January 1984
Final Report

DOT-HS-806 628

US Department of Transportation
National Highway Traffic Safety Administration

EFFECTS OF SIDE IMPACT PADDING ON DRIVER PERFORMANCE

A. Stephen Baum
Valerie J. Gawron
Kenneth N. Naab

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Advanced Technology Center
P.O. Box 400
Buffalo, New York 14215

Contract No. DTNH22-C-81-07256
Contract Amount $97,613

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16. Abstract

A three phase study was undertaken to design and evaluate an acceptable side door padding panel which did not degrade the driver's ability to control a vehicle. In Task 1, drivers' lateral clearance requirements were determined by filming test subjects performing a representative series of driving maneuvers. The films were digitized to create time histories of the left elbow, from which a padding design concept was derived.

In Task 2, two prototype test panels were fabricated from the design concept developed in Task 1. An experimental program was conducted, whereby the performance of the test subjects on a double lane change maneuver with the test panels installed was compared to their performance with a standard side door panel.

Finally, a brief consumer survey was accomplished, in an effort to obtain estimates of the likelihood that vehicles with similar side door panels would be accepted in the marketplace.

Continued on Page 2

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Abstract (cont'd.)

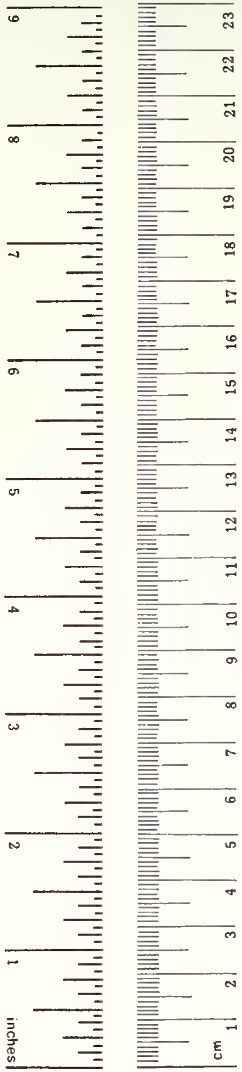
It was concluded that: 1) the side door padding concept had the potential to be accepted by consumers, and 2) a small, but statistically reliable, decrement in driver performance was caused by the prototype padding configuration. However, it was suggested that this performance decrement might have a negligible effect on the probability of an accident, which would be more than counterbalanced by the increased driver protection afforded by the side door padding.

METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

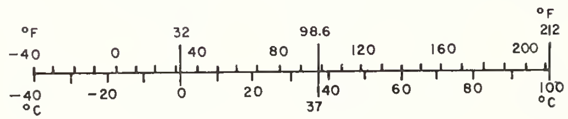
Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



FOREWORD

This report presents results from a program to investigate the effects of side impact padding on driving performance.

The reported research was performed by the Advanced Technology Center of Calspan Corporation for the National Highway Traffic Safety Administration (NHTSA) of the U.S. Department of Transportation under Contract No. DTNH22-81-C-07256. The Contract Technical Manager for this project was Mr. Michael Perel of the NHTSA.

The opinions, findings, and conclusions expressed in this publication are those of the author and not necessarily those of the National Highway Traffic Safety Administration.

This report has been reviewed and approved by:

Anthony L. Russo

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Transportation Research Branch
Physical Sciences Department

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Appreciation is extended to Mr. Michael Perel of the NHTSA for his support and suggestions throughout the entire study.

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Section 1

INTRODUCTION

Recent research, e.g. References 1 and 2 has indicated that the best method of protecting vehicle occupants in side impacts is to provide as much energy-absorbing padding as possible between the occupant and the side door panel. This is a relatively easy proposition with regards to the passenger; one can merely fill the available space between the occupant and the door panel with padding. On the driver's side of the vehicle, however, other factors have to be taken into consideration. In particular, it is essential that the operator's ability to control the automobile is in no way degraded.

There is a limited amount of available space in which padding can be added to the door panel. Illustrative of this, is the fact that in a Volkswagen Rabbit, there are only twenty-six inches between the side door panel and the vehicle center line. Furthermore, between the center of the driver's seat and the side door panel, there are only twelve inches. Considering that the 95th percentile male elbow-to-elbow breadth measurement is almost twenty inches (Reference 3), only two inches of elbow clearance are left. Similar, but less restrictive problems exist with the hips; the 95th percentile sitting hip breadth is about sixteen inches, which results in four inches of clearance.

Adding padding at the driver's shoulder level is not particularly relevant, since the shoulder in adults is typically above the top of the side door panel. Thus, this would necessitate significant changes in the size and shape of the side door window as well.

The task of designing a side door padding configuration is complicated by the fact that the arms of a vehicle operator are not stationary. There are many different driving maneuvers, each having perhaps its own unique pattern of arm movements. In addition, there may be large variations in the arm motions of different operators.

A three phase study was undertaken to design and evaluate an acceptable side door panel. This report details the methodology and results of each of the three tasks that were involved. Task 1, in which driver arm movements, and hence, lateral clearance requirements, are defined, is described in Section 2. A candidate padding configuration design concept was an additional result of Task 1, and this is also documented in Section 2. In Section 3, the procedures, data and results of an experimental evaluation of the candidate panels, i.e., Task 2, are reported. The last task in the study is documented in Section 4, wherein the reactions of a small sample of consumers were obtained and analyzed. Finally, conclusions and recommendations are given in Section 5.

Section 2

TASK 1 - DRIVER LATERAL CLEARANCE REQUIREMENTS

The primary objective of Task 1 was to define the lateral clearances necessary for vehicle operators to perform the driving "task." A secondary objective was to design a side door panel, which would be consistent with the lateral clearance data and would contain as much padding as possible.

Briefly, this entailed analyzing films of drivers performing a series of representative driving maneuvers. These analyses provided time histories of critical body areas, from which "movement envelopes" could be defined. In order to do this, representative driving maneuvers had to be defined; a method to photograph the arm movements had to be developed; and a subject test matrix (including the selection process) had to be detailed. The following three subsections expand these issues and describe how each was resolved.

2.1 REPRESENTATIVE DRIVING MANEUVERS

Operating an automobile is a complex task which involves a large variety of different actions. With regard to the driver's arm motions, a majority of the driving task requires very little motion; slight steering adjustments are made continuously in order to maintain the vehicle's lateral position on the roadway. Other driver functions, e.g., lane changes, require considerably more arm movement, while maximum arm motion is utilized for maneuvers such as turning. In many respects, the magnitude of the steering angle defines the amount of arm movement involved and limits the speed at which the maneuver can be performed. Note the implication of this: large steering inputs, with the highest probability of driver/padding interference, are most likely to be required at low speed. Conversely, high speed maneuvers are less likely to be affected by the side door padding, since less arm motion is involved.

Based on the above, it was decided that the frequency of a driving task was not of primary importance in defining the representative driving tasks. Instead those aspects of driving which involve large movements of the arm were of more interest. However, it is noted that low frequency tasks which are not critical in maintaining vehicle control were not necessarily included.

The basis for determining the Task 1 driving tasks was a complete task analysis of vehicle operation by McKnight, et al. (Reference 4). An example of the analysis for steering a vehicle is given in Figure 2-1; references to arm/hand motion have been underlined. Each element of this report was examined for references to significant arm movements and other miscellaneous motions which may involve outboard lateral displacements. Table 2-1 presents the candidate driving tasks that were identified from the task analysis. They have been divided into two groups: actual driving maneuvers and auxiliary driving tasks.

In Table 2-1, it should be noted that references to hand signals which were included in the task analysis have been deleted, as have several other activities which are concerned with relatively infrequent situations, e.g., driving with the left foot on the brakes when they are wet.

Table 2-1

CANDIDATE DRIVING TASKS

Driving Maneuvers	Auxiliary Actions
Turning	Enter car
Backing up	Adjust seat
Changing lanes	Adjust side mirror
Parallel parking	Lock door
Angular parking	Adjust head support
Perpendicular parking	Fasten restraint
Leaving parking space	Open/close window
Driving through curve	Operate control located to the left of the steering column
U-turn	
Y (or K) - turn	Exit car

14-2	TURNING		
14-21	Keeps eyes focused well ahead to anticipate turns	4	XXXX
14-22	Signals for turn at appropriate point in advance of turn (see 34, Lane Changing, 33, Entering and Leaving Traffic, and 41, Negotiating Intersections for appropriate signal distances)	8	XXXX
14-221	Activates directional turn signal	8	XXXX
14-2211	Presses lever down for left turn		
14-2212	Lifts lever up for right turn		
14-222	If directional signal is inoperative, or hand signal is otherwise required:		
14-2221	Extends left arm and hand straight out for left turn	2	XXX
14-2222	Extends left arm out with arm bent straight up at elbow for right turn	2	XXX
14-223	Observes response of other vehicles to signals	9	XXXX
14-23	Observes intended path to make sure it is clear (see 34, Lane Changing; 33, Entering and Leaving Traffic; and 41, Negotiating Intersections)	7	XXXX
14-24	Reduces speed as necessary for safe comfortable turn (see 44, Negotiating Curves; 41, Negotiating Intersections; and 33, Entering and Leaving Traffic)	10	XXXX
14-241	If necessary to shift gears, does so prior to turn, not during turn	0	XXX
14-25	Turns steering wheel an amount proportional to the degree of turn	12	XXXXX
14-251	Keeps both hands on outside of steering wheel rim	2	XXX
14-2511	Uses hand-over-hand technique for sharp turns (with exception of small foreign or sports cars)	2	XXX
14-2511-1	For right turn uses the following procedure		
14-2511-11	Places left hand on left side of steering wheel between 8 and 10 o'clock position (recommendations vary)		
14-2511-12	Rotates steering wheel clockwise with left hand to 2-4 o'clock position		

Figure 2-1Example Task Analysis
(from McKnight, et al., Reference 4)

Table 2-2 gives the driving tasks which were performed by each subject in Task 1. As can be seen, a number of the candidate tasks have been eliminated. In particular, many of the auxiliary driving tasks have been deleted. The behaviors occur so infrequently in the driving task (and generally while the vehicle is not in motion), that the procedure followed (as well as the location of appropriate controls) should be defined by the padding configuration, rather than vice versa. Calspan originally proposed to observe subjects open the door, but this was deleted when it was discovered that the door release handle on the 1977 Volkswagen test vehicle is located so that it can only be operated by reaching across one's body with the right hand. The activities that have been included are often performed while the vehicle is in motion. The decision to observe the operation of the vent control mechanism was based on the fact that it is the most outboard of the VW Rabbit controls. The next most outboard control is the headlight toggle switch, which is situated inboard of the left side of the steering wheel.

Table 2-2

REPRESENTATIVE DRIVING TASKS

Driving Maneuvers	Auxiliary Actions
Turning*	Open/close window
Backing up	Operate vent control
Changing lanes*	
Parallel parking	
Y (or K)-turn	

*Right and left

The actual driving maneuvers which were eliminated included angular and perpendicular parking, U-turn, driving through a curve, and leaving a parking space. With regards to the first three tasks, they were believed to be subsets of turning behavior; in fact, the major element of the task analysis of these various maneuvers was "turning." Similarly, it was decided that driving through a curve involved the same task elements as a lane change maneuver, and was therefore deleted.

The most troublesome of the driving maneuvers which was eliminated was leaving a parking space. This maneuver required that the driver monitor traffic approaching from the rear. In many instances, the driver may need to turn and look over his left shoulder; side door padding could conceivably interfere with this action. Since the test procedures were conducted on Calspan's Vehicle Experimental Research Facility (VERF), the test vehicle would be the only vehicle in the general vicinity. Therefore, it was believed that requiring the test subject to monitor approaching traffic in a situation known to have no traffic would not necessarily produce useful and reliable results. As a result, it was decided to eliminate this driving maneuver from the test matrix. However, in order to obtain data on this type of driver behavior, i.e., turning and looking over one's left shoulder, the backing maneuver required that the driver monitor the test vehicle's left side. Specifically, the subject was instructed to back the vehicle, and stay as close as possible to a row of pylons located to the left of the vehicle.

2.1.1 Representative Driving Task Implementation

As mentioned above, the experimental portion of Task 1 was performed on Calspan's Vehicle Experimental Research Facility (VERF). A schematic of the layout is given in Figure 2-2.

In the right turn maneuver, the subject turned into a twelve foot wide lane (a standard lane width). Pylons were set out so that the subject could not employ an unreasonably wide turning radius for the maneuver.

In the left turn, the subject guided the car into a twelve foot wide lane located twelve feet from the starting point. This simulated making a left turn onto a standard width two-lane road. In both the right and left turns, the subject was required to bring the vehicle to a complete halt before initiating the turn.

The lane change maneuvers were designed so that the vehicle operator was required to apply approximately 90° of steering input. The lane change was laid out as shown in Figure 2-3.

It is noted that the twelve foot distance moved laterally during the maneuver is, as in the case of the turning maneuver, based on a typical lane width of twelve feet. With a 20 mph entry speed, the 50 foot transverse chute resulted in lateral accelerations of 0.25 to 0.30 g's. The 20 mph was sufficient to make the lane

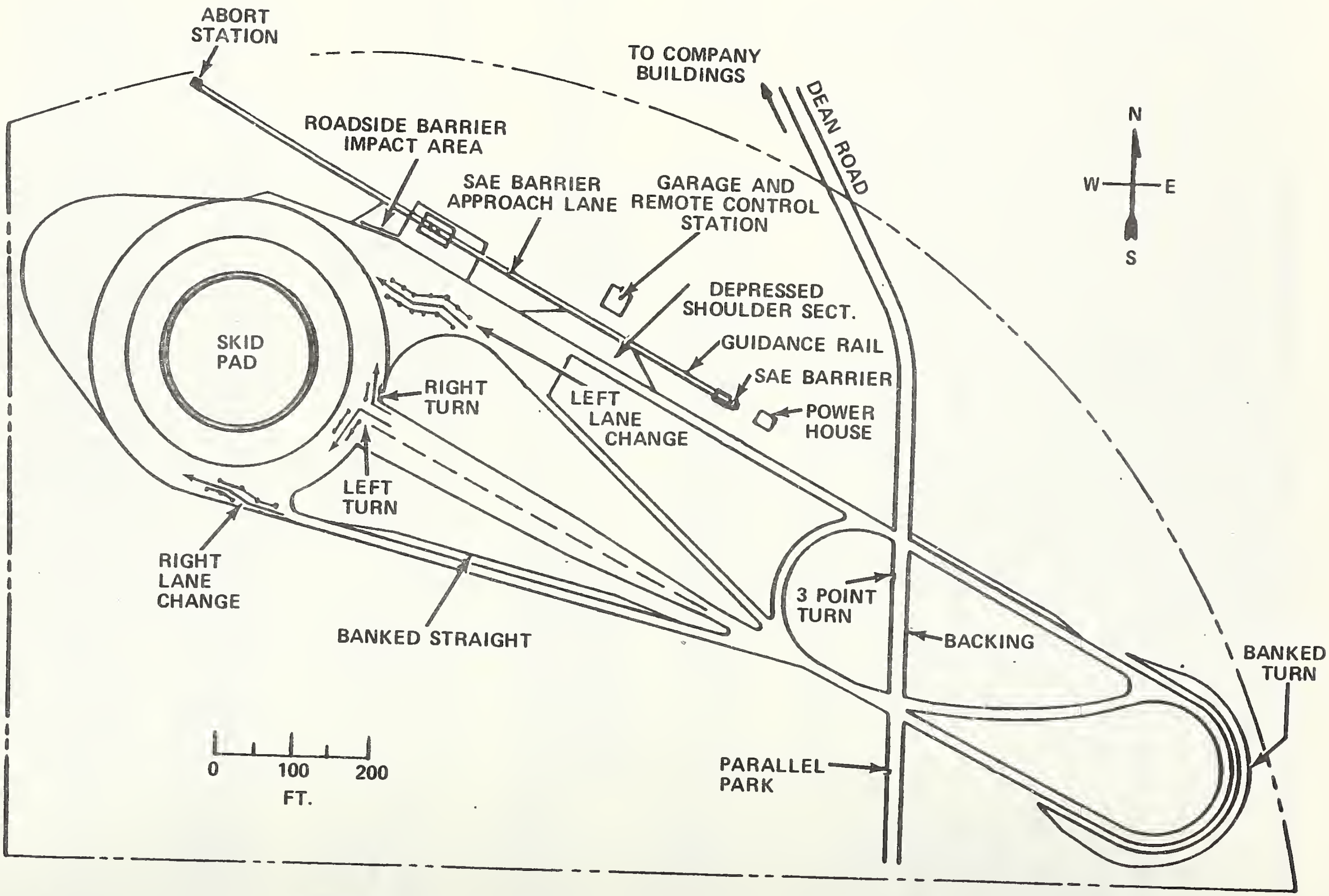

Figure 2-2 TEST LAYOUT OF CALSPAN VEHICLE EXPERIMENTAL RESEARCH FACILITY (VERF)

change maneuver non-trivial, i.e., not comparable to the turning task, but at the same time, did not subject the vehicle occupants to undue risk. The lateral acceleration level was selected on the basis of a prior study (Reference 5) in which it was determined that the maximum lateral acceleration to which non-professional drivers will subject

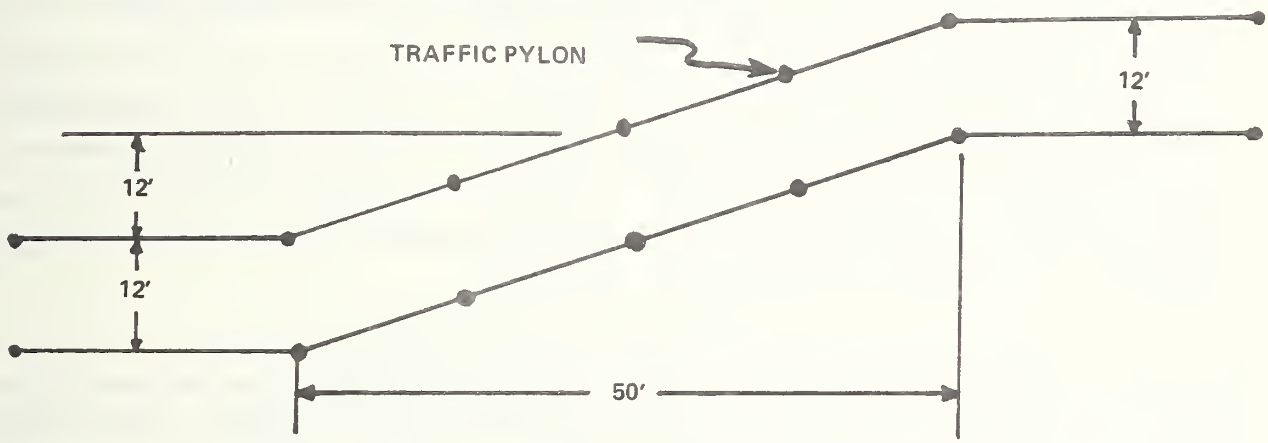

Figure 2-3 LANE CHANGE MANEUVER COURSE

themselves is about 0.4 g's. With regards to the complexity of the maneuver, it should be noted that most subjects needed five to ten practice trials before they were comfortable at 20 mph; some other subjects would not approach at speeds greater than 15 mph.

The Y (or K)-turn, backing, and parallel parking maneuvers were performed as noted in Figure 2-2.

2.2 SUBJECT SELECTION

2.2.1 Subject Selection Criteria

Subjects participating in the Task 1 experiment were selected on the basis of their physical size. In order to ensure that all seating positions were used, a wide range of subject heights was sampled. However, the study was concerned with limitations on the amount of protective padding which can be installed. Therefore, relatively broad representatives of each height category were needed to provide the types of data that were required. Originally, it was proposed to collect data on the 95th percentile weight within the heights that were to be sampled. During the Initial Briefing, which was held 22 October 1981, it was suggested that the broadest, i.e., 95th percentile weight, people within the population may not be the individuals who buy subcompact vehicles. As a result of this suggestion, 75th percentile weights within each height category were also observed during experimentation.

The best method for defining the heights and weights for each of the subject types would be based on empirical distributions of weight within height (categories) for the general population. No such reports could be found in the literature. Consequently, an indirect technique was utilized; specifically, standard regression methodology. This technique requires that the mean and standard deviation for both variables are known, as well as the correlation coefficient between them.

The parameters for the distributions of height and weight were taken from an anthropometric study of vehicle operators (Reference 6), which was published in 1970. There were other data sources available, but many of these examined only a small segment of the general population, particularly the military. Use of these groups might have created undesirable biases in the sampling procedure; notably, target weights (and, by inference, breadth) would be understated. An anthropometric survey of the general population was conducted in 1962 (cited in Reference 3) and was also considered for use. As shown in Table 2-3, the mean values of height and weight were generally higher in the 1970 study. It was decided to use the parameters from the more recent study, since they were more conservative (in the sense of using larger sized subjects) and are representative of automobile operators.

Table 2-3

COMPARATIVE POPULATION PARAMETERS

	Stoudt, et al. (1970)		Health Exam (1962)	
MALE	Mean	Standard Deviation	Mean	Standard Deviation
Height (inches)	69.8	2.78	68.2	2.71
Weight (pounds)	180.0	29.60	165.1	27.80
FEMALE				
Height (inches)	63.5	2.87	63.1	2.59
Weight (pounds)	133.0	25.70	140.4	30.45

Stoudt, et al. did not report a correlation coefficient between height and weight; therefore, an estimate for the correlation coefficient also had to be determined. Correlation coefficients from seven sources are presented by Churchill, et al. (Reference 7). The individual values of the correlation coefficient from each of the data sources are given in Table 2-4.

Table 2-4

REPORTED CORRELATION COEFFICIENTS BETWEEN HEIGHT AND WEIGHT

Population	Correlation Coefficient
U.S. Air Force Women (1968)	0.5325
U.S. Air Force Flying Personnel - Men (1967)	0.5152
U.S. Air Force Trainees - Male (1965)	0.4781
U.S. Air Force Flying Personnel - Male (1950)	0.4781
U.S. Army Separatees - Female (1949)	0.4015
Health Examination Survey - Male (1962)	0.3922
Health Examination Survey - Female (1962)	0.2047
Law Enforcement Officers - Male (1975)	0.4689

The average correlation coefficient of these reported values is 0.433. Note, however, that the two lowest correlations were obtained from a sample of the general population. This is not surprising, in view of the fact that military and quasi-military groups (such as law enforcement officers) are more homogeneous in terms of age, fitness, etc. For this reason, it was decided to arbitrarily reduce the correlation coefficient used for estimating subject sizes from the mean value of 0.433 to 0.400.

A regression equation for determining the expected weight of a person given his/her height could then be written, since the mean and standard deviation for height ($\bar{H}$ and σ_H respectively) and weight ($\bar{W}$ and σ_W) as well as the correlation coefficient ($\hat{\rho}$) are known. They are:

$$\alpha = \frac{\hat{\rho}\sigma_W}{H} \qquad (2\text{-}1)$$

$$\beta = \bar{W} - \alpha\bar{H} \qquad (2\text{-}2)$$

$$\text{predicted } W = \alpha\bar{H} + \beta \qquad (2\text{-}3)$$

In Equations (2-4) and (2-5), the appropriate values of α and β have been substituted into Equation (2-3).

$$\text{predicted } W_{male} = 4.26\bar{H} - 117.28 \qquad (2\text{-}4)$$

$$\text{predicted } W_{female} = 3.58\bar{H} - 94.45 \qquad (2\text{-}5)$$

Applying these above equations to the heights associated with the relevant percentile ranks, one obtains an estimate of the expected (or mean) weight for a person of a given height. These are given in Table 2-5.

Table 2-5

EXPECTED WEIGHT BASED ON HEIGHT

	PERCENTILE RANGE (Height)			
MALES	95%	75%	50%	25%
Height (inches)	74.3	71.6	69.8	67.8
Predicted Weight (pounds)	199.2	187.9	180.0	171.5
75th Percentile Weight (pounds)	216.8	205.5	197.6	189.8
95th Percentile Weight (pounds)	236.7	225.5	217.6	209.8
FEMALES				
Height (inches)	68.0	65.4	63.5	61.4
Predicted Weight (pounds)	149.0	139.6	133.0	125.7
75th Percentile Weight (pounds)	167.3	157.7	151.0	143.8
95th Percentile Weight (pounds)	187.8	178.3	171.6	164.3

Also included in Table 2-5 are estimates for the 75th and 95th percentile weights for each height of interest. These are calculated by first computing an estimate of the variance of weight within height ($_{W.H}$) as given in Equation (2-6).

$$\sigma_{W.H} = \sigma_{W} \sqrt{1 - \hat{\rho}^2} \qquad (2\text{-}6)$$

Under an assumption of homoscedasticity (the variance within height is the same for all heights), the predicted weights are incremented by the quantity 0.67 $\sigma_{W.H}$ (in the case of the 75th percentile weight) and $1.64\sigma_{W.H}$ (for the 95th percentile).

2.2.2 Subject Test Matrix

Initially, the subject test matrix was designed so that only the broadest people in each height category would be tested. However, there were concerns that these people would not necessarily be the same persons who would be most likely to purchase subcompact vehicles such as a Volkswagen Rabbit. Thus, the final test matrix included both subjects whose weights were in the 75th and 95th percentile rank for their height. The subject test matrix which will be discussed in the remainder of this section is presented in Table 2-6.

Table 2-6

SUBJECT TEST MATRIX - TASK 1

	MALE		FEMALE	
	Percentile Rank (height)	N	Percentile Rank (height)	N
95th percentile (weight)	95	2	75	1
	75	2	50	2
	50	2	25	4
	25	1		
75th percentile (weight)	95	2	75	1
	75	2	50	2
			25	1

In general, the subject heights in the test matrix were chosen so that a full range of seat positions (forward and aft) would be sampled. Driver width was manipulated by varying the driver weight. The two 50th percentile and one 25th percentile male subjects were chosen in order to obtain estimates of movement envelopes with the seat at midposition.

Movement data for the aft most seat position were provided by the 95th and 75th percentile height male subjects. It was initially thought that these data could be provided by 95th percentile males, but in preliminary testing, it was found that many of the elbow movements of a 95th percentile driver appeared to be above the side door panel, such that any interference that may occur involves striking the top of the padding while the arm is moving downwards. Shorter drivers, who had the seat positioned all the way back, struck a simulated padding panel much lower as a result of lateral motion instead of vertical. For this reason, it is believed that sampling both heights was necessary in order to define a realistic movement envelope.

Fifth percentile (height) females were originally proposed so that the lateral clearances for the forward-most seat location could be defined. Individuals, who are larger than 5th percentile women, however, drive with the seat positioned all the way forward. It is these people who place the greatest constraints on padding thickness.

In a poll that was informally conducted at Calspan* during the preparation of the Task 1 Test Plan, it was found that most women under 64 inches tall drove with the seat at the forward setting. Beyond that height, the probability of driving with the seat completely forward decreased, but instances were still found in which individuals who were 5'6" and 5'7" tall drove without moving their seats back from the forward setting.

Further evidence that significantly taller than 5th percentile drivers sit forward was found in Reference 8, in which seat position preferences in a Rabbit were determined by 92 subjects. The average height of the seven individuals who selected the forward-most setting was approximately 5'1½". Subjects as tall as 5'4¼" were found to prefer the forward position. For this reason, six subjects in the 5'1" to 5'3½", i.e. 25th and 50th percentile heights range were sampled. Those subjects who sit with the seat slightly aft as well as the 75th percentile subject were used to try to obtain additional data on the mid-range positions.

In selecting subjects to fill the test matrix, the heights and weights specified in Table 2-6 for the various subject types were essentially target values. It would be impossible to find subjects whose body dimensions exactly matched the target values, particularly with day-to-day fluctuations in a person's weight. Qualified subjects also had to have a valid driver's license and at least five years of driving experience.

2.3 TEST VEHICLE MODIFICATIONS

A used 1977 VW Rabbit with an automatic transmission and a sun roof was purchased as a test vehicle. The vehicle came equipped with a passive belt system and a knee blocker/package shelf. Because the knee blocker obstructed the knees of large occupants it was removed. The passive belt was replaced by a three-point belt system, which was worn by all subjects while driving. No other modifications were made to the vehicle except those required for camera viewing, as discussed below.

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*Neither vehicle type nor driver weight was considered during this "survey."

Three 16mm movie cameras were used to collect data on body motions during Task 1 driving exercises. The fields of view of the three cameras were approximately as shown in Figure 2-4. Camera 1 viewed the vertical and longitudinal movements of the driver's left side. Camera 2 viewed the lateral and longitudinal movements of the driver's left side. Camera 3 recorded the lateral and longitudinal movements of the driver's right side.

The left front door was removed from the vehicle and replaced by a door made up of ½" pipe and Plexiglas. The door had an inner panel of Plexiglas with the window crank, door opening lever, and the arm rest attached to it. The door latch was operable from the inside. The Plexiglas panel had the same location as the existing inner padded door panel. There was no outer door sheet metal skin and the camera viewed the driver through a single layer of Plexiglas. The camera was rigidly mounted to the door frame allowing the door to open and close normally. Figure 2-5 is a photograph of the modified test vehicle door.

The mounting of the other two cameras also required substantial modifications to the test vehicle. The sun-roof opening was enlarged, and the remaining portion of the roof was reinforced with 1" angle iron. The portion of the roof between the sun roof and the left edge was entirely removed and the reinforcing members were extended several inches beyond the original roof edge, as shown in Figure 2-6. This allowed an unobstructed view of the operator's elbow.

A rigid frame was attached to the reinforcing elements, and the two overhead cameras were mounted on flat surfaces included in the frame (see Figure 2-7).

A Plexiglas window was installed in the cut out portion of the roof in order to protect the driver and test conductor from the elements.

Camera 2 was located such that the center of its field of view was at the center of the driver side arm rest. The camera field of view extended forward to the rear edge of the vent window and rearward to the door lock button. The cut out in the roof permited approximately half of the driver's body to be in view.

Camera 3 was positioned at the same height and longitudinal location as Camera 2. The field of view was centered on the inboard edge of the driver seat

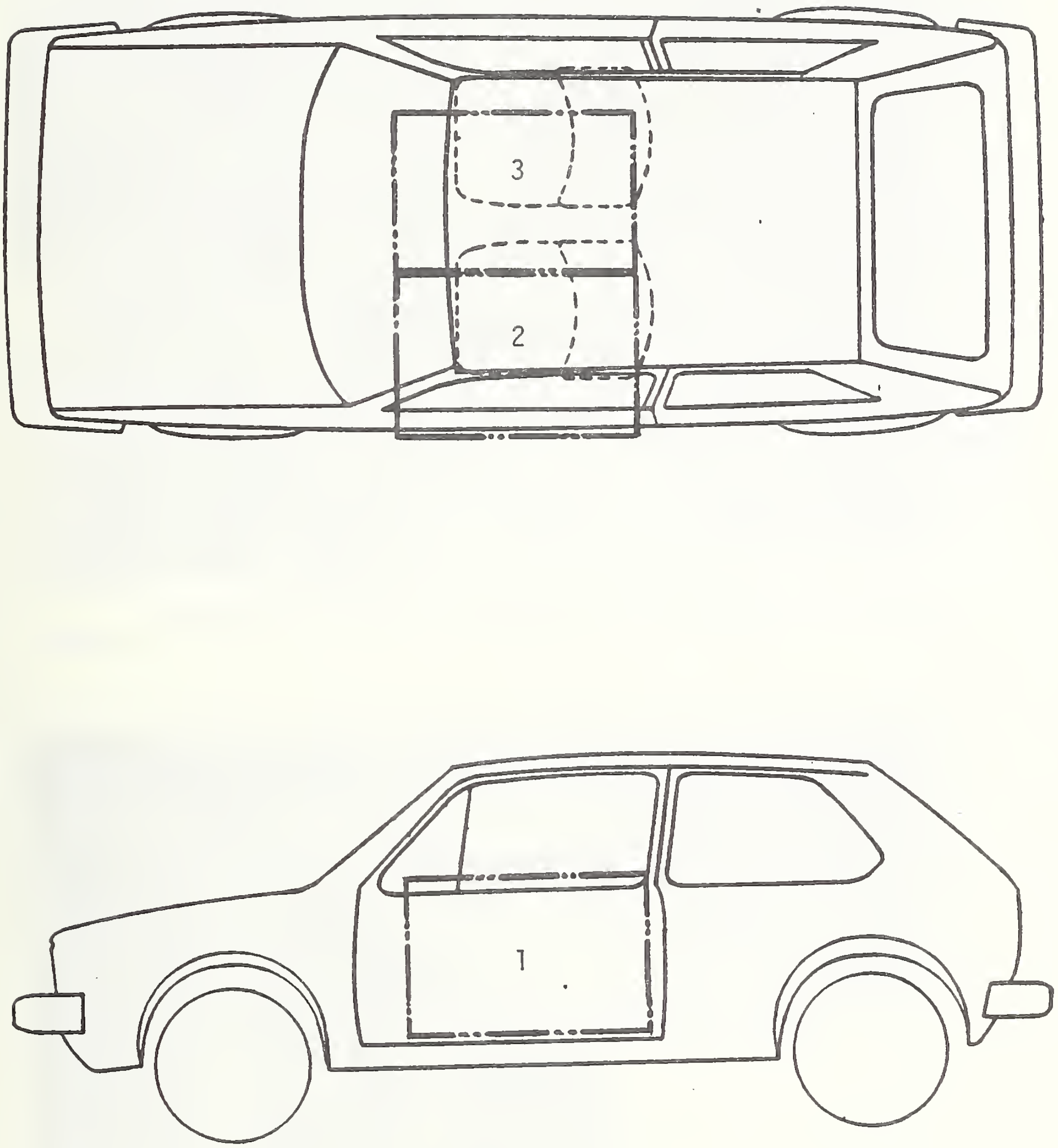

Figure 2-4 MOVIE CAMERA FIELDS OF VIEW

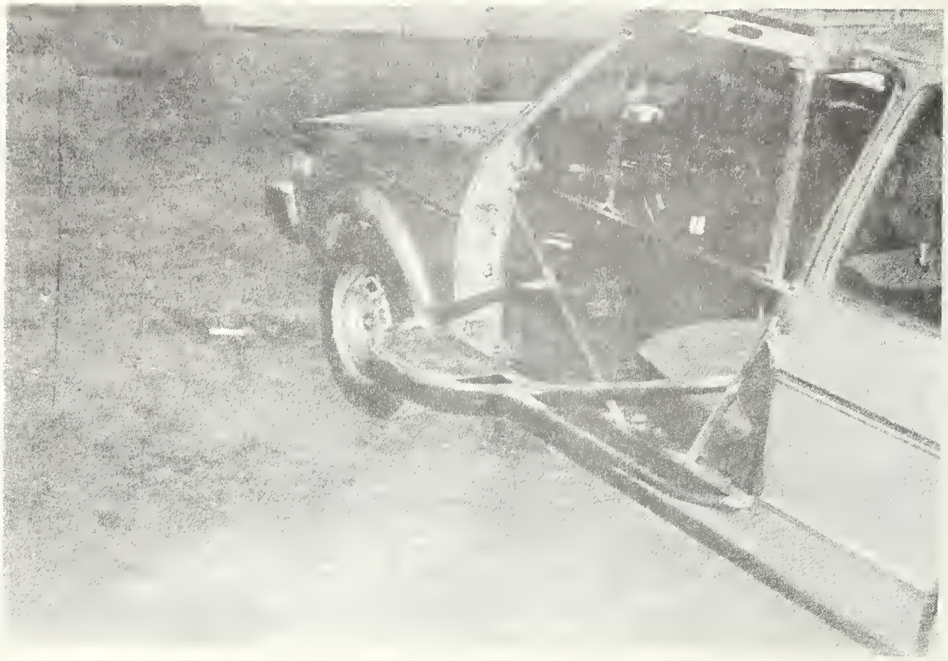

Figure 2-5 REPLACEMENT DOOR WITH CAMERA MOUNTING FRAME

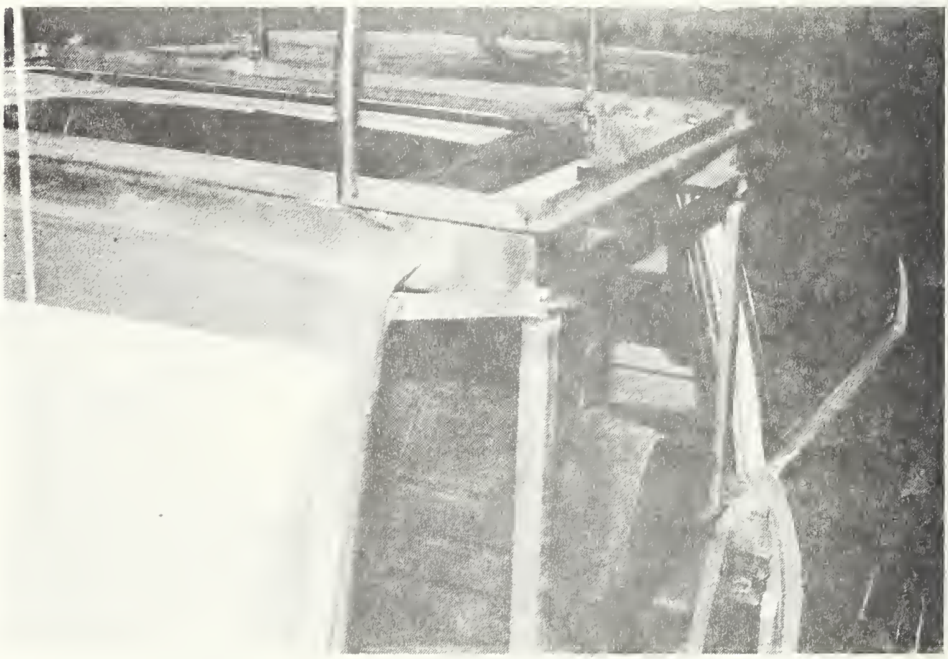

Figure 2-6 ROOF EXTENSION ALLOWING VIEW OF DRIVER LEFT SIDE

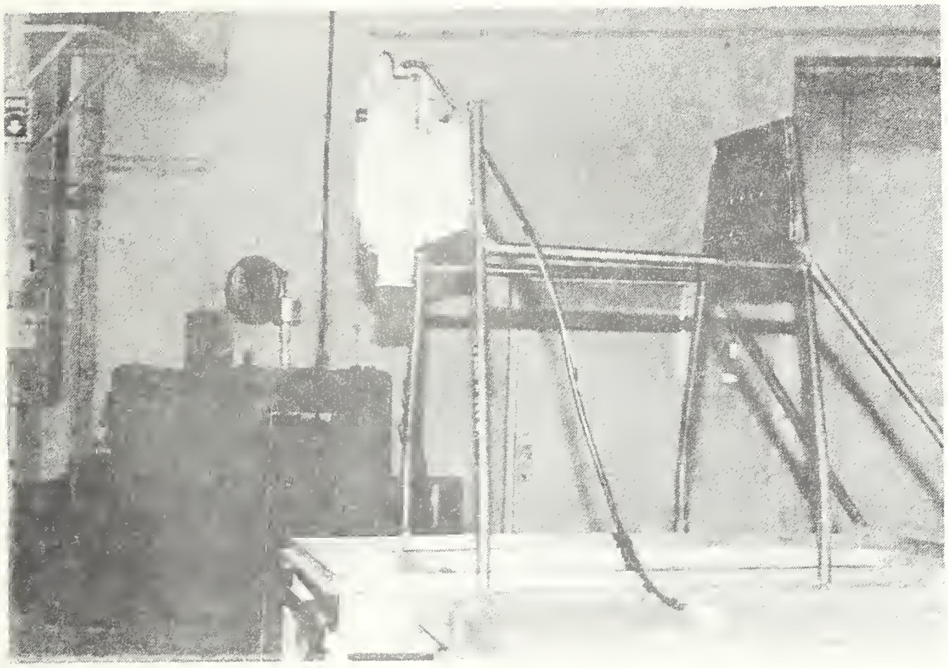

Figure 2-7 OVERHEAD CAMERA MOUNTING STRUCTURE

cushion. The field of view was the same size as that of Camera 2 and the two overlapped slightly at the driver centerline.

Photosonics high speed movie cameras were used; these cameras allowed for a range of camera speeds from 10 to 1000 frames/second. For this study, the cameras were set for a nominal 24 frames/sec. The two overhead cameras were each equipped with a 13mm lens, while the outboard camera, which was closer to the subject of interest, required an 8mm lens.

All three cameras were triggered by a single hand-held switch activated by the experimenter. This switch also controlled the onset of a timing light which marked the edge of the film to indicate time zero. There was a slight time delay, i.e., 1 second, between switch activation and the timing light flash so that the cameras could be brought up to the correct speed. A block diagram of the control and power generation circuitry is given in Figure 2-8.

The inverter and transformer/rectifiers were hard mounted in the rear compartment of the test vehicle. Cabling allowed the hand-held on/off switch to be available to the experimenter, who was seated in the front right seat. The ammeters were mounted in the glove compartment. These were implemented to ensure that the cameras functioned properly. Normal operation was indicated by a current of 1 to 6 amperes. Readings lower than 1 ampere occurred when the cameras ran out of film, whereas high currents would have been caused by jams in the film magazine. Thus, the experimenter could monitor the cameras during the representative driving test and thereby avoid catastrophic data loss.

2.4 TEST PROCEDURE

Upon arrival at Calspan, subjects were weighed and measured. The following additional information was obtained from each subject:

- o age
- o sex
- o number of years driving experience
- o handedness
- o year and model of vehicle normally driven

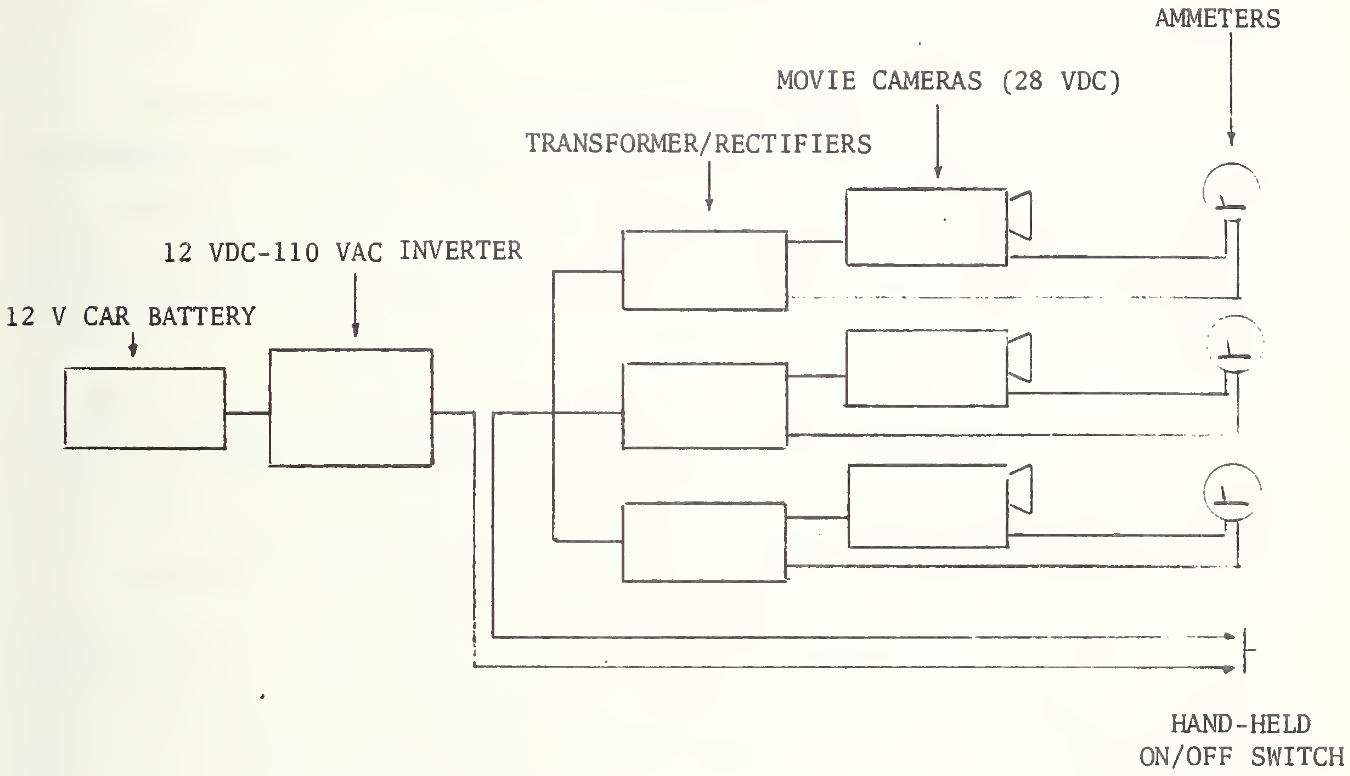

Figure 2-8 INSTRUMENTATION SCHEMATIC

In addition to the height and weight, nine other anthropometric meaurements were made. These were:

- o sitting hip breadth
- o elbow-to-elbow breadth
- o biacromial shoulder breadth
- o acromion-to-radiale length
- o sitting height
- o acromial height
- o radiale to wrist length
- o bideltoid shoulder breadth
- o radiale to grip length

After the preliminary information was obtained from the subject, he or she was taken to the test vehicle. The subject was told that the purpose of this study was to observe driver behavior for a variety of different driving maneuvers. The instructions did not, however, contain any references to lateral clearances, thereby avoiding the situation in which the subject is particularly conscious of his or her lateral movements.

The subject entered the test vehicle with the seat having been preset so that it was at midposition. Once in the vehicle, the subject was asked to position the seat to the most comfortable setting. A pointer to an external scale identified which seat detent was selected, and its position was recorded by the experimenter.

As discussed previously, special instructions were given so that the vehicle was completely stopped prior to the left and right turns; the maximum speed at the entrance of the lane change course was in the range of 20-25 mph; and, when backing, the left side of the vehicle was kept as close as possible to a row of pylons. Each maneuver was performed twice.

Since the tasks that were performed are overlearned in an experienced driver, no effort was made to control for the order of the maneuvers; rather, the order was determined on the basis of convenience. The resulting order was: right turn, left turn, right lane change, left lane change, K-turn, backing, and parallel parking. The subject was also filmed opening and closing the vent control.

It is noted that the subjects utilized in Task 1 were each paid $25 for their time, generally less than two hours.

2.5 DATA REDUCTION

The design of candidate side door panel padding configurations was based on the lateral clearance requirements of the subjects, as determined from the films of their arm movements during the representative driving tasks. Because of time and financial constraints, only data from the left arm were analyzed for the turning and lane change maneuvers.

The analysis was accomplished by rear-projecting the film on a Talos Model 6221B digitizing tablet. The location of five points were obtained from each frame that was utilized.* These points included two reference points and the position of the subjects' elbow, shoulder, and middle of the hand. The locations (in digitizing tablet coordinates) were transmitted to the Transportation Research Branch's Zilog MCZ 1/20 Microprocessor Development System. Here, the coordinates were transformed into the vehicle frame of reference, the elbow position was plotted on the console screen (for error checking) and the data were written to floppy diskette.

After both the time histories for the outboard and overhead cameras had been determined, a second computer program combined these two two-dimensional time histories into a single three-dimensional time series. These data were also stored on floppy diskettes. This entire process is described in more detail below.

2.5.1 Digitizer Calibration

When a point is digitized, the result that is sent to the computer is the location of the point on the digitizing tablet. In essence, this is the number of inches (to the nearest thousandth) above and to the right of the tablet's origin. This coordinate, then, must be converted into the coordinate system of interest, i.e., the vehicle. There are two prerequisites for this process: reference points and a mapping algorithm.

In order to accomplish this, a 2" x 2" grid was created on a piece of Plexiglas using thin strips of tape. For each camera, a grid was placed parallel to the camera's focal plane at a nominal elbow location, and photographed. In addition,

*Only every other frame was used, again due to time constraints.

thin tape "crosshairs" were put on the Plexiglas door and sun roof and projected onto the grid; these projected points served as reference points. The grid was also placed at shoulder level and photographed by the overhead cameras.

The data for the determination of the mapping algorithm consisted of over fifty known values on the grid and their corresponding digitizer coordinates. Initially, a fifth degree polynominal was curve fit to these data, but it was found that a simple linear regression performed as well. Errors of up to ½" were noted along the extremities of the field of view, but in the region of interest, the typical error was less than 0.1", with a maximum of 0.25".

The mapping algorithm, as determined above, was used to locate the reference points relative the origin of the Plexiglas grid. Since the position of the origin was known, relative to the vehicle frame of reference*, it was a simple matter to express the reference points in the vehicle frame of reference. Obviously, each camera had its own individual reference points.

2.5.2 Digitization Procedure

As was mentioned previously, every second frame from the turning and lane change maneuvers was digitized. Since each maneuver was performed twice, this resulted in eight time histories per subject. The digitization process was controlled by a FORTRAN program executing on the Zilog microprocessor system. The program required as input at least one of the two reference points and the coordinates of the driver's left shoulder, elbow, and hand. If one of these points was obscured, the point was transmitted with the digitizing tablet's "CLEAR" button depressed. This caused a coordinate of (0, 0) to be sent, which was recognized as a missing data value.

The computation of the location of the elbow, shoulder, or hand was based on its position relative to the reference point closest to it, thereby minimizing the error in the calculated position. After a frame had been processed, its data were written to floppy diskette, and the film was automatically advanced two frames.

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*The origin of the vehicle reference point was an arbitrary point on the driver door sill. Thus 0.0 inches laterally corresponded to the side door panel.

Digitization started on the first frame of sequence, as identified by a timing mark superimposed on the film, and continued until the sequence was complete. The elbow position from each frame digitized was plotted on a Tektronix 4025 graphics terminal. This served as an easy quality control test, assuring that no spurious values for the elbow (the most important element) had been accepted. In this case, the file was redigitized.

Two practices should be noted concerning the digitization process. In particular, no single point on the elbow or shoulder was specified for digitization; rather the person doing the digitizing selected the most outboard, i.e., that which required the most lateral clearance, aspect of the body element of interest. Secondly, the middle of the back of the hand was the target in obtaining the hand position.

2.5.3 Creation of a Single Time History

A single three dimensional time history was created for the left elbow, shoulder, and hand by combining the data from the overhead and outboard cameras. The former produced data in the longitudinal (X) and lateral (Y) dimensions, while the latter view provided information on the longitudinal (X) and vertical (Z) dimensions. When possible, the X and Y values from the overhead view were used directly. This was done to avoid any approximations on the most important lateral dimension.

The X dimension was used to synchronize the two time histories* in order to estimate the vertical location of the body element of interest. To do this the X-coordinates from the two frames from the outboard camera were compared to an overhead longitudinal coordinate. The time (relative to the first outboard frame) at which the coordinates were equal was determined under an assumption of linear motion. This time was then used to linearly interpolate the two outboard Z-coordinates, in order to obtain an estimate of the vertical position at a time corresponding to that of the overhead frame data.

*A rotating prism functions as a shutter on the high speed cameras and its position cannot be easily set. Thus the two cameras were not necessarily in synch.

As an example of this procedure, assume that two frames from the outboard camera result in digitized X-Z coordinates of (1, 14) and (3, 12). These data must be synchronized with a digitized X-Y position of (2, 6) obtained from the overhead camera. With straightline motion, it can be seen that the outboard Ẋ-coordinate would be equal to 2" halfway through the time interval occurring between frames. Similarly, it can be seen that halfway through the same time interval, the best estimate of the Z-coordinate is 13". Thus, at the time the overhead frame was taken, the position, in space, of the point of interest was (2, 6, 13).

These three-dimensional time histories computed as described above, were stored on floppy disk. They were the basis for the analysis to be presented later in this section.

2.6 Results

Data from nineteen subjects were successfully obtained. This was three fewer than specified in the subject test matrix. The subjects that were eliminated were all females, and included the following target heights and weights, respectively: 50th percentile, 95th percentile; 25th percentile, 95th percentile; and 50th percentile, 75th percentile. The subjects were eliminated primarily because appropriate sized females were difficult to find. It is believed that decreasing the sample size had a negligible effect on the lateral clearance requirements, since they were dictated exclusively by data from male subjects. Furthermore, as is shown in Table 2-7, a wide range of seated positions were realized without the three additional subjects.

Table 2-7
DISTRIBUTION OF SEATED POSITION

SEAT DETENT	FREQUENCY
1-3 (REAR-MOST)	7
4-6	7
7-10	5
TOTAL	19

Table 2-8 presents the anthropometric data for all of the subjects. It is notable that the male subjects were, in general, in the upper percentile ranks for most of the body dimensions measured. One exception was the hip breadth, in which many of the subjects were near or below the 50th percentile. When compared to distribution for other females, the females in the sample were typically below the upper percentile ranks in all body dimensions.

It was also interesting that the subjects tended to overestimate their height and underestimate their weight. With regard to the latter, the magnitude of the underestimate occasionally approached fifty pounds!

The primary analysis of the data was an examination of the digitized time histories. In particular, elbow lateral location was studied as a function of the elbow's longitudinal and vertical position. The door panel was essentially partitioned into a 1" x 1" grid by rounding the longitudinal and vertical coordinates to the nearest inch. Figure 2-9 shows how the grid was oriented on the door panel. It is noted that the coordinates of the center line of the foremost arm rest attachment bolt are (-6.07, 0, -1.82).

Each analysis consisted of compiling the statistics listed below for a set of one or more time histories:

- o minimum observed lateral clearance (in inches) for each cell in the grid,
- o maximum observed lateral clearance (in inches) for each cell in the grid,
- o the number of times the elbow was observed in each cell, and
- o the number of times the elbow was within two inches of the door panel while it was in that cell.

With regard to the last statistic, the two inch criterion was selected arbitrarily based on a first look at the data and engineering judgment. The aggregate of the cells in which clearances of less than two inches were noted is referred to as the

Table 2-8

SUBJECT ANTHROPOMETY

Subj #	Height (in)	Weight (lbs)	Age	Sex	Sitting Height (in)	Acromial Height (in)	Shoulder-Elbow Distance (in)	Elbow-Wrist Distance (in)	Elbow-Grip Distance (in)	Elbow-Elbow Breadth (in)	Bideltoid Breadth (in)	Biacromial Breadth (in)	Hip Breadth (in)
1	72-1/2	226	31	M	36-1/2	25-7/8	14-1/2	11-3/4	15-3/4	21-1/2	19-1/2	15-1/2	15-1/4
2	73-1/2	209	30	M	38-1/2	27-1/4	15-1/4	12	15	20	19-1/2	16-1/2	14-1/4
3	73-1/2	232	31	M	38-3/8	27-1/4	14-1/4	11-3/4	15	21	19	15-1/4	16-1/2
4	73-1/2	259	40	M	40	28-1/2	16-1/4	11	15-1/4	23-1/2	21	16-1/4	14-3/4
5	68	214	53	M	35-1/2	25-1/2	14-1/2	10-5/8	14-1/4	21-1/2	18-1/2	15-1/4	13-1/8
6	70-1/2	212	30	M	38-3/4	26-1/2	14-1/2	11-1/2	14-3/4	21-1/4	19-1/4	14-3/4	11-1/2
7	64-1/2	163	42	F	34-1/4	24	13-1/2	10	13-1/2	17-1/2	16-3/4	13	13-3/4
8	61	131	44	F	32-3/8	20-1/4	12-1/2	9-1/4	13	15-3/4	16	13-1/4	13-1/2
9	72-1/2	200	26	M	36-1/4	25	15-1/2	11-3/4	15-3/4	21	19	15-1/2	12
10	61	227	40	F	33-1/2	24	11-3/4	10-1/4	14	22-1/8	22	17-3/4	17-1/4
11	72	216	23	M	37-1/2	26	15	13	16-1/4	22-3/8	21-5/8	18-1/2	14-1/4
12	61-1/4	182	25	F	32-1/2	22-1/2	12	9	12-1/2	19-3/4	17-1/2	14	15-1/0
13	62	169	43	F	32-1/4	22-1/2	13	10-1/2	13-1/2	21	19	16	17-1/2
14	70-1/2	231	35	M	37-1/4	24-1/2	14-5/8	11-1/8	15	22	20	15-1/2	14-3/4
15	72-1/2	241	35	M	38-3/4	26-3/8	15-3/4	11-1/4	15-1/2	19-1/4	20	15-1/4	11-7/8
16	69	234	28	M	37	25-5/8	13	11	14-1/4	22-3/4	22	19-3/4	18-1/2
17	63	155	26	F	33-1/2	23-3/4	13	9-3/4	12-3/4	17-3/4	18	14	10
18	63-1/2	164	56	F	34	23-1/4	13	10	13-1/4	18-3/4	18-3/8	17	13-1/4
19	65-1/2	185	20	F	34-1/2	23-1/2	13-3/4	10-3/4	14-1/2	20-1/4	19-1/2	17	20-1/2

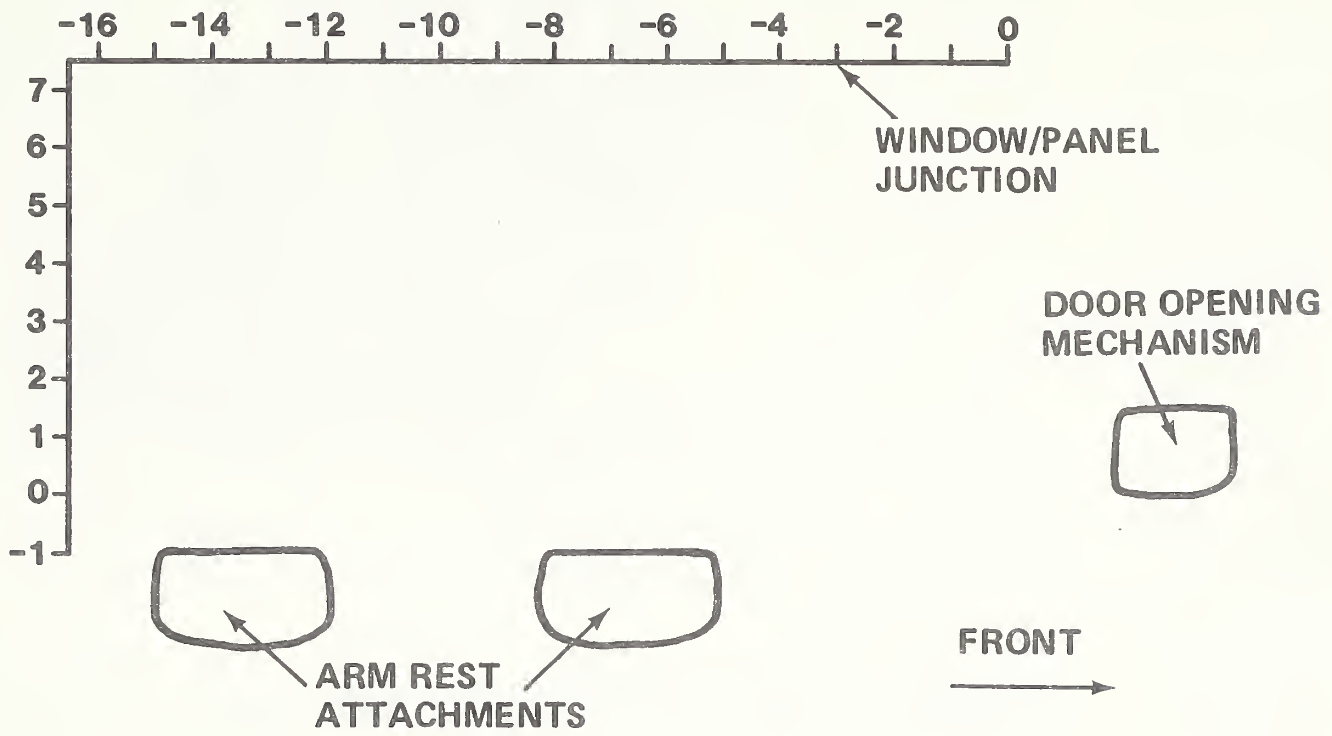

Figure 2-9 DOOR PANEL SCHEMATIC

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"critical area". These critical areas were the basis for most of the comparisons described below.

The primary objective of the analyses was to define the portions of the side door panel which could be padded. The first step was, of course, to define an aggregate critical area for all of the digitized time histories. This is presented in Figure 2-10; the critical area is superimposed on a schematic of the side door panel for clarity.

The critical area given in Figure 2-10 was broken down by the type of maneuver in Figure 2-11. In this figure, the critical area created by the lane change maneuvers is compared to that which was generated by the right and left turns. It is not surprising that the lane change maneuvers had a smaller critical area than the turns; the turns required a greater steering angle input, and consequently, greater angular displacements of the steering wheel. Note that the combined critical area in Figure 2-11 is identical to Figure 2-10.

One implication of Figure 2-11 in the design of a candidate padding configuration, is that those areas which were included in the turning critical area, but not in the lane change critical area, might be compromised without increasing the risk of a padding-related accident or near-miss. This is because the turning maneuvers were performed at very low speeds. The results of interference from the padding would, therefore, be small (in terms of deviations from one's intended heading) in addition to allowing time for corrective actions.

Figures 2-12 and 2-13 compare the critical areas for left and right turns and left and right lane changes. There are not extremely large differences as a function of the direction of the maneuver. However, the slightly larger critical for right-going maneuvers is consistent for both lane changes and turns. In left hand turns and lane changes, the maneuver was initiated with the left hand located at 9 or 10 o'clock on the steering wheel, and then moving downwards to the 6 or 7 o'clock position. for right going maneuvers, the left hand moved clockwise to the 12 or 1 o'clock position. It would appear that the elbow required greater lateral clearance when the hand was gripping to the top of the steering wheel.

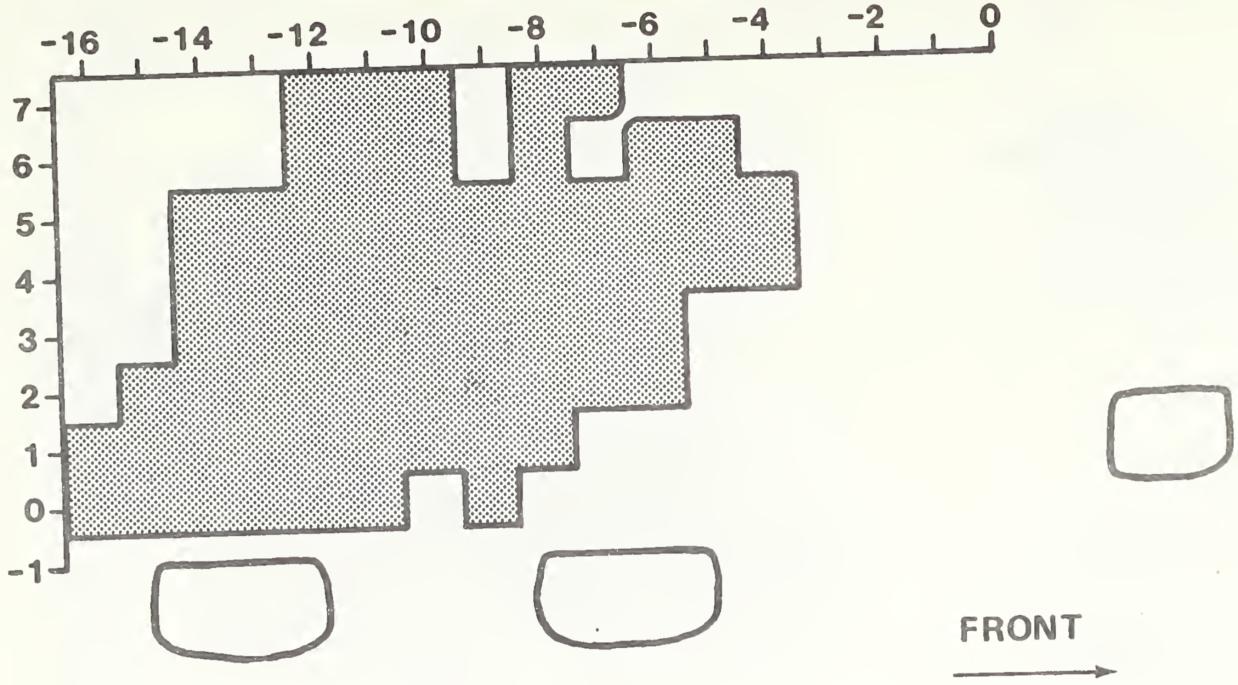

Figure 2-10 CRITICAL AREA FOR ALL DRIVING MANEUVERS

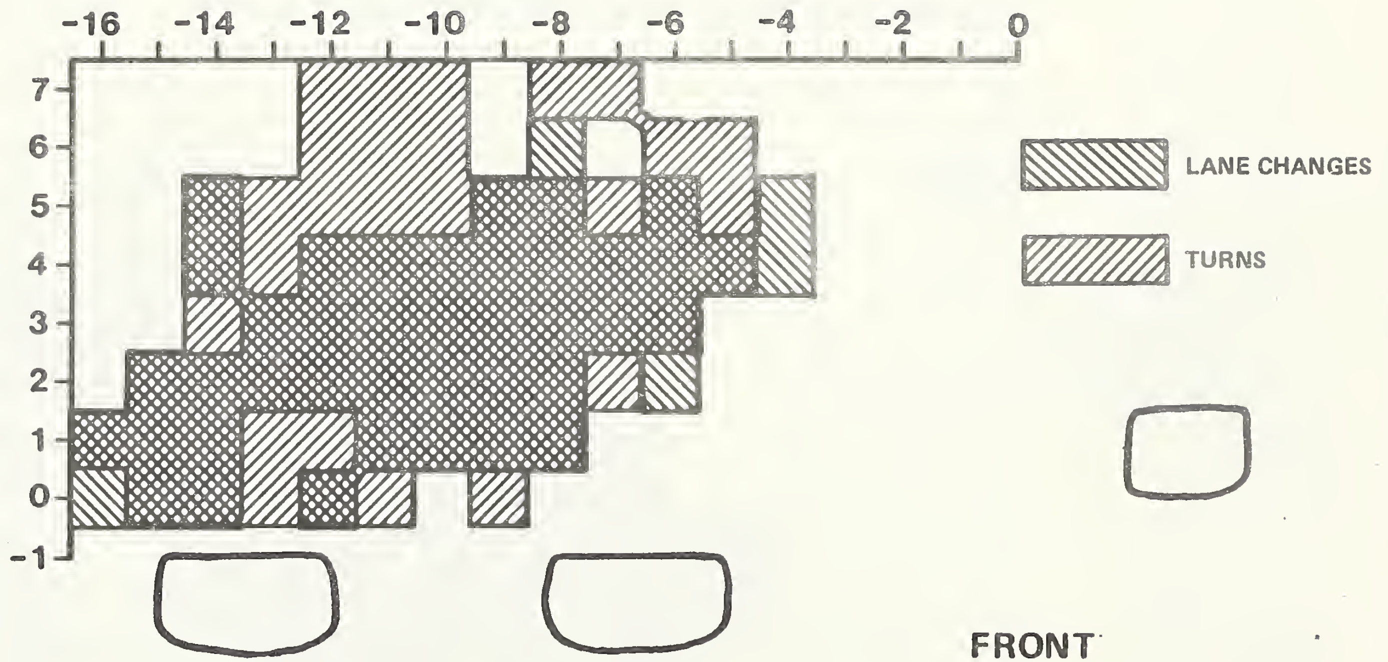

Figure 2-11 COMPARISON OF LANE CHANGE AND TURNING CRITICAL AREAS

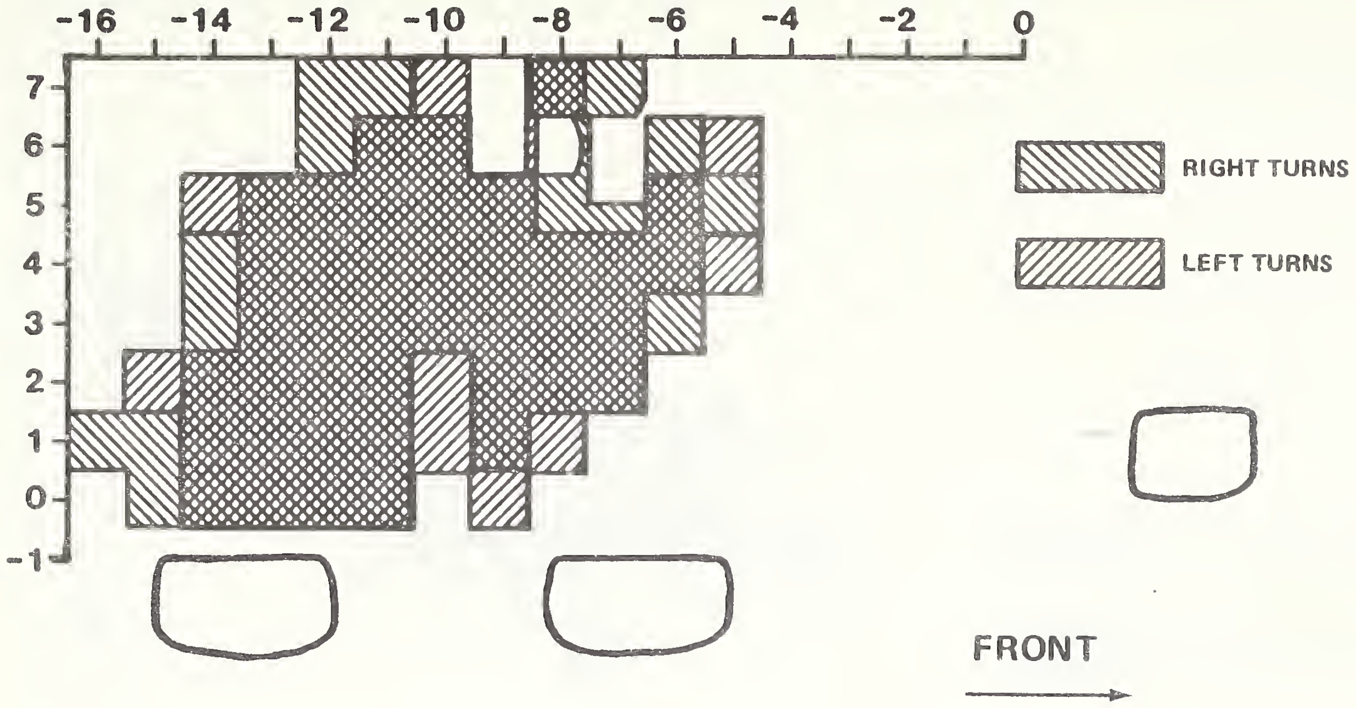

Figure 2-12 RIGHT AND LEFT TURN CRITICAL AREAS

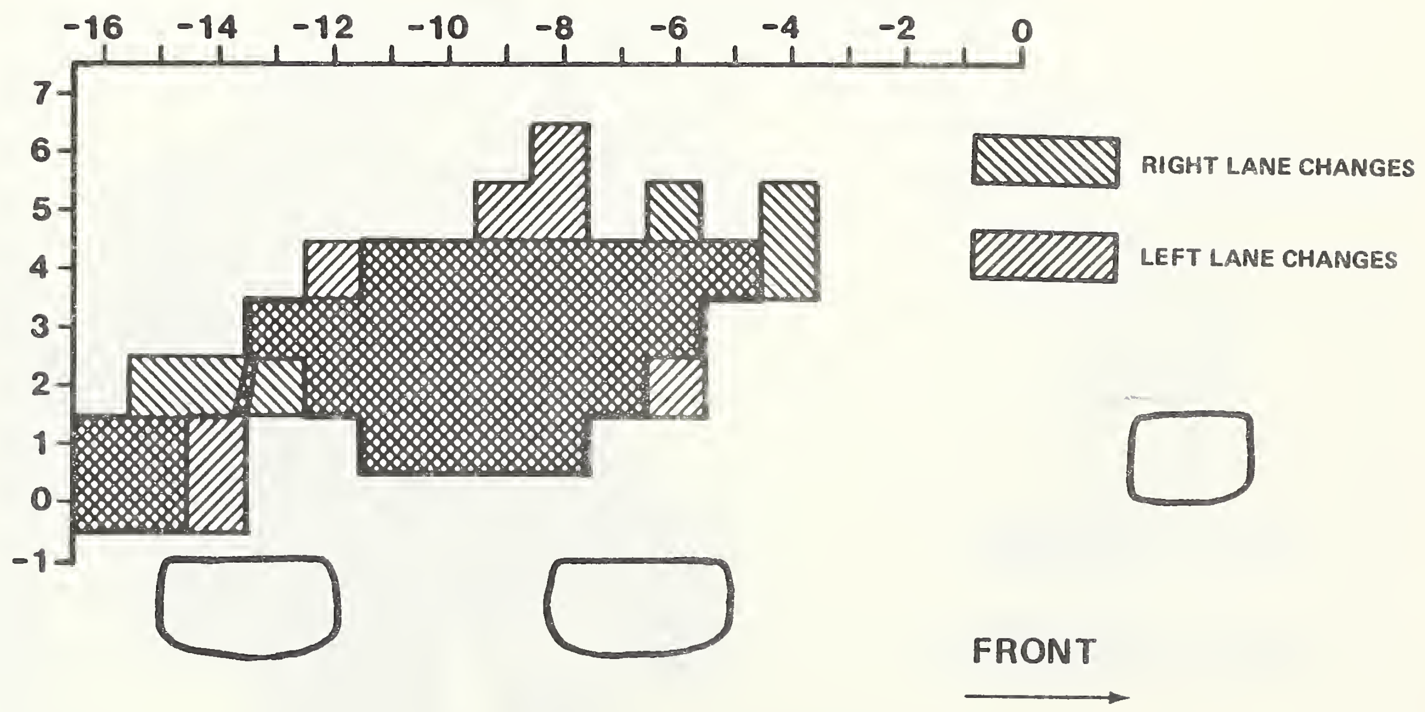

Figure 2-13 COMPARISON OF CRITICAL AREAS FROM RIGHT AND LEFT LANE CHANGES

Another possible explanation for this phenomenon involves the fact that the representative driving tasks studied are consist of two components. The initial portion requires a steering input in one direction, while the completion of the maneuver utilizes an input in the opposite direction. This second element is aided by the self-aligning torque of the front wheel, thereby decreasing the amount of force that must be applied to the steering wheel. This, in turn, may reduce the amount of driver arm motion.

The impact of this direction-related finding on the design of a candidate test panel is minimal. This is because a right-going maneuver is no more likely than a left-going one in the real world, nor are the consequences of a control failure in one direction any different from those in the other. Therefore, the padding must be designed to accommodate the worst case situation, i.e., right-going maneuvers.

The frequency data were also examined. Figure 2-14 summarizes the analysis of the frequencies obtained from combining all the subjects and all the maneuvers. In Figure 2-14, three areas have been defined. The first area, denoted as the critical area, is identical to Figure 2-10, it does not have any frequency information associated with it. A second area was defined in which significant numbers of elbow positions were observed, but in only a few of these instances (less than 10) was the elbow within two inches of the side door panel. The area is called the low critical frequency area. Finally a third area was defined which consisted of the cells in the grid with a very small number of observations, regardless of the observed lateral clearances. This is the low absolute frequency area.

Figure 2-14 is important for several reasons. Looking first at the area which is only composed of cells from the critical area, it is observed that this area not only had high cell frequencies, but also consists of cells with a significant number of lateral clearances of less than two inches. This would imply that if padding was placed in this area, a significant amount of driver/padding interference would be likely to occur. As a consequence, it would seem that little, if any, additional padding could be added.

A second result of Figure 2-14 involves that area which is defined by those portions of the intersection of the critical area and the low critical frequency area which are independent from the low absolute frequency area. Within this portion

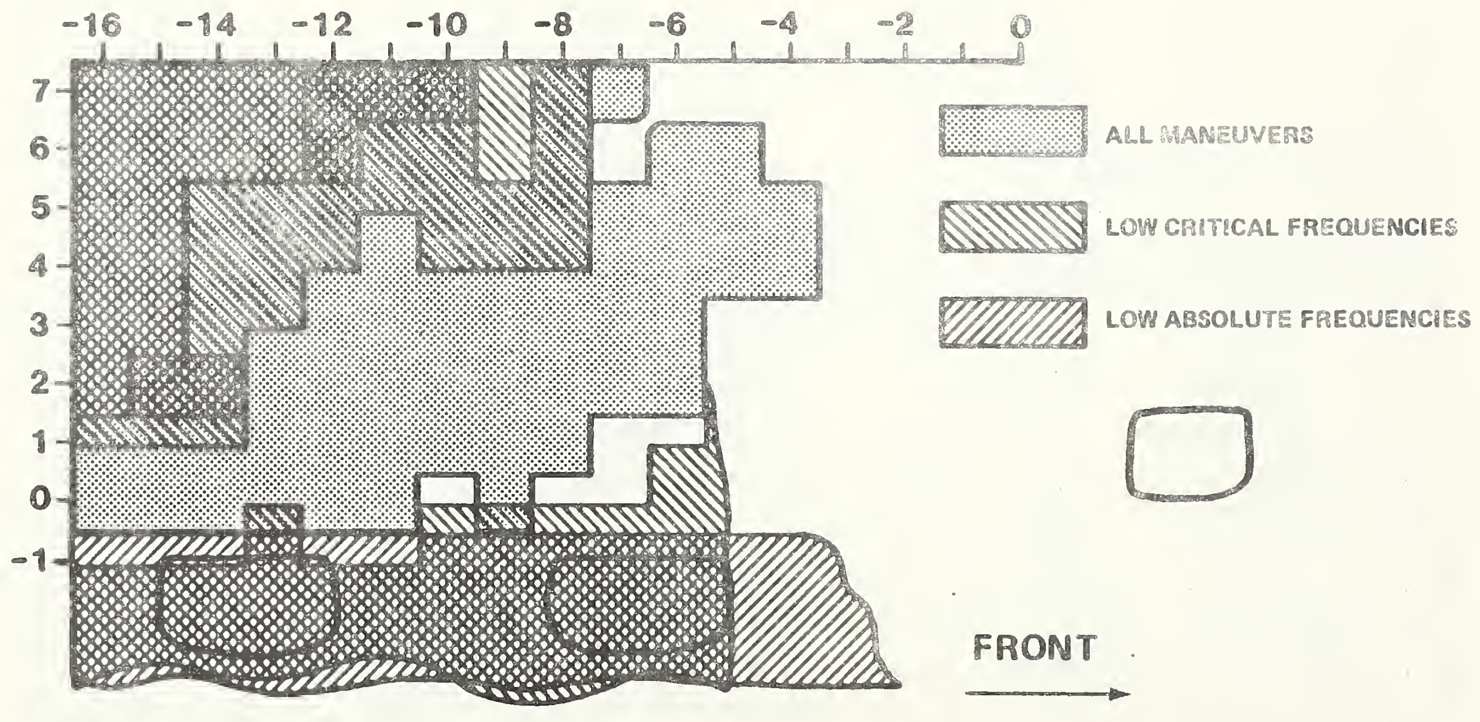

Figure 2-14 ALL MANEUVERS CELL FREQUENCIES

of the door panel, there are still a significant amount of elbow excursion; however, there is a greater lateral clearance, thereby allowing additional padding to be added. At the same time, maximum padding thickness cannot be realized, since there are still a large number of instances when the observed clearance was in the range of two to four inches. It is noted that this area is very similar in shape to the area comprising the unique portion of the turning critical area when compared to the lane change critical area (Figure 2-11).

Finally, there seems to be very little reason to restrict the amount of padding added because of dynamic motion in the region of low absolute frequency since very few elbow excursions were observed in this area. The limiting factor in this case is the static distance between the left upper arm and the door panel.

Another interesting comparison is given in Figure 2-15, which is a comparison of the critical areas for male and female subjects, using data from all maneuvers. The point to be emphasized in this comparison is that the female critical area is, in essence, a small subset of the male critical area. In other words, a padding configuration which accommodates males, will also be suitable for female drivers.

The elbow time history data were also used in an attempt to identify the relevant characteristics of the people who require the greatest lateral clearances. Briefly, a template matching procedure was employed. The critical area formed by a subset of subjects was compared to the critical area for all maneuvers and subjects, i.e., Figure 2-10. The objective was to find the best match with the fewest number of subjects. The two best matches are shown in Figures 2-16 and 2-17. The better of these two comparisons (given in Figure 2-16) included subjects with long lower arms; specifically the largest recorded elbow to grip distances. Eight subjects comprised the subset, while in Figure 2-17, in which a slightly poorer match is achieved, seven subjects were included.

The identification of long lower arms as an important factor is not surprising, in that, given a line connecting two fixed points, i.e., the shoulder and the hand on the steering wheel, the distance from the elbow to this line would be greatest for individuals with the longer arm dimensions. With the appropriate orientation of the plane formed by the shoulder, elbow, and hand, the same people would also have

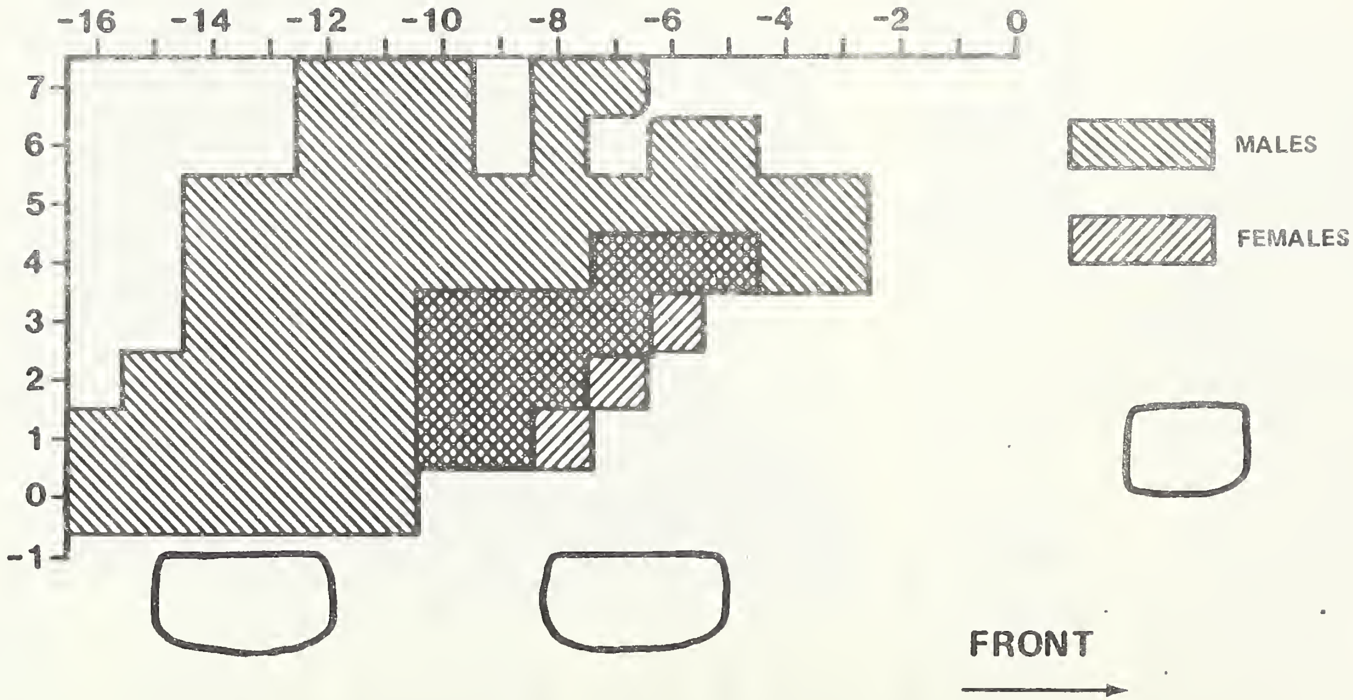

Figure 2-15 CRITICAL AREA BY SEX

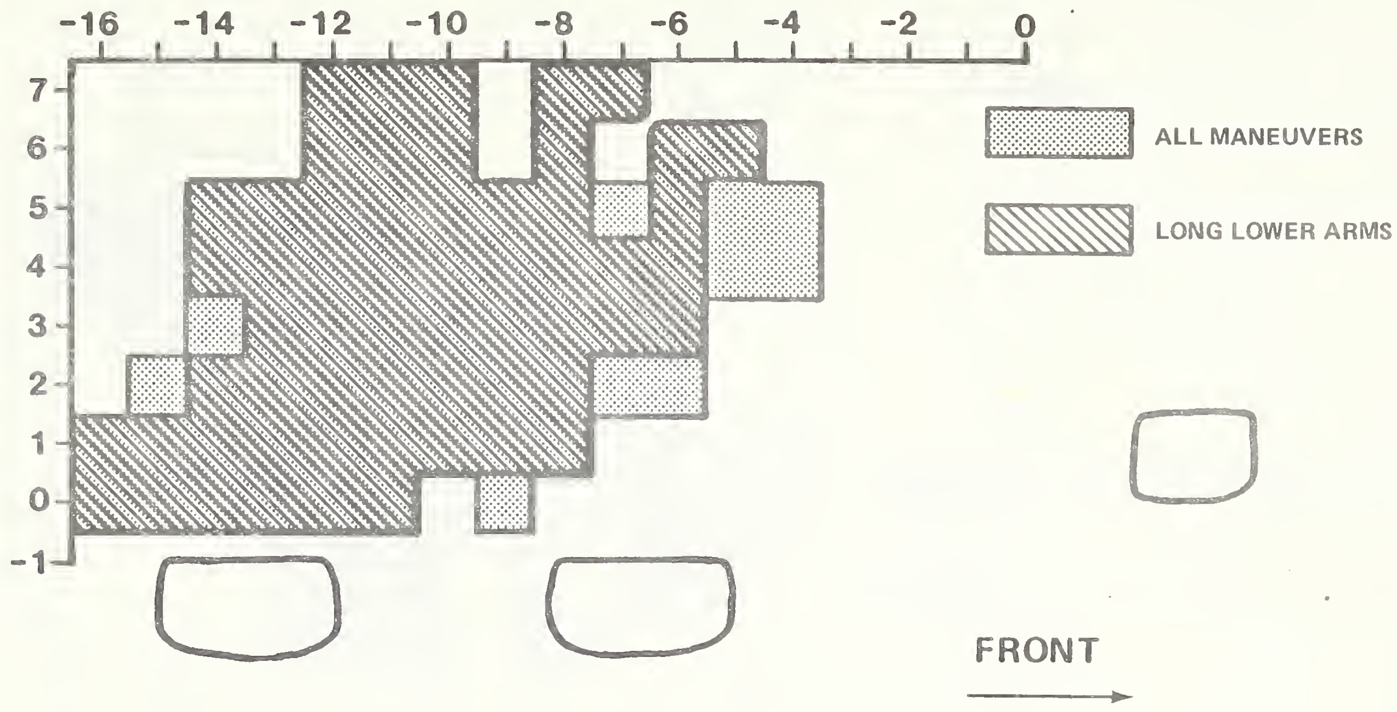

Figure 2-16 CRITICAL AREA FOR SUBJECTS WITH LONG LOWER ARMS COMPARED TO OVERALL CRITICAL AREA

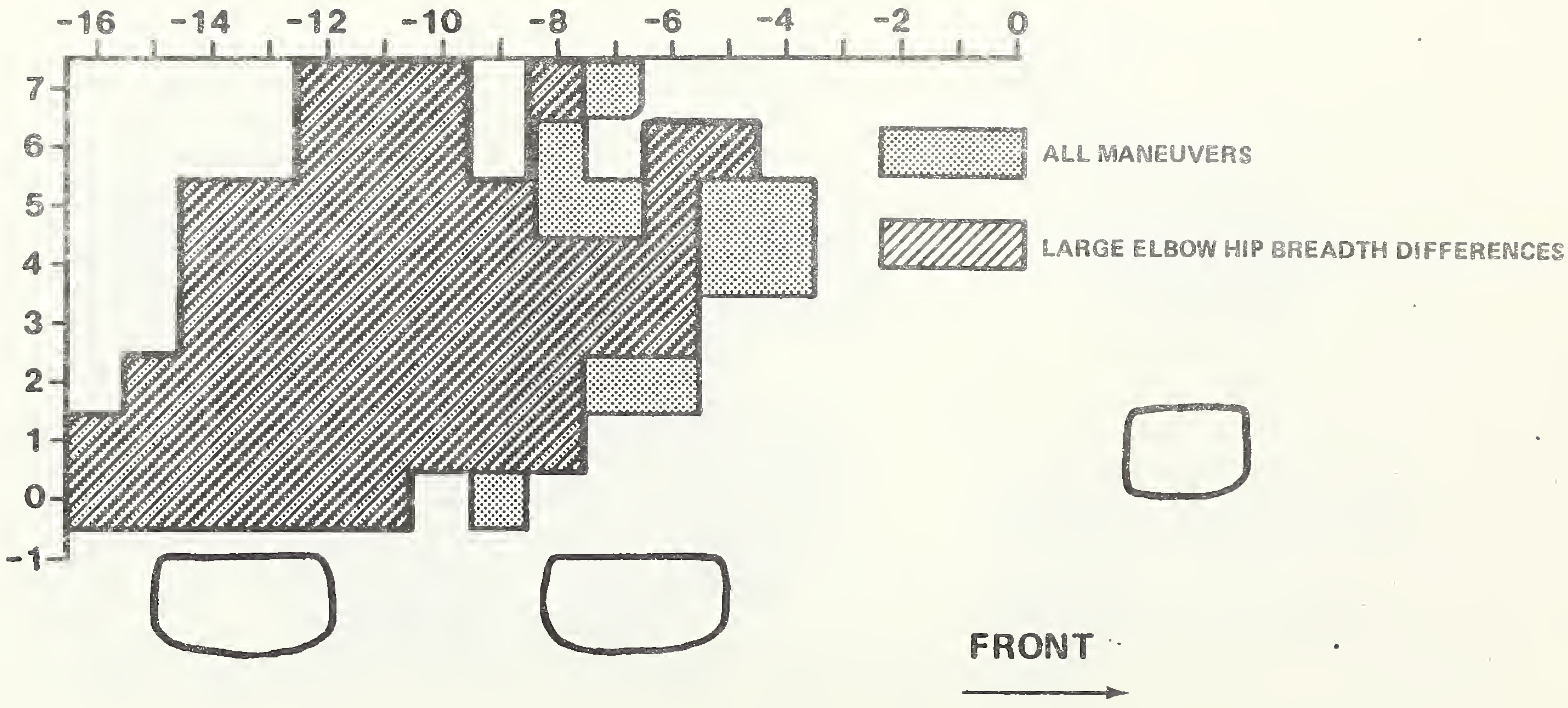

Figure 2-17 CRITICAL AREAS FOR SUBJECTS WITH LARGE ELBOW-HIP BREADTH DIFFERENCES AND ALL SUBJECTS

the greatest lateral clearance requirements. It is noted that long upper arms were a significant factor in analyzing the Task 2 performance data.

The effect of the elbow-hip breadth difference is not nearly so clear. On the surface, this appears as if it was a result of one's proximity to the door panel at the beginning of the maneuver. However, if this was indeed the case, it would seem that elbow breadth alone would be the dominant parameter.

There is a second possibility for the above observations. Specifically, they may simply be a result of sex differences; men typically have longer arms than women, and the difference between the elbow-elbow and sitting-hip breadth is generally smaller for females than for males.

The ultimate side door padding configuration will have to protect all sized occupants in a side impact. Energy management of the upper torso cannot, obviously, be adequately provided by padding designed only for the hips. This implies that padding must also be available at the level of the upper arm/upper torso.

Figure 2-18 is a schematic of the geometry involved in determining precisely how far forward the side padding must extend in order to accommodate the shortest drivers in the study.

As can be seen in Figure 2-18, padding should, as a minimum, extend to the point at which the top of the door panel and the line joining the driver's shoulder and H-point intersect. The driver H-point was measured before the subject was filmed; a nominal shoulder position was obtained by examining the shoulder time history data. It was then a simple matter to compute the intersection of these two lines. Table 2-9 gives a frequency distribution of the top of the door crossing; these values are consistent with the frame of reference pictured in Figure 2-9.

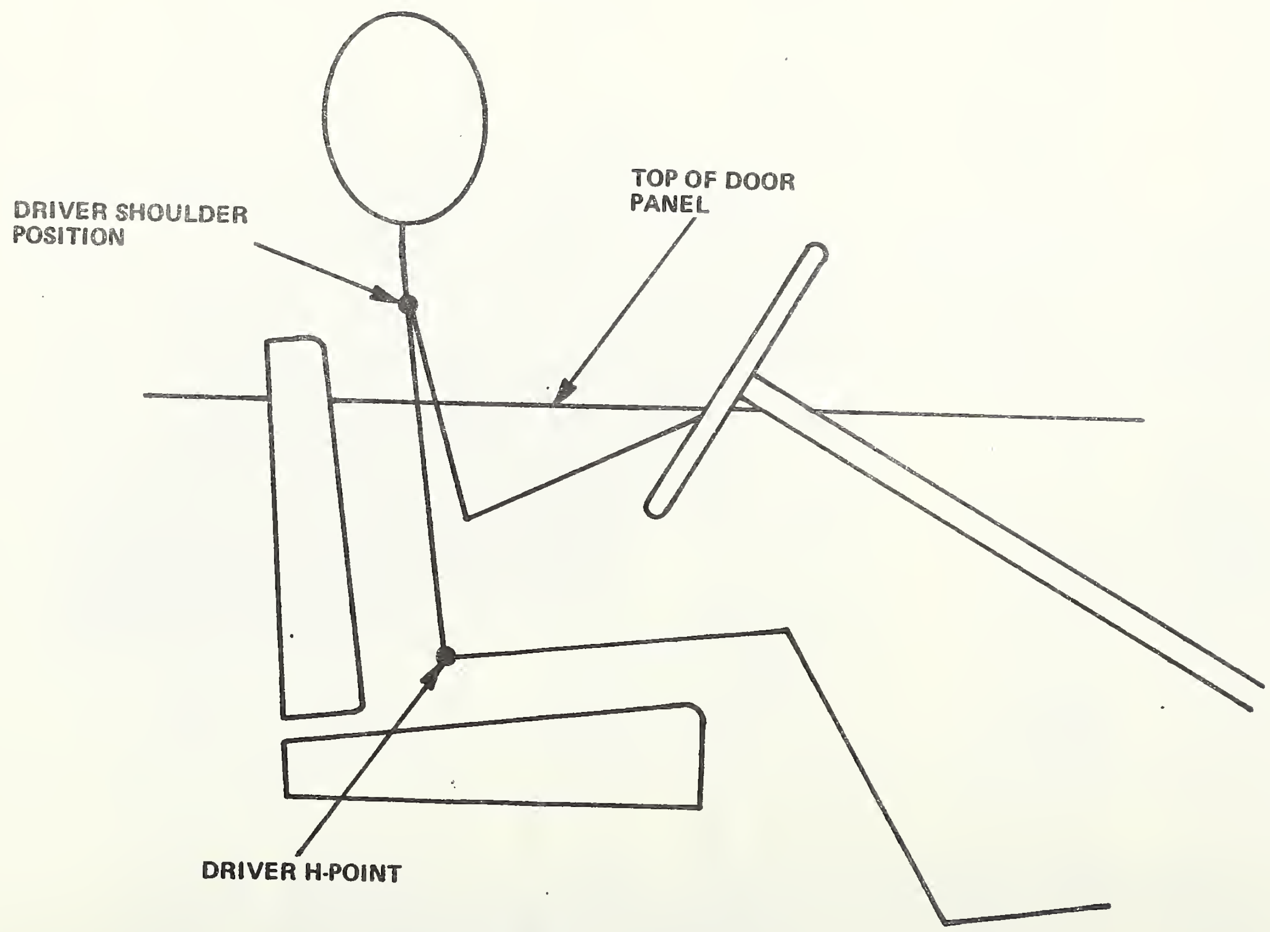

Figure 2-18 TOP OF DOOR PANEL CROSSING GEOMETRY

Table 2-9

COMPUTED TOP OF PANEL CROSSINGS

LONGITUDINAL POSITION (INCHES)		FREQUENCY
7-8		1
8-9		2
9-10		1
10-11		2
11-12		5
> 12		8
	TOTAL	19

2.7 DESIGN OF CANDIDATE SIDE PADDING PANEL

The last aspect of Task 1 was to design a side padding configuration based on the empirical lateral clearances, which was to be tested in Task 2. There were six criteria that were used in the design effort.

The first three criteria were discussed previously. In particular:

- o High frequency critical areas can only have minimal padding depths
- o High frequency areas with relatively few observations in the critical range can be compromised by adding slightly more padding than indicated by lateral clearance data
- o Thick padding can be added in those portions of the door panel which are associated with few, if any, elbow excursions.

Another criterion was alluded to at the end of the Section 2.6. This involved ensuring that the panel extended sufficiently far forward so that even the smallest occupant's upper torso or arm engaged the padding.

The padding design criteria also required that the padding be as wide as it is thick. This was included in order to guarantee that the padding remained stable when it was contacted. It would not be desirable for the padding to "fold over" during contact. A narrow strip of thick padding might very well have such a tendency.

The final criterion was introduced in an attempt to minimize occupant rotation, which might be induced by the hip padding section, of the torso about the hip in a crash environment. This concern implied that large discrepancies between the maximum thickness of the upper and lower padding sections should be avoided.

Given these above considerations, a design concept was generated. A schematic of it is given in Figure 2-19. The cross-hatched area has minimal padding, while that portion marked with a single line is padded with maximum thickness. A transition section is denoted by an unmarked area. The thickness of the various panel sections was an experimental factor in Task 2, and are consequently defined in Section 3.

Figure 2-20 shows how the design concept was determined. This is a repeat of Figure 2-14 after curve-smoothing the high critical frequency/high frequency-low critical frequency and the high frequency-low critical frequency/low frequency area boundaries.

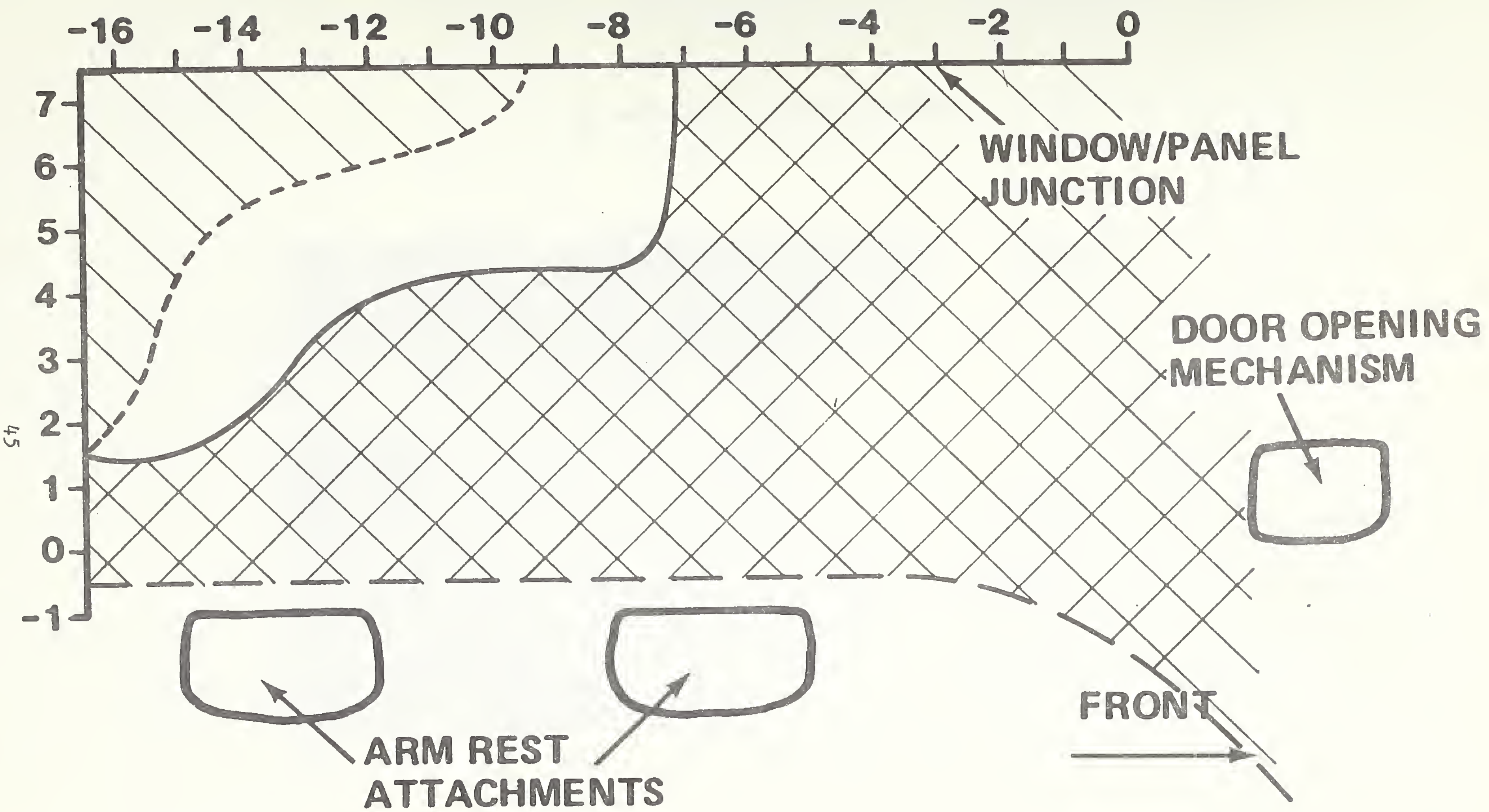

Figure 2-19 PANEL CONTOURS

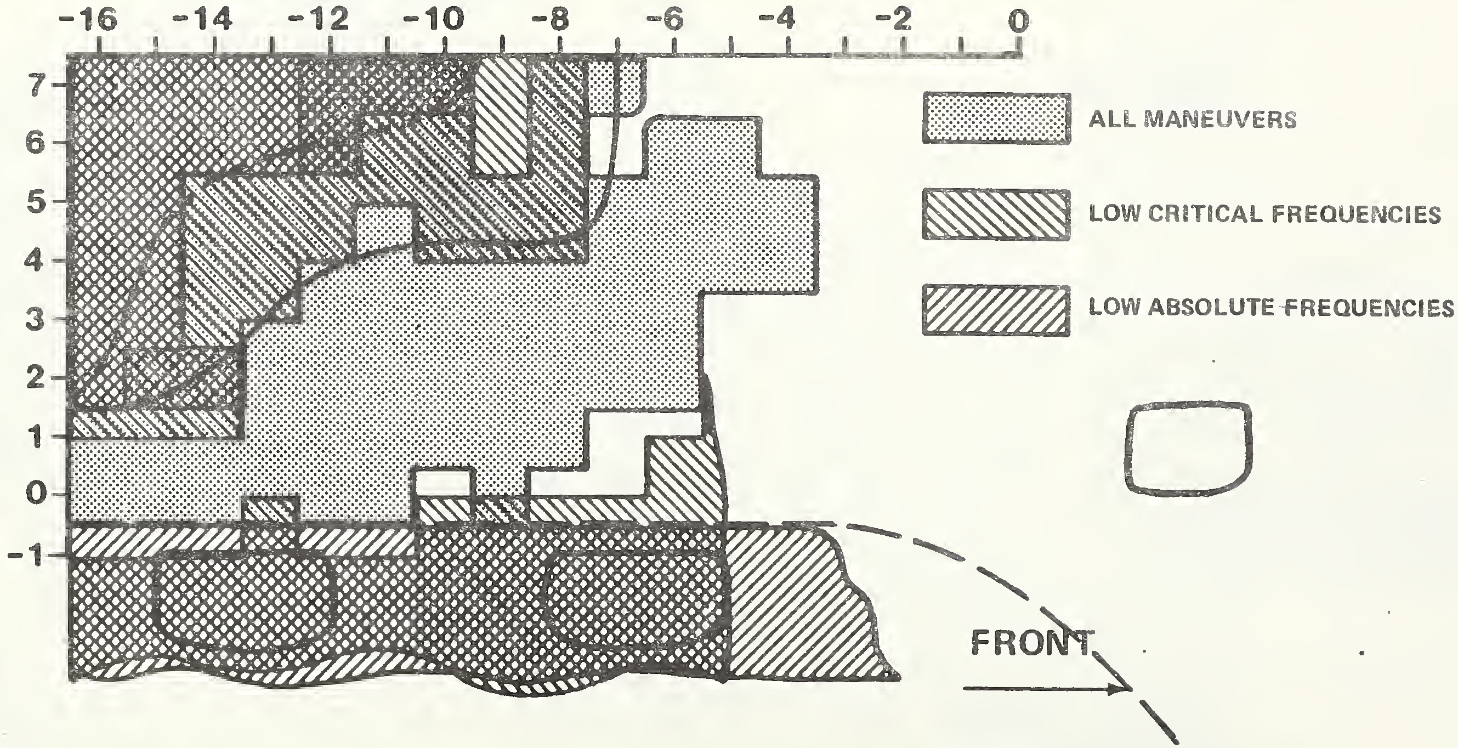

Figure 2-20 PANEL CONTOUR BASIS

Section 3
TASK 2 - EFFECT OF PADDING ON DRIVER PERFORMANCE

In Task 1, a concept for a side door padding configuration was developed. It was based on the aggregate lateral clearance requirements as determined by analyzing films of nineteen relatively broad operators performing a series of representative driving tasks. The objective of Task 2 was to assess the effect of prototype side door padding panels on a vehicle operator's driving performance. Briefly, this involved evaluating the performance of a number of drivers executing a double-lane change maneuver; both the time to complete the maneuver and the ability to stay on the course were used as dependent measures. Details of the actual testing and the results are presented in the remainder of this section.

3.1 PROTOTYPE TEST PANEL FABRICATION

The side door panels evaluated in Task 2 consisted of two segments. One segment was for the driver's hip; this was the same for both of the test panels. It was four inches thick and its shape was consistent with the contour in Figure 2-19. Since the driver's hip was observed to be reasonably stationary, this portion of the panel was not evaluated with regards to operator interference. Its primary purpose was to provide an armrest for the driver.

For the upper portion of the side panel, the same general design was used for both of the prototypes; only the padding thickness was varied. One panel consisted of a critical area with one-inch padding, which increased to a maximum of three inches. The second panel was designed so that the maximum thickness area was four inches and had a critical area with padding of two inches.

In constructing each of the panel segments, efforts were made to have the end product be visually appealing. This was a result of the pilot testing (described in Section 3.2), in which acceptance of the padding concept appeared as if it would be more dependent on subjective impressions than a function of driving performance. Thus, while performance data were the most important result of Task 2, it was desirable to obtain indications of the panels' overall acceptability to the drivers. It was believed that aesthetic differences between the test panels and the stock VW door panel could affect these subjective judgments. Accordingly, every effort was made to minimize these differences.

The first step in constructing the test panels was to create a styrofoam base, which conformed to the general shape of the contours given in Figure 2-19. The "rough cut" blocks of styrofoam were then smoothed by personnel in Calspan's Graphic Arts Department. It had been planned originally to cover the styrofoam with a thin layer of fiberglass, in order to provide rigidity and to prevent permanent deformation from arm contacts with the panel. Prior to attempting this, however, it was discovered that resins used in the fiberglassing process would destroy the styrofoam. Thus, two coats of epoxy paint were applied to each of the styrofoam bases before the fiberglass layer was formed.

A thin sheet of aluminum was glued to the back of the prototype door panels. Onto each of these aluminum panels were attached two threaded steel rods, which were inserted through the existing side door panel and door skin. Wing nuts and washer were then used to tighten the prototype panels in place.

It is noted that there was insufficient space between the door panel and the seat back to accommodate both the aft surfaces of the 4 inch maximum thickness upper panel and the hip padding segment. As a result, those portions of the panels where this conflict existed were reduced in thickness until they fit. This did not affect any surfaces that could potentially interfere with the driver.

The panels were then taken to Neuland Trim Shop, Inc., where they were upholstered with a green Naughahyde, which closely matched the color of the stock door panel. Figures 3-1, 3-2, and 3-3 contain photographs of the three finished segments. In the two upper panels, note the cut-outs that were necessary to allow the driver access to the door handle.

3.2 DRIVER PERFORMANCE MEASURE

There were a number of considerations in the choice of the test maneuver selected in Task 2. The underlying assumption was that if a task could be found which challenged the ability of a typical driver, then the lack of any noticeable effect on driving performance from the padding configuration under test conditions could be

Figure 3-1 3 INCH UPPER TEST PANEL

Figure 3-2 4 INCH UPPER TEST PANEL

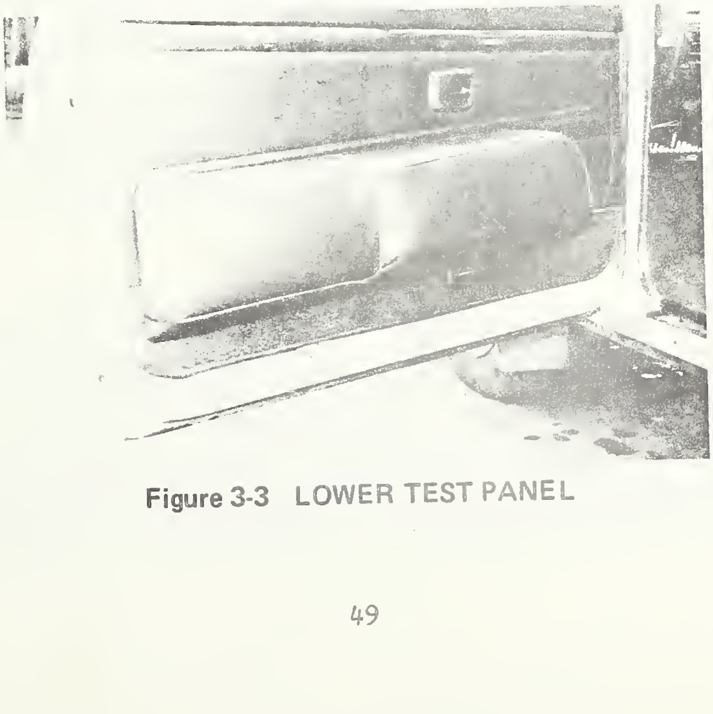

Figure 3-3 LOWER TEST PANEL

generalized to the more normal driving situation. An outgrowth of testing near the limit of the test subjects' abilities was meaningful performance measures. In particular, a difficult maneuver was more likely to produce mistakes which could be observed, both in terms of time to complete the maneuver and deviations from the desired vehicle path.

By way of illustration, consider a subject test task consisting of a right turn, defined by a series of traffic pylons. Few, if any subjects, would be expected to knock over any pylons if they were only instructed to negotiate the "course". Evaluation of the padding configuration would degenerate to an analysis of subjective opinions. However, if the subject was requested to complete the maneuver in as little time as possible, the operator would be forced to trade off errors in maintaining vehicle directional control for increases in time to complete the maneuver. Effects of the padding configurations could then be assessed by jointly comparing the number of struck pylons and time to complete associated with a test panel to that of a baseline condition, i.e., an unmodified Volkswagen side door.

Adopting the above procedure for Task 2 would, however, fail to consider another important factor. Specifically, a subject would be allowed to utilize a strategy which would be geared to completing the test maneuver at the expense of any subsequent driving-related operation. In order to avoid this situation, it was decided to employ at test maneuver which was, as a minimum, bi-directional.

One candidate maneuver was a slalom course, in which the operator weaves through a series of pylons placed in a straight line. This test was rejected for several reasons, but primarily because of its difficulty. It was believed that the time required to learn the maneuver was just not practical; it was entirely possible that some people might not even be able to consistently negotiate the course successfully. It was also thought the variance of the performance measure might also be excessively large, due to the complex relationship among the entry speed, distance travelled, and time to complete.

In the end, a double lane change maneuver, as originally proposed, was selected. This maneuver can be thought of as a "mini-slalom" course, thereby satisfying many of the criteria which made a slalom maneuver attractive. In addition, it was believed that the complexity of the double lane change maneuver was such that all subjects could be expected to perform it successfully with only a moderate amount of training. Unlike the slalom course, the double lane change maneuver also had a real world driving analog, i.e., an evasive action in which the operator steers around a hazard.

A schematic of the test course is provided in Figure 3-4. Traffic pylons were used to define the test course. At both ends strip switches were placed to start and stop a Systron-Donner Model 6150 counter/timer.

The dimensions of the course were adjusted such that the course could not be successfully negotiated at speed above 20-25 mph. This was accomplished by varying (1) the width of the straight middle section, (2) the length of the middle segment, and (3) the length of the transition segments of the lane change maneuvers.

Pilot testing was conducted in order to establish that the double lane change maneuver was sufficiently sensitive to detect decrements in driver performance. During the pilot phase, driver performance in the double lane change maneuver was relatively consistent, with average completion times just under 4 seconds with a standard deviation of 0.1 to 0.2 seconds. There were also noticable, but statistically unreliable, differences in the performance as a function of the direction, i.e., left change-right change versus right change-left change.

As mentioned above a major concern of the pilot testing was the sensitivity of the proposed metric to interference of the driver by the door panels. This was evaluated by having pilot test subjects drive under three conditions: using the standard Volkswagen side door panel; with a three-inch block of styrofoam taped to the door; and with a six-inch block of styrofoam taped to the door. Under the last condition, the vehicle operator could barely move his left arm, since the styrofoam was continually in contact with it. It was here, under the most constrained condition, that a statistically significant difference was found in the time to complete the test maneuver.

No statistical difference was detected when comparing the baseline condition to the three-inch styrofoam slab. It was believed that there were two major causes for this, one of which was controlled in the experimental phase of Task 2. The controllable factor involves the subject's learning to perform the test maneuver. In the pilot testing, the length of the learning curve was underestimated. In particular, evidence of a consolidation phenomenon was observed, i.e., when the performance

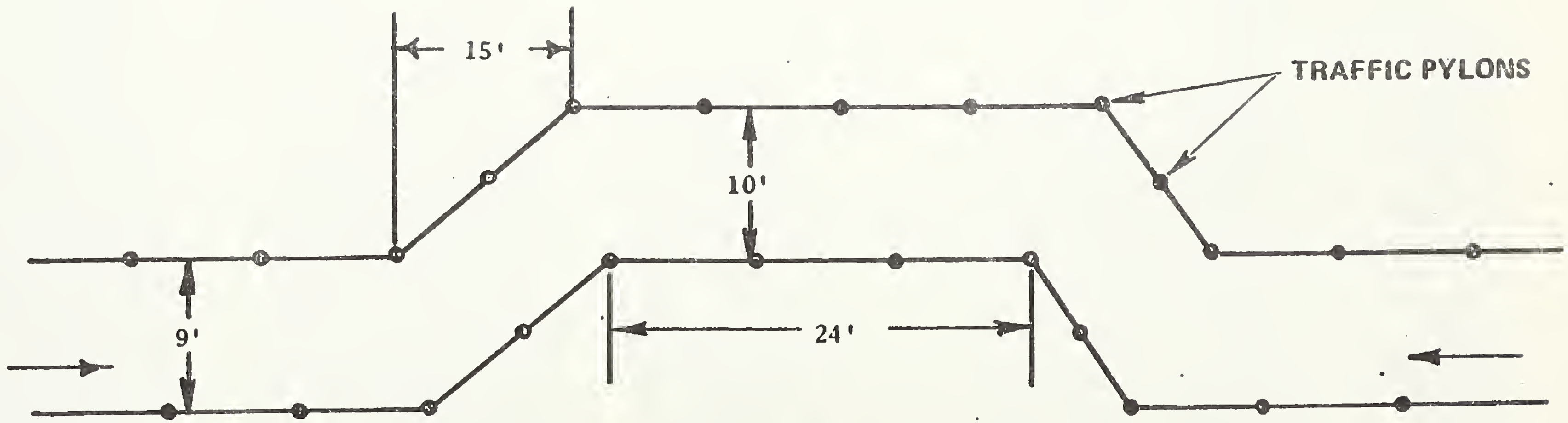

Figure 3-4 DOUBLE LANE CHANGE MANEUVER

measure had appeared to stabilize, a noticable improvement in performance would be obtained after a brief rest period. As a result, the learning phase of the experimental procedure was evaluated on the subject's performance on a block of trials. In addition, the order in which the various side door panels were presented was counterbalanced. Finally, with experience, the test conductor learned what a reasonable time to complete the course was, and used that to judge the progress of the subject's learning.

The other more critical factor affecting the driving performance was a subject's apparent ability to change his driving strategy as a result of the various side panels. Specifically, with the three- and six-inch styrofoam panels in place, each subject tended to depend more and more on the right arm and hand to generate the steering inputs. With a three-inch thick pad it appeared as if the right arm could successfully carry out the additional functions required of it. In essence, the drivers' performance remained stable despite forced variations to the individual driving techniques.

The above result is consistent with the study's objectives, providing, of course, that the "strategy-related" information is obtained from the test subjects. This was accomplished by including a debriefing period of the experimental procedure.

Thus, it was believed that the time to complete the double lane change maneuver was an appropriate performance metric. However, one other dependent variable, i.e., number of pylons struck, was also recorded. This other variable allowed the use of more sophisticated analytical techniques.

3.3 EXPERIMENTAL DESIGN

The effects of side padding on driving performance were assessed empirically using a two-factor, within-subjects experimental paradigm. The primary effect being evaluated was, of course, that of the side door panel being used. A second concern was whether the direction of the lane change maneuver, i.e., left change-right change (LC-RC) or right change-left change (RC-LC), affected the operator's performance.

Originally, it was proposed to use twelve subjects and obtain two replicate tests in both directions for each padding configuration. However, the power (β) of this design, i.e., the probability of detecting an existing small difference, does not appear to be sufficiently high, given the slight differences obtained in the pilot testing; a value of β of 0.10 was estimated for the originally proposed design. Accordingly, β values were computed for other combinations of subjects and replications. These are reported below in Table 3-1. The combination of subjects and replications that was selected was the one utilizing nine subjects each with twelve replications. This provided an estimated power greater than 0.50, while minimizing the probability of detecting differences which may be of little practical significance.

Table 3-1

ESTIMATED POWER OF PADDING MAIN EFFECT

Number of Subjects	Replications 4	8	12
6	0.14	0.28	0.38
9	0.19	0.38	0.59
12	0.24	0.49	0.69

The order of presentation of the different panel configurations was counterbalanced across subjects. The order of presentation of each test panel for all nine subjects is shown in Table 3-2. The direction of the lane change maneuver was counterbalanced within subjects, such that the number of LC-RC's following an RC-LC was the same as the number of RC-LC's following an LC-RC. In particular the order for each 2 replication sets was: LC-RC; RC-LC; RC-LC; LC-RC.

Table 3-2

ORDER OF TEST PANEL PRESENTATION BY SUBJECT

Subject	Baseline	3" Maximum Thickness Padding	4" Maximum Thickness Padding
1	1	3	2
2	2	1	3
3	3	2	1
4	1	3	2

Table 3-2 (Cont.)

Subject	Baseline	3" Maximum Thickness Padding	4" Maximum Thickness Padding
5	2	1	3
6	3	2	1
7	1	3	2
8	2	1	3
9	3	2	1

Two dependent measures were obtained from each test trial for later analysis. The variables were:

- o time to complete lane change maneuver and
- o number of pylons knocked over

To summarize the experimental design which was utlized, an ANOVA table is presented in Table 3-3.

Table 3-3
EXPERIMENTAL DESIGN SUMMARY

Source	d.f.
Padding thickness (P) (0, 3", 4")	2
Direction (D) (LC-RC; RC-LC)	1
Subjects (S)	8
P x D	2
P x S	16
D x S	8
P x D x S	16
Within (12 replications/cell)	594
Total	647

3.4 SUBJECT SELECTION

In Task 1, it may be recalled that the aggregate lateral clearance requirements were defined almost entirely by the taller male subjects. As a result, it was decided that this type of subject would provide the most useful information during Task 2. A second issue during Task 2 was to determine if a threshold existed, along some given body dimension, above which the driver was affected by the side door panels, and below which driver/padding interaction did not appear to be important.

Accordingly, a subject test matrix was desired which would include a range of subjects, all of whom were relatively large compared to the overall population. Table 3-4 gives the target percentile heights and weights of the test matrix which was adopted; all subjects were male.

Table 3-4
SUBJECT TEST MATRIX

	Subject Percential Weight		
Subject Percentile Height	95	90	75
95	1	1	1
90	1	1	1
75	1	1	1

Subjects were hired through a temporary employment agency. In order for the double lane change test to be valid, the drivers had to be continually striving for their best performance. Thus, the subjects were all told that they would be paid $20 for their participation, plus any bonuses they might earn as a result of their performance during testing. In any event, all the subjects appeared to be highly motivated during the test procedure. It is not clear whether this was attributable to the incentive bonus or the subjects' own character.

3.5 AUXILIARY DATA COLLECTION

There were two relatively simple tests which were conducted to determine 1) whether the prototype door panels interfered with the driver's ease of entry and egress, and 2) a preferred distance between a driver a door panel.

Upon completion of the driving performance tests, in which a prototype door panel was used, the subject was requested to get in and out of the vehicle a few times with the experimenter noting any contacts with the side door padding. The experimenter's observations of entry/egress problems was supplemented by asking the subject directly about any difficulties that may have been encountered entering or exiting the test vehicle.

Subjects who felt that the side door padding was too close to them were requested to participate in an additional procedure to determine an acceptable subjective lateral clearance for the padding. This was a relatively straightforward process in which the distance between the subject and a door panel was adjusted until the subject felt that the amount of clearance was adequate.

The subject was seated in another Volkswagen Rabbit on which the driver door had been removed. A planar surface was mounted on a movable platform, thereby allowing the distance between the driver and the surface to be easily adjusted. Figure 3-5 is a photograph of the movable device on which the vertical surface was mounted.

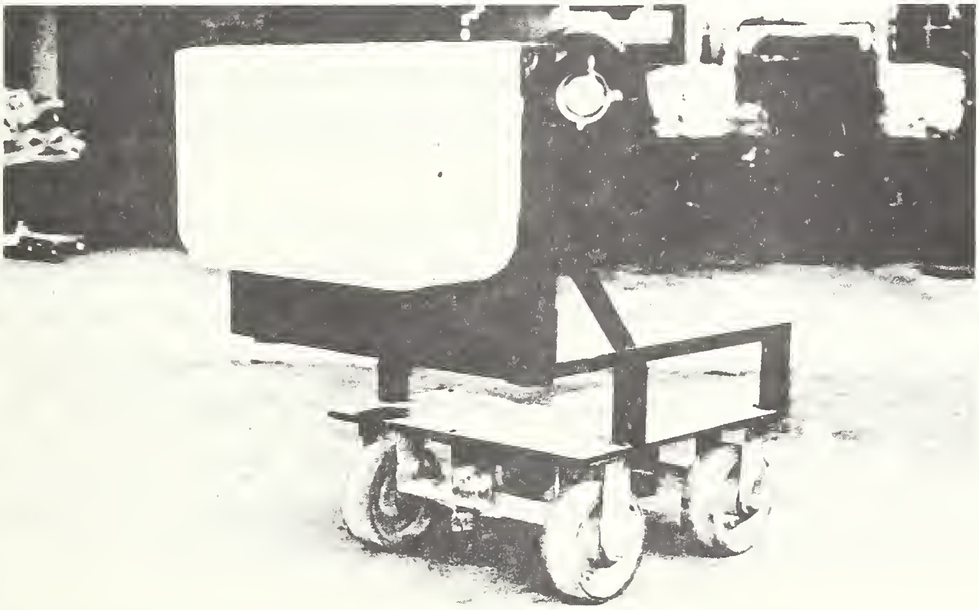

Figure 3-5 PANEL PROXIMITY TESTING DEVICE

Two judgments of the acceptable distance were obtained from each subject. The procedure that was followed for the first judgment involved positioning the door panel so that it just contacted the subject's upper arm/shoulder. It was gradually moved further and further away until the subject felt there was enough room. To obtain the second position, the panel was set six inches outboard of its actual position in the test vehicle, and moved increasingly closer to the subject until it was felt that the panel was too near. The mean value of the two judgments was the optimal position of the door panel.

3.6 TEST PROCEDURE

Upon arrival at Calspan, the test subjects height, weight, and other requried anthropometric data (see Task 1) were obtained and recorded on the Data Collection Form (Appendix 1). In the process, the subject was advised of the task he was expected to perform. This involved, primarily, a sketch of the double lane change maneuver and a description of the parameters upon which his performance was to be judged - time to complete the maneuver and the number of pylons struck.

It was at this time that the subject was informed of the performance bonus he could receive once he had become familiar with the maneuver and the test trials had begun. In particular, he was told that for each series of test trials, a five dollar bonus could be earned if both the completion times and number of struck pylons were sufficiently low. In actuality, all subjects, regardless of their performance, were to be paid the bonus; this strategy was employed in order to motivate the subject to drive at or near the limits of his ability. As mentioned previously, this was a fundamental assumption of the experimental design.

The subject was taken to the test vehicle, which was equipped with the standard (baseline) interior door panel, regardless of the initial test configuration. The driver adjusted his seat until comfortable, and the position was recorded. A series of turning and parking maneuvers were conducted on the VERF facility in order to familiarize the subject with the characteristics of the test vehicles; the maneuvers were the same ones utilized in Task 1, i.e., right and left turns, lane changes, backing, K-turn, and parallel parking.

After a short time, the learning phase on the double lane change maneuver was initiated. The subject was first instructed to drive slowly through the course. Gradually, the subject increased his speed and a technician began recording the number of pylons struck and the time required to complete the maneuver. It is noted that the maneuver was performed in both directions during this learning phase and the experimenter remained in the vehicle with the test subject during the test procedure.

Once the performance variables stabilized and the subject felt that he could not traverse the double lane change course any faster, the learning phase was completed. The first of the test panels, as defined in Table 3-2, was installed and the test phase was started.

Testing for any given configuration involved several additional familiarization trials through the double lane change maneuver, followed by a series of 24 test trials, which were described in Section 3.3. Completion times and the number of pylons struck were recorded by a technician, who also replaced any of the displaced pylons.

When all the test trials had been completed, the subject drove the test vehicle back to the main building complex, so that the next test panel could be installed. While in transit, the experimenter asked the subject a series of questions related to the side door panel that had just been tested; the specific queries are available on pages two and three of the Data Collection Form contained in Appendix 1. In addition, the subject was required to enter and exit three times before the panel was removed. Any interference with the door panel was noted.

The subject was asked another series of questions after testing on all three padding configurations had been completed. These questions were intended to obtain the subjects' general attitudes towards driving and those factors important in automotive purchases. These questions can be found on page four of the Data Collection Form.

Finally, the subject was debriefed by the experimenter. At this time, the objectives of the research study were explained to him, and any questions he had were answered.

3.7 RESULTS

As was the case in Task 1, the subjects selected for participation tended to vary from the target heights and weight in a predictable manner. In general, the

Table 3-5

SUBJECT PHYSICAL DIMENSION SUMMARY

	Subject Number								
	1	2	3	4	5	6	7	8	9
Height (in.)	73.0	73.0	73.3	73.3	74.0	70.5	73.8	70.3	71.8
Weight (lbs.)	206.5	272.8	254.0	258.0	271.0	222.5	199.0	228.5	192.0
Age	21.0	33.0	21.0	33.0	23.0	30.0	34.0	20.0	29.0
Sitting Ht. (in.)	37.4	38.6	38.8	38.3	38.8	37.5	38.3	35.8	37.5
Acromial Ht. (in.)	25.5	27.1	26.3	26.3	26.6	25.5	26.4	23.5	25.4
Hip Breadth (in.)	13.4	13.8	13.4	14.4	14.5	13.5	11.4	13.8	11.0
Biacromial Should. Brth. (in.)	16.8	17.3	18.3	16.4	16.5	17.0	17.0	16.8	17.0
Bideltoid Should. Brth. (in.)	19.6	21.0	20.8	20.0	19.8	19.6	18.6	20.0	19.0
Elbow - Elbow Brth. (in.)	21.6	22.8	22.6	23.6	23.0	23.2	18.3	19.0	17.4
Should. - Elbow Length (in.)	15.9	15.3	15.0	15.8	14.8	14.3	14.9	14.3	14.4
Elbow - Wrist Dist. (in.)	11.4	11.0	11.6	12.4	12.3	11.0	11.9	10.9	11.0
Elbow Grip Dist. (in.)	14.3	13.5	13.8	14.8	15.0	14.2	14.6	13.3	13.5

Almost all of the test drivers sat with the seat positioned all the way aft. The exceptions, subjects 1 and 6, had the seat moved forward two and one detent, respectively. Subject 5 was the only left-hander in the sample.

The most important facet of this task was, of course, the analysis of the double-lane change performance data. The recorded time-to-complete and number of pylons knocked over were keypunched onto IBM cards directly from the data collection forms. Also entered were the subject number, padding condition, and the direction of the lane change associated with the set of data points. It is noted that there was one missing data point; no attempt was made to adjust for it, since the analysis software (SAS - see Reference 9) would compensate for it.

Appendix 2 contains the means and standard deviations broken down by subject, padding type, and maneuver direction. Table 3-6 presents the data for each subject by the type of padding panel used.

In Table 3-6, it can be seen that, within a subject, the time to complete performance measure was quite consistent; the sample standard deviation in most cases was in the range of 0.10 to 0.20. It is also noteworthy, that, again within a given subject, the time variable differences are small, and are not predictable. For instance, there are occasions when the subjects performed better (in terms of time) with a prototype panel installed than under the baseline condition, e.g., Subject 3. In this regard, it is noted that the ambient temperature during testing was between 85° and 90°F for most of the subjects. Thus, the times could have been affected by fatigue.

Overall, the test course was negotiated fastest under the baseline condition. Aggregate driver performance was virtually identical for the cases in which the prototype padding was installed. The means for both these conditions were 0.05 seconds higher than the baseline.

There was also an overall difference in performance as a function of the direction in which the maneuver was performed. Again, these differences are relatively small; they are shown in Table 3-7.

Table 3-6
SUBJECT PERFORMANCE BY PADDING TYPE

Subject Number	Variable	Baseline		3" Maximum Pad		4" Maximum Pad	
		Mean	SD	Mean	SD	Mean	SD
1	Time	3.28	0.10	3.36	0.12	3.33	0.07
	Pylons	2.12	0.85	1.00	0.83	1.42	0.65
2	Time	3.12	0.23	3.32*	0.28	3.43	0.43
	Pylons	1.38	1.06	1.42	1.02	1.25	1.03
3	Time	2.98	0.14	2.91	0.14	3.14	0.15
	Pylons	2.79	0.83	2.79	0.98	3.33	1.13
4	Time	3.02	0.15	3.28	0.17	3.11	0.19
	Pylons	0.79	0.83	1.38	0.88	0.62	0.82
5	Time	3.15	0.11	3.18	0.13	3.12	0.07
	Pylons	2.17	1.20	2.38	1.24	1.88	0.95
6	Time	3.90	0.19	3.89	0.14	3.87	0.11
	Pylons	1.17	0.96	1.46	0.98	1.38	0.77
7	Time	3.15	0.23	3.15	0.16	3.09	0.15
	Pylons	2.17	1.01	2.00	0.88	2.33	1.09
8	Time	3.01	0.14	3.01	0.15	2.96	0.14
	Pylons	1.92	0.77	1.92	0.77	1.42	1.14
9	Time	2.96	0.09	2.91	0.12	2.97	0.15
	Pylons	2.08	0.83	2.13	0.95	2.17	1.31
TOTAL	Time	3.17	(0.31)	3.22	(0.33)	3.22	0.33
	Pylons	1.84	(1.09)	1.83	(1.08)	1.75	1.23

*This cell had 23 observations; all other cells for a subject contained 24 observations.

Table 3-7

EFFECT OF DIRECTION OF MANEUVER ON DRIVER PERFORMANCE

Direction of Initial Steering Input

	Left		Right	
Variable	Mean	SD	Mean	SD
Time	3.23	0.29	3.18	0.35
Pylons	1.77	1.17	1.85	1.10

Assuming that this result is an effect of padding interference, it would seem to contradict the findings in Task 1, in which right-going maneuvers required greater lateral clearances. This may have been caused by differences in technique. Specifically, it is postulated that in Task 2, subjects attempted a rapid change in the vehicle turn angle by jerking the wheel as they entered the lane change maneuver. To facilitate this, they might place one of their hands on the opposite side of the wheel, i.e., the left hand at 1 o'clock or the right at 11 o'clock, prior to the maneuver and pull laterally with that hand. In Task 1, the maneuvers did not require such violent steering, so the subjects did not need to use this strategy, and the initial motion may have started with the left hand in the nine or ten o'clock position. Thus the primary direction of elbow motion would been more vertical in contrast to the large lateral component suggested by the Task 2 data.

In order to determine the significance of the above findings, both the time to complete the double lane change and the number of pylons struck were analyzed using four-way analyses of variance. The four factors were subject (1-9), padding thickness (1-3), direction of lane change (1-2), and replication (1-12). Because of the tremendous core requirements (over 10 megabytes), none of the interactive effects for the replication factor were examined and the variances associated with these effects were pooled in the error variance. The resulting source tables are presented in Tables 3-8 and 3-9, respectively.

Not surprisingly, both dependent variables evidenced reliable subject main and first-order interactive effects. No other reliable differences occurred for the number of pylons struck.

For time to complete the lane change, however, there were two other reliable effects: direction and padding thickness. As mentioned previously, subjects took longer to perform the LC-RC lane change than the RC-LC lane change and time to complete the lane change increased as padding thickness increased (baseline mean = 3.175 sec., 3" mean = 3.222 sec., and 4" mean = 3.224 sec.). Subsequent post hoc tests indicated that time to complete the lane change maneuver with either the 3 inch or 4 inch padding present was reliably longer than performing the maneuver with the baseline padding present (p = 0.0014, p = 0.0011, respectively).

Visual inspection of the data suggested that this increase in time to perform the lane change may have occurred for only those individuals with the longest shoulder-elbow lengths. To further investigate this possibility, a three-way analysis of variance was performed on the time to complete the lane change. The three factors were shoulder elbow length (2 levels), padding (3 levels), and direction (2 levels). The resulting source table is presented in Table 3-10. Although the main effect of shoulder-elbow length was not reliable, reliable shoulder-elbow length by padding thickness interaction occurred (see Figure 3-6).

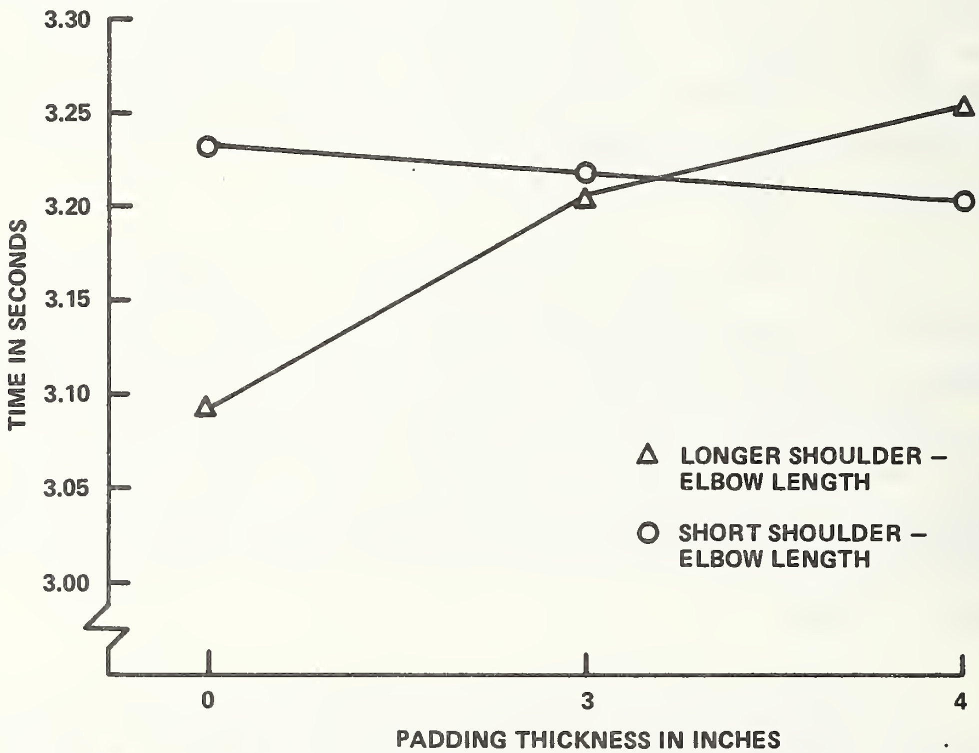

Figure 3-6 TIME TO COMPLETE THE LANE CHANGE AS A FUNCTION OF SHOULDER ELBOW LENGTH AND PADDING THICKNESS

Table 3-8

ANOVA SUMMARY TABLE FOR TIME TO COMPLETE THE LANE CHANGE

Source	df	Sum of Squares	F	p
Subject (S)	8	47.2155	245.62	0.0001
Padding (P)	2	0.3341	6.95	0.0010
Direction (D)	1	0.4896	20.38	0.0001
Replication (R)	11	0.2440	0.92	0.5179
S x P	16	2.6868	6.99	0.0001
S x D	8	3 4002	17.69	0.0001
P x D	2	0.0979	2.04	0.1314
S x P x D	16	0.3969	1.03	0.4197

Table 3-9

ANOVA SUMMARY TABLE FOR NUMBER OF PYLONS STRUCK

Source	df	Sum of Squares	F	p
Subject (S)	8	214.8501	29.54	0.0001
Padding (P)	2	0.9810	0.54	0.5833
Direction (D)	1	1.2443	1.37	0.2425
Replication (R)	11	8.0735	0.81	0.6338
S x P	16	36.6313	2.52	0.0009
S x D	8	23.5134	3.23	0.0013
P x D	2	0.5486	0.30	0.7397
S x P x D	16	18.6971	1.29	0.2005

Table 3-10

ANOVA SUMMARY TABLE FOR TIME TO COMPLETE
THE LANE CHANGE INCLUDING
SHOULDER-ELBOW LENGTH EFFECT

Source	df	Sum of Squares	F	p
Shoulder-Elbow Length (E)	1	0.1608	1.53	0.2165
Padding (P)	2	0 3310	1.58	0.2077
Direction (D)	1	0.4945	4.71	0.0304
E x P	2	0.9723	4.63	0.0101
E x D	1	0.0624	0.59	0.4411
P x D	2	0.1073	0.51	0.6002
S x P x D	2	0.0232	0.11	0.8955

The effect of shoulder-elbow length, while not sufficient to explain the entire padding effect, is still noteworthy. The result is related to the finding in Task 1, that the greatest lateral clearances were required by subjects with longer lower arms. Taken in combination, these results would indicate that, if any further testing of side door panels is undertaken, an appropriate target population would be individuals with long arms.

After the performance testing for side door panel was completed, the subject responded to a series of questions concerning his feelings about the panel.

The first of the questions is summarized in Table 3-11. This concerns the subjects' ratings of the degree of comfort associated with the padding configuration that had been installed. The 4" thick padding was rated noticeably lower than the other two panels. However, the padding with a maximum padding thickness of 3 inches compared favorably to the baseline configuration. In general, the baseline padding was rated equivalent to or slightly more comfortable than the 3" configuration; however there were two instances in which the subject rated the 3" padding panel higher than the baseline.

Table 3-11

PADDING CONFIGURATION COMFORT RATINGS

Comfort Rating	Padding Configuration		
	Baseline	3" Maximum Thickness	4" Maximum Thickness
Very Comfortable	3	1	0
Comfortable	5	7	1
No Strong Feelings	1	1	1
Uncomfortable	0	0	6
Very Uncomfortable	0	0	1

The participants were also asked to express their opinions with regards to their feelings about owning a vehicle that was equipped with similar door panels. They are summarized in Table 3-12. Clearly, the 4" maximum thickness panel was not well received. The 3 inch panel, again, compared favorably with the baseline configuration.

Table 3-12

DESIRABILITY OF OWNING SIMILARLY EQUIPPED VEHICLE

Feelings about Owning Vehicle with Similar Door Panels	Baseline	Padding Configuration: 3" Maximum Thickness	4" Maximum Thickness
Would Like Very Much	2	1	0
Would be All Right	6	4	0
Would Not Care	1	2	0
Probably Would Not	0	1	4
Never	0	1	5

The comfort and ownership-desirability ratings are interesting in the light of other subject responses. In particular, only three of the subjects (not including one abstention) felt that there was sufficient room between their arms and the door panel. Five of the nine subjects believed that the door panel interfered with their steering inputs, but only two of these five individuals stated that they would not like the idea of owning a similar vehicle.

It should also be mentioned with respect to the subjects' opinions, that all of the participants enjoyed driving and all rated spaciousness as an important consideration in making an automobile purchase decision.

Estimates of acceptable panel proximity were obtained from all of the subjects who took part in the study. In general, most of the participants would prefer the slightly greater lateral clearance than is available on a standard VW Rabbit. On average, an additional quarter of an inch would be sufficient. Only one of the subjects desired a change in the door panel location greater than an inch. Three subjects preferred the door panel slightly more inboard.

None of the test subjects experienced any difficulty entering and exiting the test vehicle with the test panels installed. It would not appear that entry/egress problems are relevant in future developmental work utilizing the side door panel concept.

Finally, five of the test subjects reported a change in the driving strategy as a result of the test panels. Three of these changes involved an attempt to keep the left elbow above the top of the test panel. It is noted, in this regard, that the side door window was not open during testing, and therefore limited the lateral clearance of these drivers using a "high elbow" strategy. Two other subjects stated that they had relied more on their right arm to supply the steering inputs.

Section 4
TASK 3 - CONSUMER ACCEPTABILITY OF CANDIDATE SIDE DOOR PANEL

The last task of the study was to obtain an indication of the acceptability to consumers of the side door panel concept. This was not intended to be a rigorous consumer survey; rather, the intent was to determine if people would reject the concept out of hand, or if there was a potential for acceptance.

Arrangements were made to display the test vehicle in the Thruway Mall, a local shopping mall located close to Calspan. In fact, the test vehicle was provided a highly desirable position within the mall; it was located at the intersection of the two main concourses. The plan was for the vehicle to be displayed for only one day, but the Thruway Mall management was amenable to extending the duration if an insufficient number of subjects was sampled.

Only one of the candidate side door panels was assessed. The panel selected was the design with a maximum thickness of three inches. While on display, the four-inch hip padding panel was also installed on the test vehicle.

The consumer survey was conducted by a single Calspan employee. Two signs were placed in the general proximity of the test vehicle, which informed passers-by that Calspan was interested in obtaining their opinions on a research vehicle. Opinions were obtained from volunteers only; no shoppers were approached by the Calspan employee.

Each volunteer was asked three questions. The first question was: "Do you find this door panel to be attractive?" The question was asked before the volunteer had an opportunity to sit in the test vehicle. The intent was the evaluate the aesthetics of the door panel, without confounding it with comfort and perceived driving performance level.

The subject was then asked to sit in the vehicle, after which two additional questions were posed: "Do you feel comfortable with the panel?" and "All other things being equal, would you buy an automobile with a door panel such as this?"

4.1 Results of Consumer Survey

Responses from 70 potential car buyers were obtained in the one day that the test vehicle was displayed at the shopping mall. Fifty of the respondents were male and the other twenty were, of course, female. The attendant observed that the sample tended to overrepresent the older segment of the population, probably because many of the younger people were working at the time the survey was conducted. A second observation by the Calspan employee might explain the reason that a disproportionate number of males comprised the sample. Specifically, it seemed as if many of the men came over to the test vehicle in preference to accompanying their wives into a store.

The responses to each of the questions are broken down by sex and are given in Tables 4-1 and 4-2 for males and females, respectively.

Table 4-1
MALE SURVEY RESULTS

	YES	NO	DON'T KNOW	OTHER	TOTALS
Question 1.	40	10	-	-	50
Question 2.	35	11	-	4	50
Question 3.	37	12	1	-	50

Table 4-2
FEMALE SURVEY RESULTS

	YES	NO	DON'T KNOW	OTHER	TOTALS
Question 1.	11	9	-	-	20
Question 2.	11	9	-	-	20
Question 3.	12	8	-	-	20

These results are encouraging with regard to the acceptability of the side door panel concept. In particular, 73% of the overall sample found the padding to be attractive and, more importantly, 70% of them said they would buy an automobile comparably equipped. With regard to the latter issue, one of the subjects stated that while he would buy a comparably equipped vehicle, he would not pay extra for the side door padding.

The area of acceptability on which the padding was judged lowest, involved the assessor's comfort perception. Only 66% of the total said that it was acceptably comfortable. Note, however, that this is, in part, a result of four "other" responses. Because of their nature, these responses were included in the denominator used to compute the percentage. In each of the "Other" responses, the person deferred making an absolute judgment, by stating that the panel would have been comfortable if it were slightly thinner. Two of these respondents suggested that one inch less would be sufficient.

It was also interesting to note that 51 of the 70 shoppers interviewed, i.e., 73%, had all "yes" responses or all "no" responses. It is also interesting that an approximately equal number of volunteers found the padding to be unattractive but would buy a car with it as found the panel attractive but would not buy it. This is shown in Table 4-3. Also in Table 4-3, a similar result for attractive and uncomfortable versus unattactive and comfortable is shown.

Table 4-3

RESPONSES AS A FUNCTION OF QUESTION 1 RESPONSE

Response to Question 1

	Panel is Attractive				Panel is Not Attractive			
	Yes	No	Don't Know	Other	Yes	No	Don't Know	Other
Question 2	42	6	0	3	4	14	0	1
Question 3	44	6	1	0	5	14	0	0

Some of the additional comments by the respondents are noteworthy. A number of people liked the solid arm rest that was formed by the hip padding and cut-out portion of the upper padding panel. Other people commented that they found that the hip padding extended too far forward and interfered with their leg movements. Since this portion of the hip panel is not functional in a side impact, eliminating this section is advisable. Finally, four of the people in the sample said that the reason they would buy a car with a padded panel would be for the increased occupant protection it afforded.

Section 5
CONCLUSIONS AND RECOMMENDATIONS

The primary objective of the study reported herein was to assess the feasibility of padding the side door panel with an energy absorbing material. The dimensions along with the feasibility were 1) the effects of the additional padding on driving performance, and 2) the potential for a side door padding concept to be accepted. by automobile consumers.

The consumer acceptability issue is the more straightforward of the two. Subjects who participated in Task 2 testing indicated that they would not generally be averse to purchasing an automobile with a side door panel similar to the test configuration, provided that the maximum thickness was three inches or less. A second, albeit non-representative, sample of consumers also expressed relatively positive feelings toward the prototype configuration. This second group did not, however, drive the vehicle with the panel installed.

With regard to the effects of padding on driving performance, the results of Task 2 clearly indicate that the modified side door panel affects the driver's ability to execute a double lane change maneuver. It should be emphasized, however, that this effect is primarily one of speed; the test subjects did not reliably deviate more from the prescribed course (as evidenced by the number of struck pylons) with the experimental door panels installed. Thus it would seem that as long as drivers are willing to make a slight decrease (perhaps imperceptible) in their speed, the incremental probability of a traffic accident caused by loss of control due to padding interference is virtually zero. Even assuming that a slight increase in the marginal probability of an accident could be attributed to the additional side door padding, the consequences of these accidents must be compared to any decreases in occupant injury severity realized by the energy management of the padding.

A second factor of importance in relation to the practical effect of the observed performance decrement with the additional padding involves the nature of the double lane change maneuver. Specifically, this maneuver can be considered outside the normal operating range. Under normal driving conditions, such a maneuver might only be attempted in an accident avoidance situation. Other research, e.g., Reference

5, has found that most drivers react to a threat by applying their brakes rather than steering. Thus, the results of Task 2 might better be considered the worst case situation; the real world performance decrement may be less than the data indicate.

The study suggests three additonal research topics be pursued. These recommendations are given below in order of their priority.

(1) Validate the findings concerning the acceptability to consumers of a modified side door panel utilizing the concept developed in the research. This more rigorous survey should be preceeded by an effort to incorporate the side door padding concept into an integral side door unit with a shortened hip padding segment.

(2) Determine any detrimental effects of the side door padding which may exist under normal driving conditions, and consider the findings of the current study as an upper bound. Particular emphasis should be placed on testing that portion of the population identified herein as requiring the greatest lateral clearances, i.e., people with long arms.

(3) Examine the cost-effectiveness of adding additional side door padding by comparing the savings afforded by the increased occupant protection to any increment in accident frequency caused by the decreased driver lateral clearance.

Section 6
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GENERAL SUBJECT DATA

SUBJECT NO.: ______________________ DATE ______________________

AGE: ______________ YEARS YEARS DRIVING EXPERIENCE ________ YEARS

HEIGHT: ____________ INCHES WEIGHT ____________ LBS.

RIGHT-HANDED/LEFT-HANDED

- ANTHROPOMETRIC DATA

  SITTING HEIGHT ____________ INCHES ELBOW-TO-ELBOW BREADTH __________ INCHES

  HIP BREADTH ______________ INCHES BIACROMIAL SHOULDER BREADTH _____ INCHES

  ACROMIAL HEIGHT ____________ INCHES BIDELTOID SHOULDER BREADTH _____ INCHES

  SHOULDER-ELBOW LENGTH ______ INCHES ELBOW-WRIST DISTANCE __________ INCHES

  ELBOW GRIP DISTANCE ________ INCHES

- WHAT MAKE, MODEL, AND YEAR CAR DO YOU DRIVE MOST OF THE TIME? ____________

  ____

- DO YOU CONSIDER YOUR CAR COMFORTABLE INSIDE, THAT IS, IS THERE SUFFICIENT ROOM IN ALL DIRECTIONS? ____

  ____

  ____

  ____

____

- PANEL PROXIMITY TEST

  OUTWARD MOVEMENT COMFORT POSITION ________ INCHES

  INWARD MOVEMENT COMFORT POSITION ________ INCHES

  AVG. __________ INCHES

COMMENTS: ____

____

____

____

SUBJECT TESTS

SUBJECT NO.: ____________________ PANEL NO.: ____________________

CAR SEAT POSITION: ________________ PRESENTATION ORDER NO.: ____________

DRIVING TEST DATA

REP.	TOWARD BANKED TURN		AWAY FROM BANKED TURN	
TEST NO.	TIME ∿ SEC.	NO. PLYONS	TIME ∿ SEC.	NO. PLYONS
1	(1)		(2)	
2	(4)		(3)	
3	(5)		(6)	
4	(8)		(7)	
5	(9)		(10)	
6	(12)		(11)	
7	(13)		(14)	
8	(16)		(15)	
9	(17)		(18)	
10	(20)		(19)	
11	(21)		(22)	
12	(24)		(23)	

- HOW COMFORTABLE WERE YOU WHILE YOU WERE DRIVING THE VEHICLE?

  ☐ VERY COMFORTABLE ☐ COMFORTABLE

  ☐ NO STRONG FEELINGS ☐ UNCOMFORTABLE

  ☐ VERY UNCOMFORTABLE

- DID YOU EXPERIENCE ANY DIFFICULTY IN THE FOLLOWING:

  TURNING ☐ YES ☐ NO EXPLAIN, IF YES ____________

  CHANGING LANE ☐ ☐ ____________

  BACKING ☐ ☐ ____________

  PARKING ☐ ☐ ____________

  TURNING AROUND ☐ ☐ ____________

  OTHER ____________

COMMENTS: ____________

SUBJECT TESTS (Cont.)

SUBJECT NO. ____________________ PANEL NO. ____________________

- WHEN PERFORMING THE TEST MANEUVERS ON THE TRACK, DID YOU DRIVE DIFFERENTLY THAN NORMAL? ____________________

  IF YES, WHAT IN PARTICULAR ____________________

  ____

- EASE OF ENTRY AND EXIT FROM VEHICLE.

  (Request subject to get in and out of car approximately three (3) times)

  SUBJECTS DIFFICULTY (OBSERVATION) ____________________

  DID YOU HAVE ANY DIFFICULTY ENTERING OR LEAVING THIS CAR? ____________________

  ____

- AFTER THIS EXPERIENCE, HOW WOULD YOU FEEL ABOUT OWNING A CAR WITH A DOOR PANEL LIKE THIS?

  ☐ WOULD LIKE VERY MUCH ☐ WOULD BE ALL RIGHT

  ☐ WOULD NOT CARE ☐ PROBABLY WOULD NOT

  ☐ NEVER

- DO YOU FEEL THAT THERE WAS SUFFICIENT ROOM BETWEEN YOU AND THE SIDE DOOR PANEL? ____________________

- DO YOU RECALL IF YOUR ARM CONTACTED THE DOOR PANEL DURING THE DRIVING TEST?

  ____

- DID THE DOOR PANEL EVER INTERFERE WITH YOUR STEERING MANEUVERS? ____________________

  ____

  IF ABOVE ANSWER IS YES, CONDUCT THE PANEL PROXIMITY TEST - PAGE 1

COMMENTS: ____________________

____

____

SUBJECTS DRIVING ATTITUDES

SUBJECT NO. ____________

- HOW DO YOU FEEL ABOUT DRIVING?

  ☐ I ENJOY DRIVING VERY MUCH ☐ I ENJOY DRIVING

  ☐ I HAVE NO STRONG FEELINGS ☐ I DISLIKE DRIVING

  ☐ I DISLIKE DRIVING VERY MUCH

- HOW OFTEN DO YOU DRIVE YOUR VEHICLE EACH WEEK?

  ☐ 0 - 3 ROUND TRIPS/WEEK

  ☐ 5 - 7 ROUND TRIPS/WEEK

  ☐ 8 OR MORE ROUND TRIPS/WEEK

- HOW IMPORTANT ARE EACH OF THE FOLLOWING ITEMS IN DETERMINING YOUR FEELINGS OF COMFORT IN AN AUTOMOBILE?

	NOT IMPORTANT	LITTLE IMPORTANCE	SOMEWAHT IMPORTANT	IMPORTANT	VERY IMPORTANT
NOISE					
SEAT COMFORT					
VIBRATION					
SPACIOUSNESS					

- HOW IMPORTANT ARE EACH OF THE FOLLOWING ITEMS IN YOUR DECISION TO PURCHASE AN AUTOMOBILE?

	NOT IMPORTANT	LITTLE IMPORTANCE	SOMEWHAT IMPORTANT	IMPORTANT	VERY IMPORTANT
COST					
RELIABILITY					
APPEARANCE					
COMFORT					
SAFETY					
FUEL ECONOMY					

COMMENTS: ____________

____

____

VARIABLE	N	MEAN	STANDARD DEVIATION
SUBJ=1 PAD=1 DIR=1			
TIME	12	3.332	0.096
PYLONS	12	1.917	0.793
SUBJ=1 PAD=1 DIR=2			
TIME	12	3.237	0.084
PYLONS	12	2.333	0.888
SUBJ=1 PAD=2 DIR=1			
TIME	12	3.393	0.117
PYLONS	12	0.583	0.669
SUBJ=1 PAD=2 DIR=2			
TIME	12	3.328	0.111
PYLONS	12	1.417	0.793
SUBJ=1 PAD=3 DIR=1			
TIME	12	3.332	0.086
PYLONS	12	1.333	0.651
SUBJ=1 PAD=3 DIR=2			
TIME	12	3.319	0.060
PYLONS	12	1.500	0.674
SUBJ=2 PAD=1 DIR=1			
TIME	12	2.994	0.216
PYLONS	12	1.083	1.240
SUBJ=2 PAD=1 DIR=2			
TIME	12	3.247	0.180
PYLONS	12	1.667	0.778
SUBJ=2 PAD=2 DIR=1			
TIME	12	3.198	0.255
PYLONS	12	0.833	0.937
SUBJ=2 PAD=2 DIR=2			
TIME	11	3.453	0.250
PYLONS	12	2.000	0.739
SUBJ=2 PAD=3 DIR=1			
TIME	12	3.293	0.272
PYLONS	12	0.917	0.996

VARIABLE	N	MEAN	STANDARD DEVIATION
------------- SUBJ=2 PAD=3 DIR=2 -------------			
TIME	12	3.565	0.532
PYLONS	12	1.583	0.996
------------- SUBJ=3 PAD=1 DIR=1 -------------			
TIME	12	2.964	0.136
PYLONS	12	2.917	0.900
------------- SUBJ=3 PAD=1 DIR=2 -------------			
TIME	12	2.987	0.158
PYLONS	12	2.667	0.778
------------- SUBJ=3 PAD=2 DIR=1 -------------			
TIME	12	2.963	0.116
PYLONS	12	2.583	1.084
------------- SUBJ=3 PAD=2 DIR=2 -------------			
TIME	12	2.850	0.140
PYLONS	12	3.000	0.853
------------- SUBJ=3 PAD=3 DIR=1 -------------			
TIME	12	3.211	0.130
PYLONS	12	3.250	1.215
------------- SUBJ=3 PAD=3 DIR=2 -------------			
TIME	12	3.067	0.128
PYLONS	12	3.417	1.084
------------- SUBJ=4 PAD=1 DIR=1 -------------			
TIME	12	3.121	0.093
PYLONS	12	0.917	0.793
------------- SUBJ=4 PAD=1 DIR=2 -------------			
TIME	12	2.909	0.126
PYLONS	12	0.637	0.888
------------- SUBJ=4 PAD=2 DIR=1 -------------			
TIME	12	3.422	0.107
PYLONS	12	1.167	0.718
------------- SUBJ=4 PAD=2 DIR=2 -------------			
TIME	12	3.145	0.104
PYLONS	12	1.583	0.996

VARIABLE	N	MEAN	STANDARD DEVIATION
------------- SUBJ=4 PAD=3 DIR=1 -------------			
TIME	12	3.247	0.145
PYLONS	12	0.500	0.674
------------- SUBJ=4 PAD=3 DIR=2 -------------			
TIME	12	2.979	0.131
PYLONS	12	0.750	0.965
------------- SUBJ=5 PAD=1 DIR=1 -------------			
TIME	12	3.159	0.091
PYLONS	12	2.083	0.996
------------- SUBJ=5 PAD=1 DIR=2 -------------			
TIME	12	3.141	0.136
PYLONS	12	2.250	1.422
------------- SUBJ=5 PAD=2 DIR=1 -------------			
TIME	12	3.253	0.093
PYLONS	12	2.500	1.314
------------- SUBJ=5 PAD=2 DIR=2 -------------			
TIME	12	3.104	0.124
PYLONS	12	2.250	1.215
------------- SUBJ=5 PAD=3 DIR=1 -------------			
TIME	12	3.163	0.072
PYLONS	12	2.000	0.953
------------- SUBJ=5 PAD=3 DIR=2 -------------			
TIME	12	3.036	0.057
PYLONS	12	1.750	0.965
------------- SUBJ=6 PAD=1 DIR=1 -------------			
TIME	12	3.800	0.174
PYLONS	12	1.250	1.215
------------- SUBJ=6 PAD=1 DIR=2 -------------			
TIME	12	4.007	0.149
PYLONS	12	1.083	0.669
------------- SUBJ=6 PAD=2 DIR=1 -------------			
TIME	12	3.931	0.147
PYLONS	12	1.750	1.138

VARIABLE	N	MEAN	STANDARD DEVIATION
------------- SUBJ=6	PAD=2	DIR=2 -------------	
TIME	12	3.852	0.118
PYLONS	12	1.167	0.718
------------- SUBJ=6	PAD=3	DIR=1 -------------	
TIME	12	3.822	0.100
PYLONS	12	1.750	0.622
------------- SUBJ=6	PAD=3	DIR=2 -------------	
TIME	12	3.925	0.105
PYLONS	12	1.000	0.739
------------- SUBJ=7	PAD=1	DIR=1 -------------	
TIME	12	3.279	0.202
PYLONS	12	2.167	1.267
------------- SUBJ=7	PAD=1	DIR=2 -------------	
TIME	12	3.018	0.168
PYLONS	12	2.167	0.718
------------- SUBJ=7	PAD=2	DIR=1 -------------	
TIME	12	3.264	0.093
PYLONS	12	2.333	0.651
------------- SUBJ=7	PAD=2	DIR=2 -------------	
TIME	12	3.035	0.114
PYLONS	12	1.667	0.985
------------- SUBJ=7	PAD=3	DIR=1 -------------	
TIME	12	3.173	0.097
PYLONS	12	2.167	0.835
------------- SUBJ=7	PAD=3	DIR=2 -------------	
TIME	12	3.000	0.154
PYLONS	12	2.500	1.314
------------- SUBJ=8	PAD=1	DIR=1 -------------	
TIME	12	3.036	0.156
PYLONS	12	1.833	0.718
------------- SUBJ=8	PAD=1	DIR=2 -------------	
TIME	12	2.959	0.107
PYLONS	12	2.000	0.853

VARIABLE	N	MEAN	STANDARD DEVIATION
------------- SUBJ=8	PAD=2	DIR=1 -------------	
TIME	12	3.068	0.135
PYLONS	12	1.917	0.793
------------- SUBJ=8	PAD=2	DIR=2 -------------	
TIME	12	2.934	0.129
PYLONS	12	1.917	0.793
------------- SUBJ=8	PAD=3	DIR=1 -------------	
TIME	12	3.010	0.124
PYLONS	12	1.083	0.996
------------- SUBJ=8	PAD=3	DIR=2 -------------	
TIME	12	2.903	0.145
PYLONS	12	1.750	1.215
------------- SUBJ=9	PAD=1	DIR=1 -------------	
TIME	12	3.003	0.063
PYLONS	12	1.917	0.793
------------- SUBJ=9	PAD=1	DIR=2 -------------	
TIME	12	2.923	0.085
PYLONS	12	2.250	0.866
------------- SUBJ=9	PAD=2	DIR=1 -------------	
TIME	12	2.913	0.122
PYLONS	12	2.167	0.937
------------- SUBJ=9	PAD=2	DIR=2 -------------	
TIME	12	2.900	0.115
PYLONS	12	2.083	0.996
------------- SUBJ=9	PAD=3	DIR=1 -------------	
TIME	12	2.955	0.195
PYLONS	12	2.750	1.357
------------- SUBJ=9	PAD=3	DIR=2 -------------	
TIME	12	2.977	0.096
PYLONS	12	1.583	0.996