjects to be used in regresssions and vehicle comparisons presented in the remainder of this report, the NBM seat positions, rounded to the nearest integer value, were substituted for the missing POST positions for these 16 subjects.

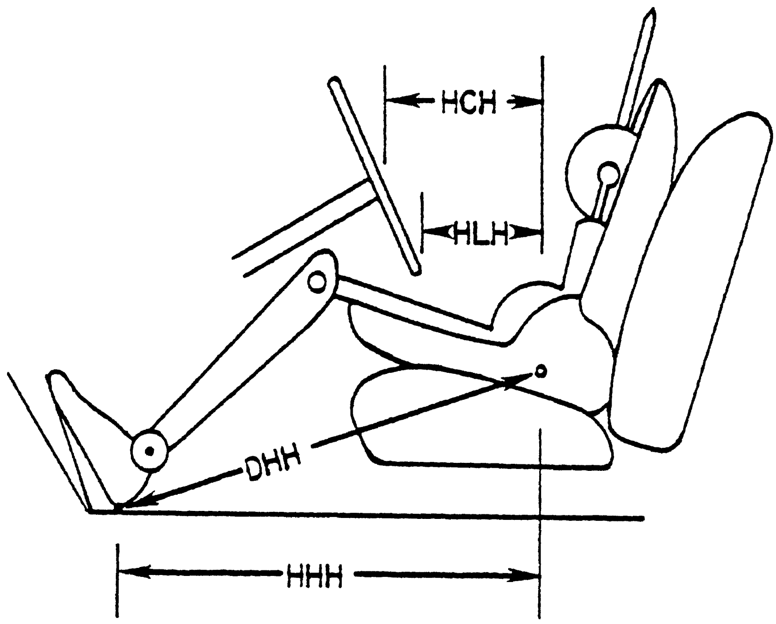

Fig. 13 - Seat position dimensions computed from vehicle measurements obtained by H-point machine techniques

TABLE 8 DIMENSIONALIZED SEAT POSITIONS*

Detent No.	Dodge Van				GM Van				Lemans				Fairmont				Fiesta				Rabbit				Detent No.
	HHH	DHH	HCH	HLH	HHH	DHH	HCH	HLH	HHH	DHH	HCH	HLH	HHH	DHH	HCH	HLH	HHH	DHH	HCH	HLH	HHH	DHH	HCH	HLH	
1	23.1	27.8	11.8	6.8	23.5	27.0	10.6	5.6	28.5	30.1	7.1	3.7	28.3	30.1	8.2	5.3	26.4	28.7	10.3	6.8	22.6	25.0	7.8	4.2	1
2	23.6	28.3	12.3	7.3	24.0	27.4	11.1	6.1	29.3	30.9	7.9	4.5	28.9	30.6	8.7	5.8	27.0	29.2	10.9	7.4	23.5	25.8	8.6	5.0	2
3	24.2	28.7	12.8	7.8	24.5	27.8	11.6	6.6	30.2	31.7	8.8	5.4	29.4	31.1	9.3	6.4	27.6	29.8	11.5	8.0	24.3	26.0	9.5	5.9	3
4	24.7	29.1	13.4	8.4	25.0	28.2	12.1	7.1	31.0	32.4	9.6	6.2	30.0	31.6	9.8	6.9	28.2	30.3	12.1	8.6	25.2	27.4	10.3	6.8	4
5	25.3	29.5	13.9	8.9	25.5	28.6	12.6	7.6	31.9	33.2	10.5	7.1	30.5	32.1	10.4	7.5	28.8	30.8	12.7	9.2	26.0	28.2	11.2	7.6	5
6	25.8	30.0	14.5	9.5	26.0	29.0	13.1	8.1	32.7	34.0	11.3	7.9	31.1	32.6	10.9	8.0	29.4	31.3	13.3	9.8	26.9	29.0	12.1	8.5	6
7	26.3	30.4	15.0	10.0	26.5	29.4	13.6	8.6	33.5	34.7	12.1	8.8	31.6	33.1	11.4	8.5	30.0	31.0	13.9	10.4	27.8	29.8	12.9	9.3	7
8	26.9	30.8	15.5	10.5	27.0	29.9	14.1	9.1	34.4	35.5	13.0	9.6	32.2	33.6	12.0	9.1	30.6	32.4	14.5	11.0	28.6	30.6	13.8	10.2	8
9	27.4	31.3	16.1	11.1	27.5	30.3	14.6	9.6	35.2	36.3	13.8	10.4	32.7	34.1	12.6	9.7	31.2	33.0	15.1	11.6	29.5	31.4	14.6	11.1	9
10	28.0	31.7	16.6	11.6	28.0	30.7	15.1	10.1					33.3	34.6	13.1	10.2					30.3	32.2	15.5	11.9	10
11	28.5	32.2	17.2	12.2	28.5	31.2	15.6	10.6					33.8	35.1	13.7	10.8									11

HHH = horizontal distance from H-point to heel point
DHH = diagonal distance from H-point to heel point
HCH = horizontal distance from H-point to center of steering wheel
HLH = horizontal distance from H-point to lower rim of steering wheel

*All dimensions in inches.

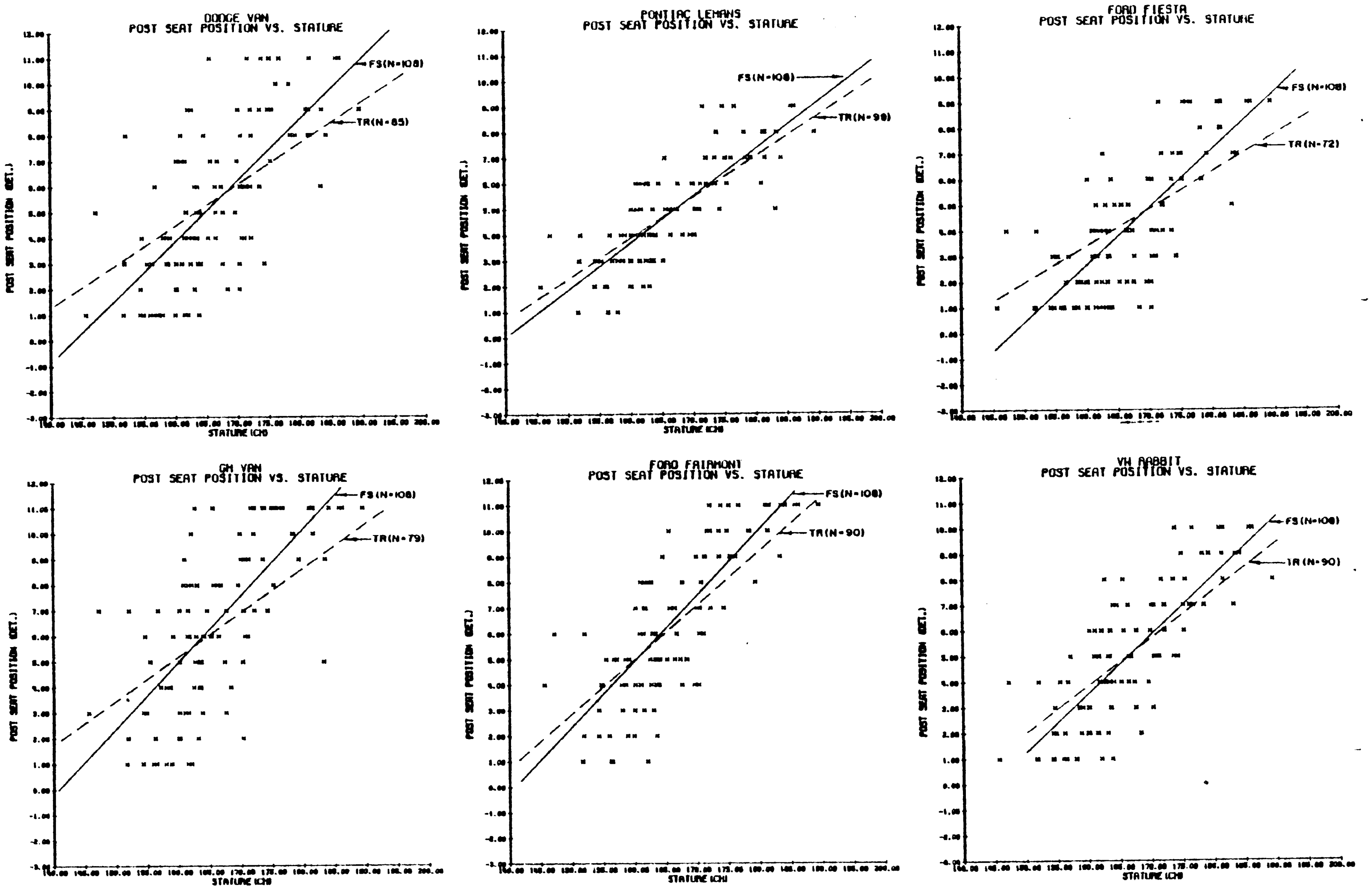

Fig. 14 - Scatter plots and linear regressions for POST seat positions versus stature. Solid line is regression for full sample, dashed line is for sample truncated by excluding subjects at end detents

reduced samples resulting from elimination of subjects in the first and last detents of a particular vehicle (dashed line). Several observations can be made from these data.

While it is true that shorter subjects tend to sit forward and taller subjects rearward, there is a fairly wide range of positions for any stature (i.e., the variation of both variables can be quite large). This latter fact is especially true for the vans, where, for example, for statures of 160-165 cm. (5'3" to 5'5") there are persons selecting positions throughout the seat travel range. For the Fiesta, and to a lesser extent for the other vehicles, there is a considerable range of statures for subjects selecting the full forward position.

Comparing the linear regression lines with the scatter plots, it is seen that the "fits" are rather poor for short and tall subjects. Tables 9A - 9J show the regression equations and the seat positions predicted for the 2.5 and 5th percentile stature females, and 95th and 97.5 percentile stature males for detent and dimensionalized seat positions. For the full sample and especially the truncated sample regressions, the predicted seat positions for these population extremes suggest that the seat track travel ranges for all the vehicles were nearly adequate, when in fact they were not. Furthermore, the regression equations for the truncated samples suggest smaller seat travel ranges than those for the full sample.

It is clear from these results that a linear equation does not adequately describe the relation between stature and seat position and that one cannot accurately predict seat track travel required for the population extremes using a linear model derived from mid-percentile stature

TABLE 9A - REGRESSION EQUATIONS FOR POST SEAT POSITION (DETENTS) ON STATURE (CM) FOR FULL SAMPLE (N=108) AND PREDICTED POSITIONS FOR POPULATION EXTREMES

		Predicted Position For Statures of:			
Vehicle	Equation	2.5%ile Female 148.8cm	5th%ile Female 151.4cm	95th%ile Male 186.9cm	97.5%ile Male 189.0cm
Dodge Van	P=.234(S)-33.5	1.3	1.9	10.2	10.7
GM Van	P=.254(S)-35.8	2.0	2.7	11.7	12.2
Lemans	P=.183(S)-25.6	1.6	2.1	8.6	9.0
Fairmont	P=.258(S)-36.4	2.0	2.7	11.8	12.4
Fiesta	P=.221(S)-32.7	.2	.8	8.6	9.1
Rabbit	P=.228(S)-33.0	.9	1.5	9.6	10.1

TABLE 9B - REGRESSION EQUATIONS FOR POST SEAT POSITION (DETENTS) ON STATURE (CM) FOR TRUNCATED SAMPLES AND PREDICTED POSITIONS FOR POPULATION EXTREMES

			Predicted Position For Statures of:			
Vehicle	N	Equation	2.5%ile Female 148.8cm	5thile Female 151.4cm	95th%ile Male 186.9cm	97.5%ile Male 189.0cm
Dodge Van	85	P=.159(S)-21.0	2.7	3.1	8.8	9.1
GM Van	79	P=.165(S)-21.2	3.3	3.8	9.6	10.0
Lemans	99	P=.160(S)-21.8	2.0	2.4	8.1	9.0
Fairmont	90	P=.216(S)-29.6	2.5	3.1	10.8	11.2
Fiesta	72	P=.142(S)-19.3	1.8	2.2	7.2	7.5
Rabbit	90	P=.180(S)-24.9	1.9	2.4	8.7	9.1

TABLE 9C - REGRESSION EQUATIONS FOR H-POINT TO HEEL POINT HORIZONTAL DISTANCE (HHH=INCHES) ON STATURE (CM) FOR FULL SAMPLE (N=108) AND PREDICTED HHH DISTANCES FOR POPULATION EXTREMES

		Predicted Distance for Statures of:			
Vehicle	Equation	2.5%ile Female 148.8cm	5th%ile Female 151.4cm	95th%ile Male 186.9cm	97.5%ile Male 189.0cm
Dodge Van	HHH=.126(S)+4.5	23.2	23.6	28.0	28.3
GM Van	HHH=.127(S)+5.1	24.0	24.3	28.8	29.1
Lemans	HHH=.153(S)+6.2	29.0	29.4	34.8	35.1
Fairmont	HHH=.142(S)+7.8	28.9	29.3	34.3	34.6
Fiesta	HHH=.133(S)+6.2	26.0	26.3	31.1	31.3
Rabbit	HHH=.195(S)-6.5	22.5	23.0	29.9	30.4

TABLE 9D - REGRESSION EQUATIONS FOR H-POINT TO HEEL POINT DIAGONAL DISTANCE (DHH=INCHES) ON STATURE (CM) FOR FULL SAMPLE (N=108) AND PREDICTED POSITIONS FOR POPULATION EXTREMES

		Predicted Distance for Statures of:			
Vehicle	Equation	2.5%ile Female 148.8cm	5th%ile Female 151.4cm	95th%ile Male 186.9cm	97.5%ile Male 189.0cm
Dodge Van	DHH=.101(S)+12.9	27.9	28.2	31.8	32.0
GM Van	DHH=.108(S)+11.4	27.5	27.8	31.6	31.8
Lemans	DHH=.141(S)+ 9.7	30.7	31.0	36.1	36.3
Fairmont	DHH=.128(S)+11.4	30.4	30.8	35.3	35.6
Fiesta	DHH=.117(S)+10.9	28.3	28.6	32.8	33.0
Rabbit	DHH=.181(S)- 1.9	25.0	25.5	31.9	32.3

TABLE 9E- REGRESSION EQUATIONS FOR H-POINT TO CENTER OF STEERING WHEEL HORIZONTAL DISTANCE (HCH=INCHES) ON STATURE (CM) FOR FULL SAMPLE (N=108) AND PREDICTED POSITIONS FOR POPULATION EXTREMES

		Predicted Distance For Stature of:			
Vehicle	Equation	2.5%ile Female 148.8cm	5th%ile Female 151.4cm	95th%ile Male 186.9cm	97.5%ile Male 189.0cm
Dodge Van	HCH=.126(S)- 6.9	11.8	12.1	16.6	16.9
GM Van	HCH=.127(S)- 7.8	11.1	11.4	15.9	16.2
Lemans	HCH=.153(S)-15.2	7.6	8.0	13.4	13.7
Fairmont	HCH=.142(S)-12.4	8.7	9.1	14.1	14.4
Fiesta	HCH=.133(S)- 9.9	9.9	10.2	14.9	15.2
Rabbit	HCH=.195(S)-21.3	7.7	8.2	15.1	15.6

TABLE 9F- REGRESSION EQUATIONS FOR H-POINT TO LOWER RIM OF STEERING WHEEL HORIZONTAL DISTANCE (HLH=INCHES) ON STATURE (CM) FOR FULL SAMPLE (N=108) AND PREDICTED POSITIONS FOR POPULATION EXTREMES

		Predicted Distances For Statures of:			
Vehicle	Equation	2.5%ile Female 148.8cm	5th%ile Female 151.4cm	95th%ile Male 186.9cm	97.5%ile Male 189.0cm
Dodge Van	HLH=.126(S)-11.8	6.9	7.3	11.7	12.0
GM Van	HLH=.127(S)-12.8	6.1	6.4	10.9	11.2
Lemans	HLH=.153(S)-17.8	5.0	5.4	10.8	11.1
Fairmont	HLH=.142(S)-15.3	5.8	6.2	11.2	11.5
Fiesta	HLH=.133(S)-13.4	6.4	6.7	11.5	11.7
Rabbit	HLH=.195(S)-24.9	4.1	4.6	11.5	12.0

TABLE 9G - REGRESSION EQUATIONS FOR H-POINT TO HEEL POINT HORIZONTAL DISTANCE (HHH=INCHES) ON STATURE (CM) FOR TRUNCATED SAMPLES AND PREDICTED POSITIONS FOR POPULATION EXTREMES

			Predicted Distance For Statures of:			
Vehicle	N	Equation	2.5%ile Female 148.8cm	5th%ile Female 151.4cm	95th%ile Male 186.9cm	97.5%ile Male 189.0cm
Dodge Van	85	HHH=.086(S)+11.2	24.0	24.2	27.3	27.5
GM Van	79	HHH=.083(S)+12.4	24.8	25.0	27.9	28.1
Lemans	99	HHH=.134(S)+ 9.4	29.3	29.7	34.4	34.7
Fairmont	90	HHH=.119(S)+11.5	29.2	29.5	33.7	34.0
Fiesta	72	HHH=.085(S)+14.2	26.8	27.1	30.1	30.3
Rabbit	90	HHH=.154(S)+ .45	27.4	27.8	33.3	33.6

TABLE 9H - REGRESSION EQUATIONS FOR H-POINT TO HEEL POINT DIAGONAL DISTANCE (DHH=INCHES) IN STATURE (CM) FOR TRUNCATED SAMPLES AND PREDICTED POSITIONS FOR POPULATION EXTREMES

			Predicted Distance For Statures of:			
Vehicle	N	Equation	2.5%ile Female 148.8cm	5th%ile Female 151.4cm	95th%ile Male 186.9cm	97.5%ile Male 189.0cm
Dodge Van	85	DHH=.069(S)+18.3	28.6	28.7	31.2	31.3
GM Van	79	DHH=.069(S)+17.6	27.9	28.0	30.5	30.6
Lemans	99	DHH=.123(S)+12.6	30.9	31.2	35.6	35.8
Fairmont	90	DHH=.108(S)+14.8	30.9	31.2	35.0	35.2
Fiesta	72	DHH=.075(S)+17.9	29.1	29.2	31.9	32.1
Rabbit	90	DHH=.143(S)+ 4.5	25.8	26.2	31.2	31.5

TABLE 9I - REGRESSION EQUATIONS FOR H-POINT TO CENTER OF STEERING WHEEL HORIZONTAL DISTANCE (HCH=INCHES) ON STATURE (CM) FOR TRUNCATED SAMPLES AND PREDICTED POSITIONS FOR POPULATION EXTREMES

			Predicted Distance For Statures of:			
Vehicle	N	Equation	2.5%ile Female 148.8cm	5th%ile Female 151.4cm	95th%ile Male 186.9cm	97.5%ile Male 189.0cm
Dodge Van	85	HCH=.086(S)- .1	12.7	12.9	16.0	16.2
GM Van	79	HCH-.083(S)- .5	11.9	12.1	15.0	15.2
Lemans	99	HCH=.134(S)-12.1	7.8	8.2	12.9	13.2
Fairmont	90	HCH=.119(S)- 8.7	9.0	9.3	13.5	13.8
Fiesta	72	HCH=.085(S)- 1.9	10.7	11.0	14.0	14.2
Rabbit	90	HCH=.154(S)-14.4	8.5	8.9	14.4	14.7

TABLE 9J - REGRESSION EQUATIONS FOR H-POINT TO LOWER RIM OF STEERING WHEEL HORIZONTAL DISTANCE (HLH=INCHES) ON STATURE (CM) FOR TRUNCATED SAMPLES AND PREDICTED POSITIONS FOR POPULATION EXTREMES

			Predicted Distance For Statures of:			
Vehicle	N	Equation	2.5%ile Female 148.8cm	5th%ile Female 151.4cm	95th%ile Male 186.9cm	97.5%ile Male 189.0cm
Dodge Van	85	HLH=.086(S)- 5.1	7.7	7.9	11.0	11.2
GM Van	79	HLH=.083(S)- 5.5	6.9	7.1	10.0	10.2
Lemans	99	HLH=.134(S)-14.6	5.3	5.7	10.4	10.7
Fairmont	90	HLH=.119(S)-11.6	6.1	6.4	10.6	10.9
Fiesta	72	HLH=.085(S)- 5.4	7.2	7.5	10.5	10.7
Rabbit	90	HLH=.154(S)-17.9	5.0	5.4	10.9	11.2

subjects sitting within a limited seat travel range. Those persons who choose to sit close-up or far-back seem to do so to a greater extent than a linear regression on mid-range stature and seat position suggests. Perhaps other factors come into play for the short and tall subjects, such as visibility over the dash and steering wheel and knee-steering wheel interference, which cause these people to sit closer or further back than the linear model predicts. It also seems that some persons choose to sit up-close or far-back more out of psychological or behavioral considerations (i.e., they feel they have better control, they are more relaxed, or it is "the" way to drive) than out of anthropometric considerations.

ESTIMATION OF SEAT POSITIONS FOR POPULATION EXTREMES FROM MEASURED DISTRIBUTIONS

It is clear from the distributions of seat positions in Fig. 10 that some subjects would have chosen to be further forward or further rearward if the seat travel range had been longer (i.e., the data are truncated). If it is assumed that these distributions are normal except for the "piling-up" of subjects at the first and last detents, the mean and standard deviation of the distributions for unlimited seat travel and therefore the seat positions that correspond to the extreme percentiles of the population can be estimated. That this assumption of normality is reasonable is supported by the data for the Le Mans, in which the seat travel seemed nearly adequate for the study sample and the resulting seat positions are fairly normally distributed. Two approaches were used for estimating the means and standard deviations based on this assumption of normality inside the end detents.

In the first approach which will be referred to as the "10th-tile" procedure, the 20th, 30th, 40th, 50th, 60th, 70th, and 80th percentiles of the POST seat position distribution were calculated for each vehicle. In order that the sample population more adequately represent the actual adult population by age/stature characteristics, the POST seat position data for each subject were weighted appropriately by factors resulting from Tables A-1 and A-3 in Appendix A. Since for a normal distribution, each percentile corresponds to a known number of standard deviations from the mean, and the mean is equal to the median or 50th percentile, the standard deviation of the total distribution can be estimated from these percentile computations by:

$$\bar{\sigma} = \frac{Xn-\bar{x}}{Zn}$$

where $\bar{x}$ = 50th %ile, Xn = nth %ile, and Zn = Z statistic for the nth %ile from a standard normal distribution table. Calculations of $\bar{\sigma}$ were made for the 20th, 30th, 40th, 60th, 70th, and 80th percentiles for each vehicle, and the average used as the standard deviation of the distributions.

In the second approach the procedure of Cohen (8) for estimating the mean and standard deviation of singly censored or truncated normal distributions was used. Since the POST distributions for the total sample size were often truncated at both ends, singly truncated distributions were created by separating males and females, computing the estimates for the means and standard deviations of these distributions, and combining the results. Appendix E presents a summary of the calculations made for the "Cohen" approach. Table 10 shows the estimated mean values for dimensionalized seat positions and the standard deviations obtained by these two approaches. In general, there is good agreement of results for these two procedures with the primary difference being in the results for the Dodge van. Since the results of the 10th-tile procedure are more consistent for all vehicles including the Dodge van, this procedure was used for computation of percentile extremes. Tables 11 and 12 show the population extreme percentile seat positions for detent and dimensionalized data respectively, and show the additional seat travel or number of seat track detents that would be required to accomodate 95 percent of the driving population.

COMPARISONS OF RESULTS ACROSS VEHICLES USING DIMENSIONALIZED SEAT POSITIONS

Fig. 15 compares the dimensionalized mean POST seat positions for the full sample of subjects estimated by the 10th-tile procedure (see Table 10) along with the seat travel ranges for the six vehicles. Examining the horizontal distance of H-point from the heel point (HHH), it is seen that, with the exception of the Rabbit, the relations are about as expected based on vehicle seat height (1, 9). That is, people tend to sit further back in vehicles where the seat height is lower. For the Rabbit, however, the mean horizontal distance is similar to the vans and, because the seat height is lower, the mean diagonal distance (DHH) is the smallest of all the vehicles. For the other five vehicles the mean DHH distances are in about the same relation as the mean HHH distance, except that the distance for the GM van is smaller than for the Dodge van due to its shorter seat height, and mean DHH distance in the Fiesta is only slightly greater than for the vans. Excluding the Rabbit again,

TABLE 10 - ESTIMATES OF THE MEANS AND STANDARD DEVIATIONS FOR DISTRIBUTIONS OF HHH, DHH, HCH, AND HLH POST DRIVE POSITIONS BASED ON THE METHOD OF COHEN AND COMPUTATION OF 10TH-ILES

		By Cohen					By 10th-Tiles				
		$\bar{X}$				$\bar{\sigma}$	$\bar{X}$				$\bar{\sigma}$
Vehicle	N	HHH	DHH	HCH	HLH		HHH	DHH	HCH	HLH	
Dodge Van	108	26.3	30.4	15.0	10.0	2.6	25.2	29.4	13.9	8.0	1.8
GM Van	108	26.4	29.3	13.5	8.5	2.1	26.2	29.2	13.3	8.3	1.9
Lemans	108	31.8	33.1	10.4	7.5	1.9	31.5	32.9	10.1	7.2	1.9
Fairmont	108	31.4	32.9	11.3	8.4	1.9	31.0	31.6	10.9	8.0	2.0
Fiesta	108*	28.1	30.2	12.0	8.5	2.0	27.9	30.5	11.8	8.3	1.7
Rabbit	108*	26.0	28.2	11.2	7.6	2.6	25.9	28.1	11.1	7.5	2.2

All dimensions in inches

*For 16 subjects who did not drive stick-shift, NBM seat positions rounded to nearest integer were used.

TABLE 11 - ESTIMATES OF POST-DRIVE SEAT POSITION MEANS, STANDARD DEVIATIONS, AND EXTREME PERCENTILES IN VEHICLE DETENTS BASED ON 20TH TO 80TH 10TH-TILE COMPUTATIONS AND ASSUMPTION OF NORMALITY FOR FULL SAMPLE (N=108) DISTRIBUTIONS

				Detent for Population Percentiles of:						Additional #'s of detents needed to accomodate 95% of population	
Vehicle	No.of Detents	Mean 50th%ile	$\bar{\sigma}$	2.5	5th	10th	90th	95th	97.5	Forward	Rearward
Dodge Van	11	4.9	3.4	-1.8	- .7	.5	9.3	10.5	11.6	3	1
GM Van	11	6.4	3.8	-1.0	.1	1.5	11.3	12.6	13.8	2	3
Lemans	9	4.6	2.3	.1	.8	1.7	7.5	8.4	9.1	1	0
Fairmont	11	5.9	3.7	-1.4	- .2	1.2	10.6	12.0	13.2	2	2
Fiesta	9	3.4	3.8	-2.1	-1.2	- .2	7.0	8.0	8.9	3	0
Rabbit	10	4.8	2.5	- .1	.6	1.6	8.0	8.9	9.7	1	0

TABLE 12 - ESTIMATES FOR PREFERRED HHH, HCH, AND HLH DISTANCES FOR POPULATION EXTREMES BASED ON ASSUMPTION OF NORMAL DISTRIBUTIONS IN SELECTED SEAT POSITION AND ESTIMATES OF MEANS AND STANDARD DEVIATION FROM 10TH-TILE COMPUTATIONS

			2.5 %ile			5th %ile			10th %ile			90th %ile			95th %ile			97.5 %ile			Additional Seat Travel Needed To Accomodate 95% Of Population (inches)	
Vehicle	$\bar{X}$	$\bar{\sigma}$	HHH	HCH	HLH	HHH	HCH	HLH	HHH	HCH	HLH	HHH	HCH	HLH	HHH	HCH	HLH	HHH	HCH	HLH	Forward	Rearward
Dodge Van	25.2	1.8	21.7	10.4	5.4	22.2	10.9	5.9	22.9	11.6	6.6	27.5	16.2	11.2	28.2	16.9	11.9	28.7	17.4	12.4	1.4	.2
GM Van	26.2	1.9	22.5	9.6	4.6	23.1	10.2	5.2	23.8	10.9	5.9	28.6	15.7	10.7	29.3	16.4	11.4	29.9	17.0	12.0	1.0	1.4
Lemans	31.5	1.9	27.8	6.4	3.0	28.4	7.0	3.6	29.1	7.7	4.3	33.9	12.5	9.1	34.6	13.2	9.8	35.2	13.8	10.4	.7	0
Fairmont	31.0	2.0	27.1	7.0	4.1	27.7	7.6	4.7	28.4	8.3	5.4	33.6	13.5	10.6	34.3	14.2	11.3	34.9	14.8	11.9	1.2	1.1
Fiesta	27.9	1.7	24.6	8.5	5.0	25.1	9.0	5.5	25.7	9.6	6.1	30.1	14.0	10.5	30.7	14.6	11.1	31.2	15.1	11.6	1.8	0
Rabbit	25.9	2.2	21.6	6.8	3.2	22.3	7.5	3.9	23.1	8.3	4.7	28.7	13.9	10.3	29.5	14.7	11.1	30.2	15.4	11.8	1.0	- .1

All distances in inches.

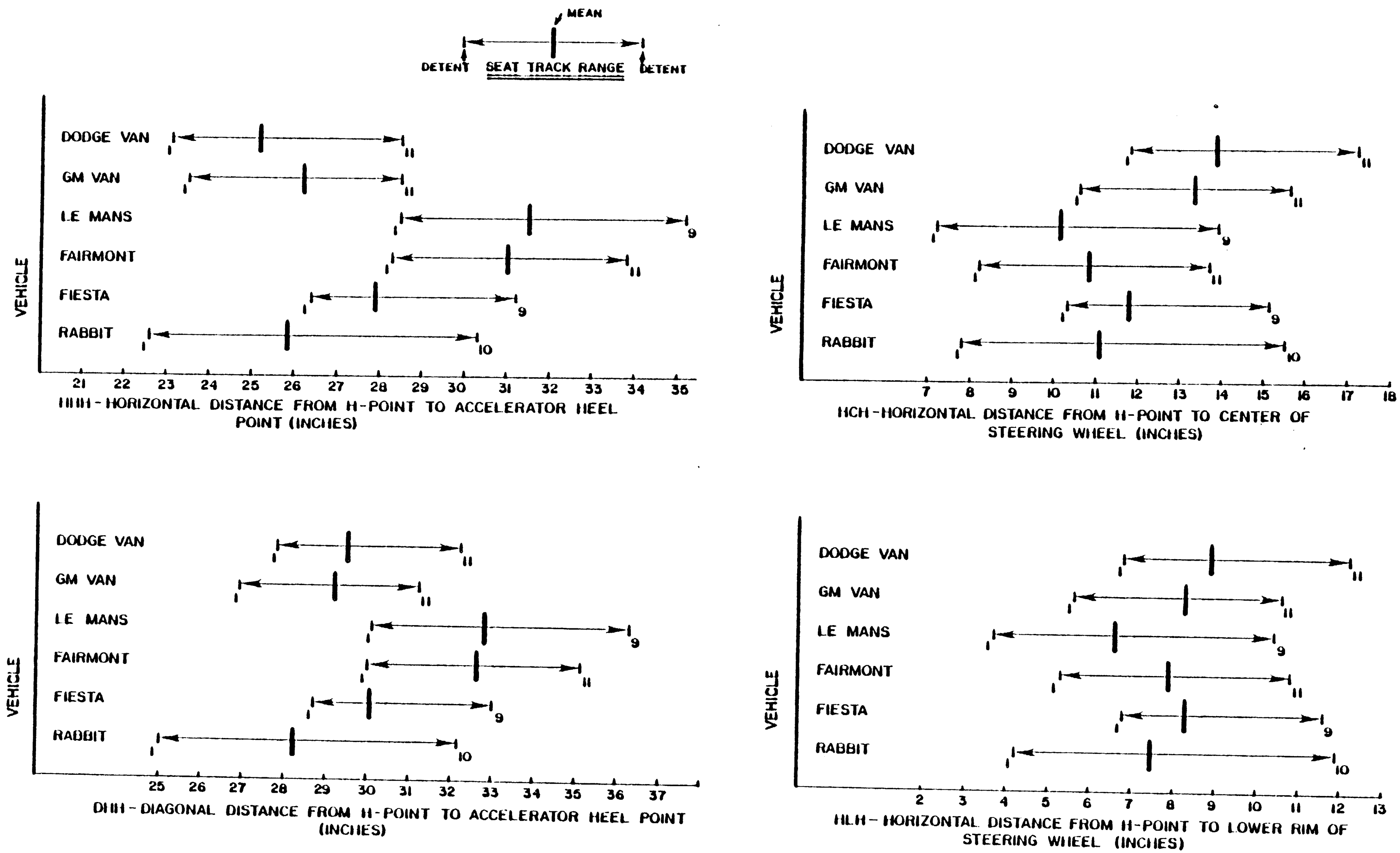

Fig. 15 - Comparisons across vehicles of dimensionalized seat track travel and mean POST seat positions for full sample of subjects

the range of mean HHH distances is 6.3 inches while the range of mean DHH distances is 3.7 inches. This indicates the tendency for people to maintain a similar "leg room" despite varying seat heights.

Looking at the mean distances to the steering wheel (HCH and HLH), the distances to the center of the wheel are all quite similar except for the vans. The larger distances for these vehicles are a result of the larger steering wheel tilt angles. The mean horizontal distances to the steering wheel lower rim (HLH) are similar for all six vehicles, with a range of only 1.1 inch. This suggests that while people try to position themselves for similar "leg room" in different vehicles, they are also strongly influenced by their interaction with the lower (and perhaps upper) rim of the steering wheel.

In this regard it is particularly interesting to examine the mean distances for the Rabbit. While subjects tended to sit closer than expected in terms of pedal location in this vehicle, they sat more toward the midrange of the vehicles in terms of steering wheel location. Thus, the relatively short mean distance to the pedals in the Rabbit can perhaps be explained by an overriding desire to get "close enough" to the steering wheel.

In a similar way, it is interesting to note that for the Le Mans the distances to the heel point (HHH and DHH) are greatest while the distances to the steering wheel (HCH and HLH) are smallest. This again may indicate the pedal/steering wheel interaction which takes place when selecting a seat position. In an attempt to get an appropriate distance away from the steering wheel (see item 1 of Table C-1), subjects may sit further back from the pedals than they otherwise would have. Yet, they may not move as far from the steering wheel as desired at the cost of getting too far from the pedals. Excluding the Le Mans, the range of mean HLH distances is reduced from 1.1 inch to .8 inch, an extremely small spread considering the different vehicle packaging factors.

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APPENDIX A

SUBJECT POOL COMPOSITION BY AGE/STATURE AND STATURE/WEIGHT GROUPINGS

Table A-1 - Age versus Stature Groupings for Males

Stature (cm.)	Age (yrs) A<30	30≤A<42	42≤A<55	A≥55	Row Totals
S<165.1	1 (1.5)*	2 (2)	4 (2.5)	5 (4)	12 (10)
165.1≤S<169.2	1 (2.5)	3 (2)	1 (2.5)	1 (3)	6 (10)
169.2≤S<172.5	3 (2.5)	2(2.5)	2 (2.5)	4(2.5)	11 (10)
172.5≤S<176.8	3 (2.5)	3 (3)	1 (2.5)	2 (2)	9 (10)
S≥176.8	5 (3.5)	5 (3)	2 (2.5)	1 (1)	13 (10)
Column Totals	13(12.5)	15(12.5)	10(12.5)	13(12.5)	51 (50)

*Numbers in parenthesis are based on proportions in U.S. population from 1960-1962 HEW Survey Data.

Table A-2 - Stature Versus Weight Groupings for Males

Weight (kg)	Stature (cm) S<165.1	165.1≤S<169.2	109.2≤S<172.5	172.5≤S<176.8	S≥176.8	Row Totals
W<66.4	7 (5.5)*	3 (4)	5 (3.5)	1 (3.5)	1 (1.5)	17 (17)
66.4≤W<76.8	3 (3)	1 (3.5)	2 (3.5)	3 (3.5)	4 (3)	13 (16.5)
W≥76.8	2 (1.5)	2 (2.5)	4 (3)	5 (4)	8 (5.5)	21 (16.5)
Column Totals	12 (10)	6 (10)	11 (10)	9 (10)	13 (10)	51 (50)

*Numbers in parentheses are based on proportions in U.S. population from 1960-1962 HEW Survey Data.

Table A-3 - Age versus Stature Groupings for Females

Stature (cm)	Age (yrs) A<30	30≤A<42	42≤A<55	A≥55	Row Totals
S<156.0	1 (1.6)*	2 (1.8)	3 (2.5)	6 (4.0)	12 (10)
156.0≤S<159.3	4 (2.2)	1 (2.2)	2 (2.5)	2 (3.1)	9 (10)
159.3≤S<162.6	2 (2.3)	5 (2.5)	5 (2.8)	3 (2.4)	15 (10)
162.6≤S<166.4	1 (2.9)	3 (2.9)	2 (2.4)	4 (1.8)	10 (10)
S≥166.4	4 (3.5)	3 (3.1)	3 (2.2)	1 (1.2)	11 (10)
Column Totals	12 (12.5)	14 (12.5)	15 (12.5)	16 (12.5)	57 (50)

*Numbers in parenthesis are based on proportions in U.S. population from 1960-1962 HEW Survey Data.

Table A-4 - Stature versus Weight Groupings for Females

Weight (kg)	Stature (cm) S<156.0	156.0≤S<159.3	159.3≤S<162.6	162.6≤S<166.4	S≥166.4	Row Totals
W<57.7	6 (4.3)*	7 (3.0)	9 (3.4)	1 (3.0)	0 (2.3)	23 (16.6)
57.7≤W<67.3	3 (3.1)	1 (3.1)	3 (3.1)	6 (3.5)	4 (3.9)	17 (16.7)
W≥67.3	3 (2.6)	1 (3.3)	3 (3.5)	3 (3.5)	7 (3.8)	17 (16.7)
Column Totals	12 (10)	9 (10)	15 (10)	10 (10)	11 (10)	(50)

*Numbers in parentheses are based on proportion in U.S. population from 1960-1962 HEW Survey Data.

APPENDIX B

VEHICLE DIMENSIONAL DATA

Table B-1 - Vehicle Dimensional Data Using SAE J826 H-Point Machine

Dimension*	Dodge Van	GM Van	Le Mans	Fairmont	Fiesta	Rabbit
L53	28.5	28.5	35.2	33.8	31.2	30.3
H30	15.0	12.6	8.8	9.2	10.6	10.3
L11	11.4	12.9	21.4	20.2	16.1	14.3
H17	27.6	26.8	24.0	23.7	25.9	25.5
W9	14.8	16.0	15.2	15.5	14.7	15.0
H18	42°	39°	19.5°	22°	28.4	28.5
L40	20°	17.5°	26.8°	25°	24°	24°
L42	94°	85°	98.8°	94.7°	90°	90°
L44	109.5°	105°	130.4°	123.5°	110°	110°
L46	87°	87°	87°	87°	87°	87°
L17	5.4	5.0	6.7	5.5	4.8°	7.7
H58	0.6	0.6	1.0	.93	0.7	0.0
G	.27	.14	-.84	-.74	-.41	-.36
Detents	11	11	9	11	9	10

*See Table B-2 for definitions.

Table B-2 - Dimension Definitions Using SAE J826 H-Point Machine(9)

L53 - Horizontal distance from H-point to accelerator heel point

H30 - Vertical distance from H-point to accelerator heel point

L11 - Horizontal distance from accelerator heel point to center of steering wheel

H17 - Vertical distance from accelerator heel point to center of steering wheel

W9 - Steering wheel maximum outside diameter

H18 - Steering wheel angle from vertical

L40 - Back angle from vertical

L42 - Hip angle between torso line and thigh center line

L44 - Knee angle between thigh centerline and lower leg centerline

L46 - Foot angle between lower leg center line and line tangent to ball and heel of the H-point machine bare foot

L17 - Horizontal distance between H-points in frontmost and rearmost seat positions

G - General Package Factor, the principal factor highly correlated with nine workspace dimensions

H58 - Vertical distance between H-points from rearmost to frontmost seat positions

APPENDIX C

VEHICLE EVALUATION FORM AND FINAL QUESTIONNAIRE RESULTS

TABLE C-1 - SUMMARY OF POST-DRIVE EVALUATION FORM RESPONSES

	Percent of Subjects					
Item	Dodge Van	GM Van	Le Mans	Fairmont	Fiesta	Rabbit
1. Steering wheel too close	.6	1.8	23.4	7.6	6.4	4.4
2. Steering wheel too far	17.2	9.2	1.8	2.2	11.9	7.2
3. Top of steering wheel rim too high	4.2	4.5	22.8	0	1.6	8.5
4. Bottom of steering wheel rim too low	5.3	5.6	5.0	14.4	22.1	14.7
5. Brake pedal too close	16.8	37.0	5.1	5.1	11.4	15.5
6. Brake pedal too far	3.8	.6	5.3	1.2	3.7	3.8
7. Gas pedal too close	8.3	6.6	1.7	2.0	11.2	6.5
8. Gas pedal too far	3.4	9.0	6.7	1.5	.8	2.4
9. Too little foot space	13.2	11.8	4.7	5.2	18.9	20.2
10. Steering wheel angle too flat	11.1	8.8	5.7	0	1.7	1.0
11. Steering wheel angle too tilted	5.2	8.0	23.2	11.2	9.6	9.7
12. Forward seat adjustment not enough	6.6	5.3	6.8	7.0	9.3	11.1
13. Rearward seat adjustment not enough	1.0	7.2	3.1	6.9	6.5	2.7
14. Seat angle too upright	12.4	18.8	4.8	10.0	10.4	13.1
15. Seat back angle too reclined	11.5	10.1	15.4	8.2	15.4	15.9
16. Seat cushion too high	10.8	8.3	0	1.2	4.0	4.5
17. Seat cushion too low	1.5	3.1	14.5	12.3	9.9	9.2
18. Seat cushion too long	5.0	4.1	1.4	2.3	4.3	7.4
19. Seat cushion too short	6.7	9.1	6.2	7.6	5.2	6.1
20. Seat cushion front too high	4.4	6.1	3.5	1.2	3.8	14.1
21. Seat cushion front too low	2.0	3.9	12.3	11.8	10.1	4.2

Table C-2 - Subject Rankings of Vehicles By Seat Accommodation For Driving

	Percent of Subjects					
Rank Order	Dodge Van	GM Van	Le Mans	Fairmont	Fiesta*	Rabbit*
1st	9.3	7.3	41.1	23.2	10.8	8.3
2nd	8.8	13.9	22.2	30.5	9.7	14.8
3rd	22.6	30.4	8.7	13.9	14.3	10.2
4th	26.6	16.0	13.5	18.7	11.4	13.8
5th	20.5	20.0	4.9	10.7	20.6	23.3
6th	16.5	16.6	11.5	4.8	27.2	23.5

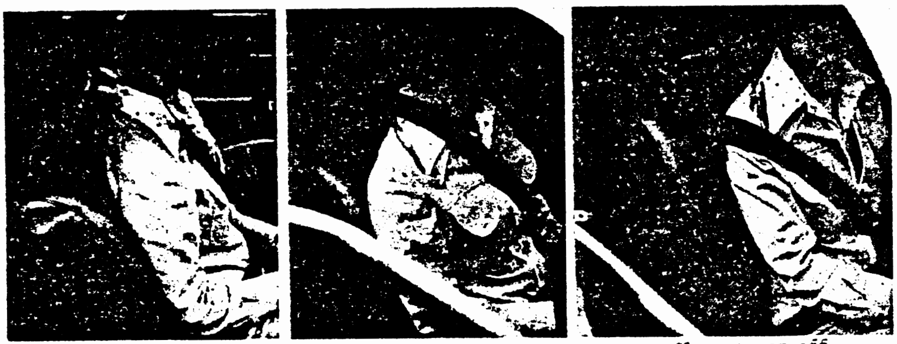
*Sample sizes for Rabbit and Fiesta are smaller than other vehicles

TABLE C-3 - SHOULDER HARNESS ACCOMMODATION RESULTS

	Accomodation Factor*	Percent of Subjects Driving Vehicle			
		LeMans	Fairmont	Fiesta	Rabbit
1.	Excellent	44.1	39.5	42.2	11.2
2.	Good but toward neck	17.3	23.9	19.1	7.7
3.	Good but toward shoulder	17.9	14.0	8.1	20.2
4.	Loss of upper torso contact	.9	5.6	2.4	19.1
5.	Close to or on neck	10.7	12.1	7.4	1.3
6.	Close to or on shoulder	7.3	4.9	8.3	36.2
7.	High on chest	1.8	0	5.4	4.4
8.	Below plane of shoulder	0	0	7.1	0
9.	Interferes with seat back or head restraint	0	0	0	0

*See Figure C-1 for illustrations

1. Excellent
2. Good, with tendency toward neck
3. Good, with tendency toward shoulder



4. Loss of upper torso contact
5. Close to or on neck
6. Close to or off shoulder

7. Rides high across chest
8. Below horizontal plane of shoulder
9. Seat back or head restraint interference with shoulder harness

Fig. C-1 - Shoulder Harness Accomodation Ratings

TABLE C-4 - SUMMARY OF FINAL QUESTIONNAIRE RESULTS

1) Number of Years Driving Experience

	N	Mean	S.D.
Males	51	26.4	17.2
Females	57	26.0	15.3
Total	108	26.2	16.1

2) Miles Driven Per Year

	N	Mean	S.D.
Males	51	15,696	14,894
Females	57	7,212	5,533
Total	108	11,219	11,738

3) Percent of Subjects Who Drive Vehicle Most Similar To:

	Percent		Percent
Dodge Van	1.9	Fairmont	32.4
GM Van	2.8	Fiesta	10.2
Le Mans	33.3	Rabbit	19.4

4) Approximately 11% of the subjects usually drove a rental vehicle three or more times per year.

5) Only 8.4% of the subjects said that they never (1.9%) or seldom (6.5%) adjusted the seat before driving a vehicle not their own. While 91.6% said they usually (44.4%) or always (47.2%) adjusted the seat.

6) 49.1% of the subjects said that they always fastened the seat belts on a short drive while 29.6% said they seldom would and 21.3% said they never would.

APPENDIX D

TABULATION OF PAIRED T-TEST RESULTS FOR STATIC (NBM) VERSUS DYNAMIC (POST) SEAT POSITION COMPARISONS

Table D-1 - Summary of Paired T-Test Statistics for Dodge Van

Test*	N	Mean Diff.	Std.Div.	Signif.
NBM-WBM	49	.18	.76	.09
NBM-PRE	108	.30	1.4	.03
NBM-POST	108	.03	1.4	.84
NBF-NBR	108	-.21	.76	.005
WBM-PRE	49	-.09	1.4	.64
WBM-POST	49	-.11	1.5	.60
PRE-POST	108	-.26	.81	.001
NBF-WBM	49	.12	.81	.30
NBF-POST	108	-.08	1.5	.59

Table D-2 - Summary of Paired T-Test Statistics for GM Van

Test*	N	Mean Diff.	Std. Dev.	Signif.
NBM-WBM	49	.13	.91	.33
NBM-PRE	108	.13	1.67	.40
NBM-POST	108	-.09	1.69	.59
NBF-NBR	108	-.3	.82	.000
WBM-PRE	49	-.22	1.53	.31
WBM-POST	49	-.37	1.68	.13
PRE-POST	108	-.22	1.03	.03
NBF-WBM	49	-.05	.97	.72
NBF-POST	108	-.24	1.8	.16

Table D-3 - Summary of Paired T-Test Statistics for Pontiac Le Mans

Test	N	Mean Diff.	Std. Dev.	Signif.
NBM-WBM	49	.19	.48	.008
NBM-PRE	108	.42	.81	.000
NBM-POST	108	.35	.74	.000
NBF-NBR	108	-.31	.49	.000
WBM-PRE	49	.10	.92	.44
WBM-POST	49	.10	.92	.44
PRE-POST	108	-.06	.57	.24
NBF-WBM	49	.02	.49	.77
NBF-POST	108	.19	.79	.01

Table D-4 - Summary of Paired T-Test Statistics for Ford Fairmont

Test	N	Mean Diff.	Std. Dev.	Signif.
NBM-WBM	49	.34	.83	.007
NBM-PRE	108	.54	1.15	.000
NBM-POST	108	.45	1.18	.000
NBF-NBR	108	-.32	.62	.000
WBM-PRE	49	-.04	1.31	.82
WBM-POST	49	-.04	1.50	.85
PRE-POST	108	-.09	.66	.15
NBF-WBM	49	.15	.86	.22
NBF-POST	108	.29	1.24	.02

Table D-5 - Summary of Paired T-Test Statistics for Ford Fiesta

Test	N	Mean Diff.	Std. Dev.	Signif.
NBM-WBM	49	.06	.57	.454
NBM-PRE	92	.39	1.16	.002
NBM-POST	92	.47	1.04	.000
NBF-NBR	108	-.15	.63	.016
WBM-PRE	40	.26	1.26	.194
WBM-POST	40	.33	1.03	.046
PRE-POST	92	.08	.65	.265
NBF-WBM	49	-.02	.57	.80
NBF-POST	92	.41	1.1	.000

Table D-6 - Summary of Paired T-Test Statistics for VW Rabbit

Test	N	Mean Diff.	Std. Dev.	Signif.
NBM-WBM	49	.16	.57	.058
NBM-PRE	92	.35	1.15	.004
NBM-POST	92	.33	1.12	.006
NBF-NBR	108	-.33	.74	.000
WBM-PRE	40	-.01	1.09	.94
WBM-POST	40	-.06	1.17	.74
PRE-POST	92	-.02	.74	.78
NBF-WBM	49	.06	.63	.49
NBF-POST	92	.17	1.1	.15

APPENDIX E

APPLICATION OF COHEN PROCEDURE FOR EXTIMATING THE MEANS AND STANDARD DEVIATIONS OF DISTRIBUTIONS IN POST-DRIVE SEAT POSITIONS

In his paper "Simplified Estimators for the Normal Distribution When Samples are Singly Censored or Truncated"(8), A. Clifford Cohen,Jr. outlines a procedure and presents a table for estimating means and standard deviations of normal distributions where, for experimental reasons, some of the sampled data at the ends of the distribution are either excluded (truncated) or counted but not observed (censored).

In this study the limitations in seat track travel for the different vehicles results in the situation of censored data at either or both ends of the post-drive seat position distribuion. That is, for many of the measurements at the first and last detents, the data are counted but not actually observed since some of the subjects would probably have selected closer or further back positions had the seat travel been extended. Since the exact number of subjects at the end detents who would have chosen other positions is not known, all the subjects choosing end detent positions must be considered censored. It is also apparent from Figure 10 that, for the total sample of subjects, many of the distributions should be considered censored at both ends rather than singly sensored. If, however, the males and females are taken separately for each vehicle, then the distributions by sex can be considered singly censored. Figure E-1 illustrates this point showing the post-drive seat position distributions (by detent) for all subjects and males and females separately. Using the procedures outlined by Cohen and values obtained from his Table 2 (Table E-1), values for the means and standard deviations of the post-drive distributions by sex were calculated. Tables E-2 through E-7 illustrate the values used and calculated in working through this procedure for seat position as a function of H-

	DETENT	ALL SUBJECTS	FEMALES	MALES
DODGE VAN	1.0000	14	13	1
	2.0000	7	5	2
	3.0000	13	6	7
	4.0000	16	12	4
	5.0000	8	4	4
	6.0000	11	4	7
	7.0000	7	3	4
	8.0000	10	5	5
	9.0000	11	4	7
	10.000	2	1	1
	11.000	9	0	9
GM VAN	1.0000	8	8	0
	2.0000	6	3	3
	3.0000	10	8	2
	4.0000	9	5	4
	5.0000	9	7	2
	6.0000	12	8	4
	7.0000	11	5	6
	8.0000	9	5	4
	9.0000	7	2	5
	10.000	6	1	5
	11.000	21	5	16
LEMANS	1.0000	3	3	0
	2.0000	9	7	2
	3.0000	20	16	4
	4.0000	20	13	7
	5.0000	17	8	9
	6.0000	14	7	7
	7.0000	12	3	9
	8.0000	7	0	7
	9.0000	6	0	6
FAIRMONT	1.0000	4	3	1
	2.0000	6	6	0
	3.0000	7	6	1
	4.0000	18	13	5
	5.0000	13	8	5
	6.0000	10	6	4
	7.0000	11	6	5
	8.0000	8	3	5
	9.0000	8	2	6
	10.000	9	2	7
	11.000	14	2	12
FIESTA	1.0000	23	17	6
	2.0000	12	7	5
	3.0000	10	3	7
	4.0000	13	6	7
	5.0000	9	4	5
	6.0000	6	4	2
	7.0000	6	1	5
	8.0000	3	0	3
	9.0000	9	0	9
RABBIT	1.0000	9	8	1
	2.0000	9	6	3
	3.0000	11	8	3
	4.0000	11	7	4
	5.0000	14	3	11
	6.0000	10	4	6
	7.0000	11	6	5
	8.0000	6	1	5
	9.0000	5	0	5
	10.000	6	0	6

Fig. E-1 - Distributions of Post-Drive Seat Positions for All Subjects and Males and Females Separately

TABLE E-1 - SIMPLIFICATION ESTIMATORS (λ) FOR NORMAL DISTRIBUTION.. FROM COHEN(8)

Auxiliary estimation function, λ, for singly censored samples

$\epsilon = s^2/(\bar{x} - x_0)^2$ \ h	.01	.02	.03	.04	.05	.10	.15	.20	.25	.30	.35	.40	.45	.50
.00	.0101	.0204	.0309	.0416	.05245	.1102	.1734	.2427	.3185	.4021	.4941	.5961	.7096	.8368
.05	.01055	.02120	.03222	.04334	.05467	.1143	.1793	.2503	.3279	.4130	.5066	.6101	.7251	.8539
.10	.01095	.02208	.03340	.04490	.05659	.1180	.1848	.2574	.3366	.4233	.5184	.6234	.7400	.8703
.15	.01131	.02280	.03440	.04632	.05836	.1215	.1898	.2640	.3448	.4329	.5290	.6361	.7542	.8860
.20	.01164	.02340	.03545	.04763	.05999	.1247	.1940	.2703	.3525	.4422	.5403	.6483	.7678	.9012
.25	.01195	.02408	.03638	.04886	.06152	.1277	.1991	.2763	.3599	.4510	.5506	.6600	.7810	.9158
.30	.01224	.02466	.03725	.05002	.06297	.1306	.2034	.2819	.3670	.4595	.5604	.6712	.7937	.9299
.35	.01252	.02521	.03808	.05112	.06434	.1333	.2075	.2874	.3738	.4676	.5699	.6821	.8060	.9437
.40	.01278	.02574	.03887	.05217	.06566	.1360	.2114	.2926	.3803	.4755	.5791	.6927	.8179	.9570
.45	.01304	.02624	.03962	.05318	.06692	.1385	.2152	.2976	.3866	.4831	.5880	.7029	.8295	.9700
.50	.01328	.02673	.04035	.05415	.06813	.1409	.2188	.3025	.3928	.4904	.5967	.7129	.8407	.9826
.55	.01351	.02720	.04105	.05509	.06930	.1432	.2223	.3073	.3987	.4976	.6051	.7225	.8517	.9949
.60	.01374	.02765	.04173	.05600	.07044	.1455	.2558	.3118	.4045	.5016	.6133	.7320	.8625	1.0070
.65	.01396	.02809	.04239	.05687	.07154	.1477	.2291	.3163	.4101	.5114	.6213	.7412	.8730	1.0188
.70	.01417	.02851	.04303	.05773	.07260	.1499	.2323	.3206	.4156	.5180	.6291	.7502	.8832	1.0303
.75	.01438	.02893	.04365	.05856	.07364	.1520	.2355	.3249	.4209	.5244	.6367	.7590	.8932	1.0416
.80	.01458	.02933	.04426	.05936	.07465	.1540	.2386	.3290	.4261	.5308	.6441	.7676	.9031	1.0527
.85	.01478	.02972	.04485	.06015	.07564	.1560	.2416	.3331	.4312	.5370	.6514	.7761	.9127	1.0636
.90	.01497	.03011	.04542	.06092	.07660	.1580	.2445	.3370	.4362	.5430	.6586	.7844	.9222	1.0742
.95	.01515	.03048	.04599	.06167	.07755	.1599	.2474	.3409	.4411	.5490	.6656	.7925	.9314	1.0847
1.00	.01531	.03085	.04654	.06241	.07847	.1617	.2502	.3447	.4459	.5548	.6725	.8005	.9406	1.0951

In type II censored samples, x_0 is replaced with x_n.

point to heel point horizontal distance (HHH).

In order to obtain the mean and standard deviations of the total distributions, the means and standard deviations for the distributions by sex must be combined by using the appropriate relations. The mean of the total sample ($\bar{x}_T$) can be calculated directly using the equation:

$$(1) \qquad \bar{x}_T = \frac{N_m \cdot \bar{x}_m + N_f \cdot \bar{x}_f}{N_m + N_f}$$

where N_m, N_f, $\bar{x}_m$ and $\bar{x}_f$ are the sample sizes and means of the male and female samples respectively.

Calculation of the full sample standard deviation can be determined using the equation:

$$(2) \qquad \bar{\sigma}^2 = \frac{\sum_{i=1}^{N} x_i^2 - \left(\sum_{i=1}^{N} x_i\right)^2 / N}{N-1}$$

where x_i are the observed seat positions, $\bar{\sigma}^2$ is the estimated variance, and $\bar{\sigma}$ is the estimated standard deviation. While the x_i are not all known (since the data are censored), the quantity Σx_i can be determined from the relation:

$$(3) \qquad \Sigma x_i = N\bar{x}$$

which gives:

$$(4) \qquad \frac{(\Sigma xi)^2}{N} = N\bar{x}^2$$

Since $\overline{x}$, $\overline{\sigma}$, and N are known for the distributions by sex, the quantities $\sum_{i=1}^{N} x_i^2$ can be calculated from equation (2) for males and females separately:

$$(5) \qquad \sum_{i=1}^{N_m} x_{im}^2 = (N-1)\ \overline{\sigma}_m^2 + N_m\ \overline{x}_m^2$$

$$(6) \qquad \sum_{i=1}^{N_f} x_{if}^2 = (N-1)\ \overline{\sigma}_f^2 + N_f\ \overline{x}_f^2$$

The value of $\sum_{i=1}^{N} x_i^2$ for the total sample is simply the sum of these quantities for both sexes:

$$(7) \qquad \sum_{i=1}^{N_T} x_i^2 = \sum_{i=1}^{N_f} x_{if}^2 + \sum_{i=1}^{N_m} x_{im}^2$$

where $N_T = N_m + N_f$.

Since the mean of the total sample is known from equation (1) the only unknown in equation (2) for the total sample size is $\overline{\sigma}_T^2$ which can then be calculated.

$$(8) \qquad \overline{\sigma}_T^2 = \frac{\sum_{i=1}^{N_f} x_{if}^2 + \sum_{i=1}^{N_m} x_{im}^2 - N_T\ \overline{x}_T^2}{N_T - 1}$$

Performing these calculations using the results shown in Tables E-2 through E-7 results in the total sample means and standard deviations for post-drive seat positions (H-point to heel point) shown in Table 10.

TABLE E 2 - SUMMARY OF CALCULATIONS USED FOR COMPUTING ESTIMATES OF MEANS AND STANDARD DEVIATIONS BY COHEN PROCEDURE

Vehicle Dodge Van

		Males	Females
Sample Size	N	51	57
Censored Portion	N_c	9	13
Observed Portion	N_o	42	44
Value Censored	X_c	28.5	23.1
Mean of Observed Sample	$\bar{X}_o$	25.7	25.3
Variance of Observed Sample	$\bar{\sigma}_o^2$	1.72	1.56
del = $\bar{X}_o - X_c$		-2.8	2.2
Var/(del)^2		.2194	.3223
$h = N_c/N$		.1765	.228
λ (from Cohen Table 2)		.2367	.3324
Estimated Mean $\bar{X} = \bar{X}_o - \lambda \cdot (\text{del})$		28.26	24.57
Estimated Variance $V = \bar{\sigma}_o^2 + \lambda \cdot (\text{del})^2$		3.57	3.17
Estimated Standard Deviation $\bar{\sigma} = \sqrt{V}$		1.89	1.78

TABLE E3 - SUMMARY OF CALCULATIONS USED FOR COMPUTING ESTIMATES OF MEANS AND STANDARD DEVIATIONS BY COHEN PROCEDURE

Vehicle GM Van

		Males	Females
Sample Size	N	51	57
Censored Portion	N_c	16	8
Observed Portion	N_o	35	49
Value Censored	X_c	28.5	23.5
Mean of Observed Sample	$\overline{X}_o$	26.3	26.0
Variance of Observed Sample	$\overline{\sigma}_o^2$	1.60	1.72
del = $\overline{X}_o - X_c$		-2.2	2.5
Var/(del)^2		.3306	.275
$h = N_c/N$		.3137	.1403
λ (from Cohen Table 2)		.4923	.1872
Estimated Mean $\overline{X} = \overline{X}_o - \lambda \cdot$(del)		27.38	25.53
Estimated Variance $V = \overline{\sigma}_o^2 + \lambda \cdot$(del)^2		3.98	2.89
Estimated Standard Deviation $\overline{\sigma} = \sqrt{V}$		1.99	1.7

TABLE E4 - SUMMARY OF CALCULATIONS USED FOR COMPUTING ESTIMATES OF MEANS AND STANDARD DEVIATIONS BY COHEN PROCEDURE

Vehicle Le Mans

		Males	Females
Sample Size	N	51	57
Censored Portion	N_c	6	3
Observed Portion	N_o	45	54
Value Censored	X_c	35.2	28.5
Mean of Observed Sample	$\overline{X}_o$	32.31	31.03
Variance of Observed Sample	$\overline{\sigma}_o^2$	2.12	1.42
del $= \overline{X}_o - X_c$		-2.89	2.53
Var/(del)^2		.2538	.2218
$h = N_c/N$		.1176	.0526
λ (from Cohen Table 2)		.1530	.0640
Estimated Mean $\overline{X} = \overline{X}_o - \lambda \cdot$(del)		32.75	30.87
Estimated Variance $V = \overline{\sigma}_o^2 + \lambda \cdot$(del)^2		3.398	1.83
Estimated Standard Deviation $\overline{\sigma} = \sqrt{V}$		1.84	1.35

TABLE E 5 - SUMMARY OF CALCULATIONS USED FOR COMPUTING ESTIMATES OF MEANS AND STANDARD DEVIATIONS BY COHEN PROCEDURE

Vehicle Fairmont

		Males	Females
Sample Size	N	57	57
Censored Portion	N_c	12	3
Observed Portion	N_o	39	54
Value Censored	X_c	38.8	28.3
Mean of Observed Sample	$\overline{X}_o$	31.64	30.69
Variance of Observed Sample	$\overline{\sigma}_o^2$	1.695	1.703
del = $\overline{X}_o - X_c$		-2.16	2.39
Var/(del)^2		.3633	.2982
$h = N_c/N$		.2353	.0526
λ (from Cohen Table 2)		.3500	.06738
Estimated Mean $\overline{X} = \overline{X}_o - \lambda \cdot$(del)		32.396	30.53
Estimated Variance $V = \overline{\sigma}_o^2 + \lambda \cdot$(del)^2		3.33	2.087
Estimated Standard Deviation $\overline{\sigma} = \sqrt{V}$		1.82	1.44

TABLE E 6 - SUMMARY OF CALCULATIONS USED FOR COMPUTING ESTIMATES OF MEANS AND STANDARD DEVIATIONS BY COHEN PROCEDURE

Vehicle Fiesta

		Males	Females
Sample Size	N	51	57
Censored Portion	N_c	9	19
Observed Portion	N_o	42	38
Value Censored	X_c	31.2	26.4
Mean of Observed Sample	$\overline{X}_o$	28.3	28.3
Variance of Observed Sample	$\overline{\sigma}_o^2$	1.748	1.281
del = $\overline{X}_o - X_c$		-2.9	1.9
Var/(del)^2		.2078	.3548
$h = N_c/N$		.1765	.3333
λ (from Cohen Table 2)		.2355	.5365
Estimated Mean $\overline{X} = \overline{X}_o - \lambda \cdot (\text{del})$		28.99	27.28
Estimated Variance $V = \overline{\sigma}_o^2 + \lambda \cdot (\text{del})^2$		3.73	3.217
Estimated Standard Deviation $\overline{\sigma} = \sqrt{V}$		1.93	1.79

TABLE E 7 - SUMMARY OF CALCULATIONS
USED FOR COMPUTING ESTIMATES OF MEANS
AND STANDARD DEVIATIONS BY COHEN PROCEDURE

Vehicle Rabbit

		Males	Females
Sample Size	N	51	57
Censored Portion	N_c	6	10
Observed Portion	N_o	45	47
Value Censored	X_c	30.3	22.6
Mean of Observed Sample	$\bar{X}_o$	26.6	25.6
Variance of Observed Sample	$\bar{\sigma}_o^2$	3.39	2.81
del = $\bar{X}_o - X_c$		-3.7	3.0
Var/(del)^2		.2476	.3122
$h = N_c/N$		.1176	.1754
λ (from Cohen Table 2)		.1526	.2444
Estimated Mean $\bar{X} = \bar{X}_o - \lambda \cdot (del)$		27.16	24.87
Estimated Variance $V = \bar{\sigma}_o^2 + \lambda \cdot (del)^2$		5.479	5.01
Estimated Standard Deviation $\bar{\sigma} = \sqrt{V}$		2.34	2.24