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Desired Clearance Around a Vehicle While Parking or Performing Low Speed Maneuvers

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16. Abstract

This experiment examined how close to objects (such as a wall or another vehicle) people would drive when parking. The findings will to be used as a basis for visual and/or auditory warnings provided by parking assistance systems.

A total of 16 people (8 ages 18-30, 8 over age 65) served as subjects. Data were collected both for the subjects sitting in the driver's seat of a 2004 Infinity Q45 and standing outside the vehicle (as if directing someone else to park). Data were collected for the desired clearance distance between the test vehicle and a wall (for safety concerns, the wall was moved instead of the vehicle) in ascending and descending thresholds, for 8 cardinal clock positions.

The overall mean distance was 20.4 in for the 640 data points collected, with a range of 2.5 to 48.5 in. As an example of the specific results, when the wall was moved towards the driver and the subject was an observer (outside the car), the desired distances were 17.0, 18.9, 19.1, 20.3, 17.4, 18.7, 14.7, and 15.8 in for 1:30, 3:00, 4:30, 6:00, 7:30, 9:00, 10:30 and 12:00 clock positions.

Using the regression method, 1 of the 2 methods developed, desired distance in inches was equal to 9.5 + 1.6 (if the position was to the side or rear) + 6.7 (if a door was to be opened) + 5.7 (if the object was approaching the car) + 4.9 (if the driver's clearance was estimated) + .07 times the driver's age.

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DESIRED CLEARANCE AROUND A VEHICLE WHILE PARKING OR PEFORMING LOW SPEED MANEUVERS

UMTRI Technical Report 2004-30
October, 2004

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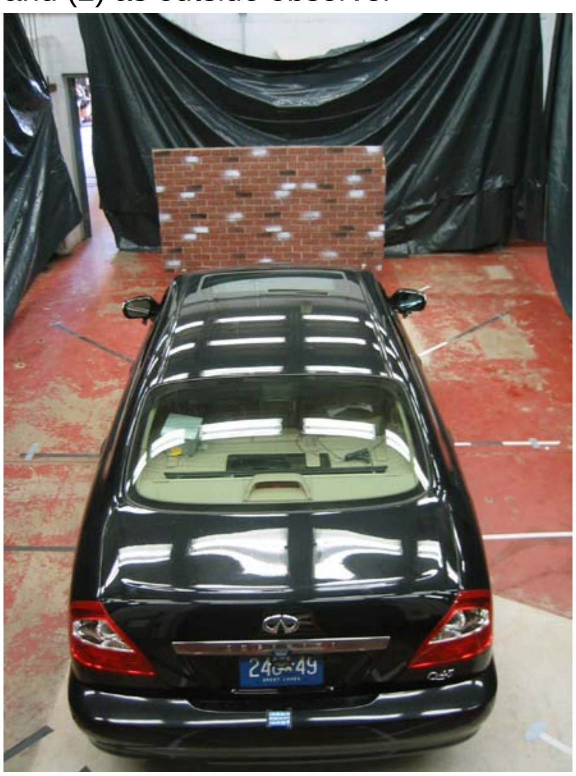
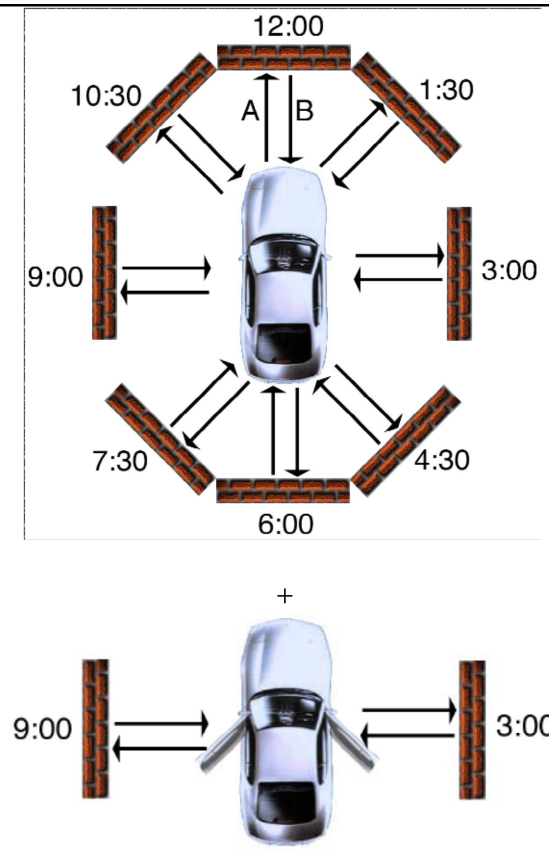
1 Primary Issues

1. How much clearance is desired around a car as a function of location (front, rear, sides, corners)?
2. Does the desired clearance vary with how the measurement is made (moving an object away from versus toward the car, the subject as a driver versus an outside observer)?
3. Does the desired clearance vary with driver age and sex?
4. Is the size of the person exiting a vehicle related to the clearance desired to exit?

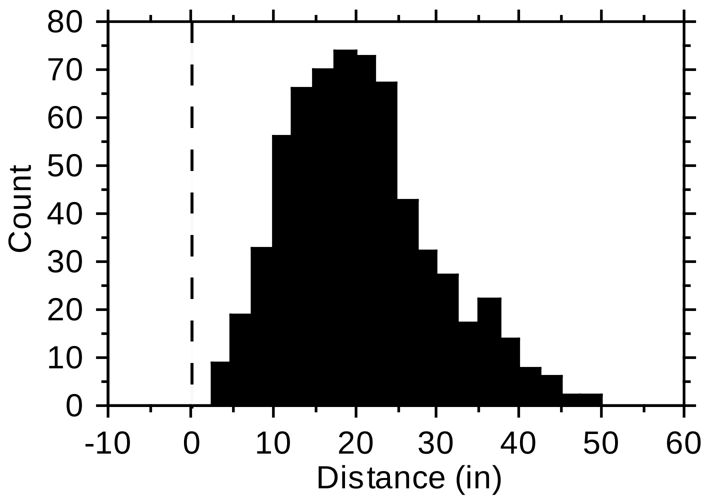
2 **Method –** Move brick wall in and out

Subject was located: (1) in driver seat and (2) as outside observer





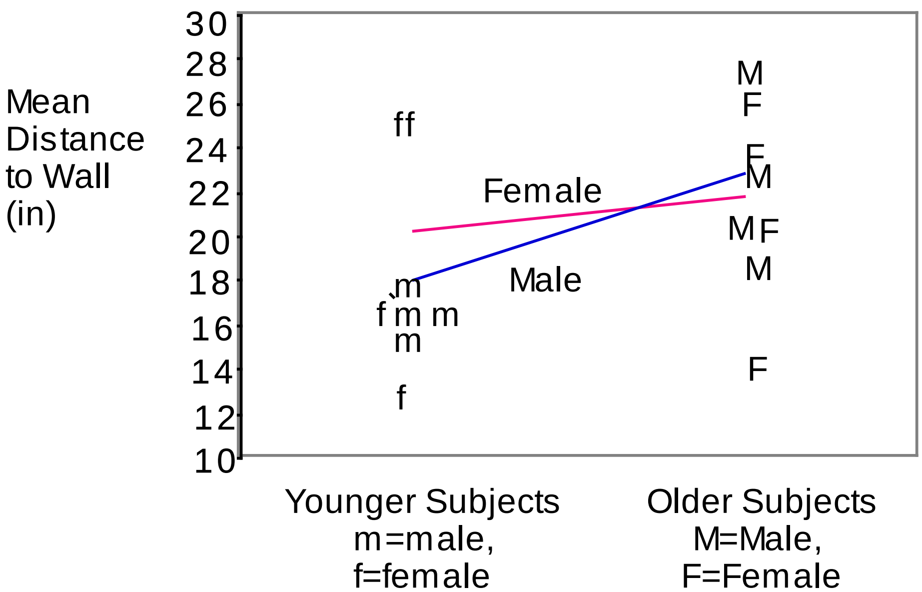
3 Results and Conclusions



Overall Distribution
of Desired Clearance

640 data points
Mean = 20.4

Combination of 4 distributions
(driver vs. observer and wall
moves in vs. away)



Values (in) for Drivers, Average Age 46

Mean Clearance

	Wall Moves Toward Vehicle		Wall Moves Away	
	A	B	C	D
Position	Driver	Outside Observer	Driver	Outside Observer
10:30	24.9	14.7	13.8	13.7
12:00	27.5	15.8	14.4	13.9
1:30	30.2	17.0	16.7	13.4
3:00 (approach)	26.4	18.9	18.4	17.9
3:00 (exit)	32.6	26.9	27.2	23.8
4:30	29.0	19.1	17.5	14.2
6:00	28.8	20.3	20.2	15.5
7:30	22.8	17.4	16.2	14.1
9:00 (approach)	22.6	18.7	17.5	16.5
9:00 (exit)	27.7	25.4	24.8	24.1

ANOVA METHOD - Prediction of Desired Distance

Step	Action	Comment
1	Pick desired column and clock position in table	If driving and watching wall approach, use A. If camera gives outside view and approaching wall, use B.
2	Adjust for driver age = (driver age – 46)*.07	If age is less than 46, then adjustment decreases total.

Example: 40- year old driver is backing towards wall

if the user thinks of themselves as the driver then = 28.8 + (40-46)*.07 = <u>28.4 in</u>
if the user thinks of themselves as observer, then = 20.3 + (40-46)*.07 = <u>19.9 in</u>

REGRESSION METHOD - Prediction of Desired Distance

Term	Coefficient	Comment
Intercept	9.5	
Forward/Rear code	1.6	Add if side or rear
Exit code	6.7	Add if exit
Toward/away code	5.7	Add if toward
Driver/observer code	4.9	Add if driver
Age	.07	Multiple by age

Example: 40 year old driver is backing towards wall

if user thinks of themselves as driver then = 9.6 + 1.6 + 5.7 + 4.9 + 40*.07 = <u>24.5 in</u>
if user thinks of themselves as observer then = 9.6 + 1.6 + 5.7 + 40*.07 = <u>19.6 in</u>

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INTRODUCTION

Over the last decade, many new driver-operated functions related to communications, navigation, and safety have been added to motor vehicles. Of particular note are systems that assist drivers with parking, specifically back up aids, of which many are in production. The following link to Consumer Reports does a good job of summarizing the problem of backing out, and listing the types of devices currently on the market.

(http://www.consumerreports.org/main/content/display_report.jsp?FOLDER%3C%3Efolder_id=399905).

In the broad sense, the number of fatalities associated with parking is not that high but the number of crashes and the amount of property damage is substantial. In addition because many parking-related crashes occur on private property, the number of parking crashes is likely to be underreported.

To support the design and evaluation of a parking assistance system, several studies were conducted by UMTRI - Human Factors. In the initial study of this effort, Smith, Green, and Jacob (2004) reviewed the literature and the State of Michigan crash database for parking-related crashes, and also interviewed local insurance agents about those types of crashes. From that evidence it was apparent that the most common crash involved a person backing out of a perpendicular space and backing into or being struck by another vehicle that was either driving down the parking aisle or backing up from an adjacent spot.

To assess the effectiveness of a parking assistance system, baseline data are needed on how people normally park. To obtain such data, Cullinane, Smith, and Green (2004) contacted 30 drivers by phone and had them respond to 11 questions concerning when and where they parked. Drivers parked 3 times/day on average, with the number being roughly the same for weekdays and weekend days, and with about ¾ of all parking being perpendicular. There were few differences among various driver age groups or between men and women.

Of the 8 crashes reported, 6 involved backing, exactly as would be predicted from the literature.

In a field study in Ann Arbor, Michigan, the parked location of 102 vehicles was measured. Perpendicular and angle parking spaces were about 8.5 ft wide and parallel spaces were about 24 ft long. Vehicles were parked13 in on average from a barrier, such as a wall in perpendicular spaces, but overlapped by 5 in if a barrier was present. Drivers parked on average about 4 in to the right of center.
In contrast, for angle parking, drivers parked only 1 in from the end of the space and only 1 in to the right.

For parallel parking, drivers averaged 4 in from the curb, and 8 in forward of the midpoint.

In most cases, the yaw angles were always less than 1 deg, except for parallel parking, where the maximum was 3 deg.

To follow up on these reports, 3 experiments were conducted to examine perpendicular parking, parallel parking, and the desired clearance for parking in general. This report describes the desired clearance experiment. The purpose of this experiment was to determine the amount of space desired around a vehicle to avoid crashes without the assistance of a camera-based parking system for both exiting a vehicle and driving by a wall or another vehicle.

Questions of interest include:

1. In general, how much clearance is desired around a car as a function of location (front, rear, sides, corners)?

   Note: Only 1 test vehicle was considered in this initial effort. The size and shape of the vehicle could affect the recommendation.

2. Does the desired clearance vary with how the measurement is made:
   a. Ascending thresholds versus descending thresholds (moving away versus approaching the car)?
   b. Subjects sitting inside the vehicle versus watching from outside the vehicle?

3. Does the desired clearance vary with driver age and sex?
4. Is the desired clearance to exit a vehicle related to the size of the person exiting?

TEST PLAN

Participants

Sixteen subjects holding valid drivers licenses volunteered to participate in this 1.5-hour experiment. They were paid $30 for their time and recruited via personal connections to UMTRI, as well as an existing list of subjects from prior driver interface studies.

Eight of the 16 subjects were between the ages of 18 and 30, and the remaining 8 were 60 years of age or older. Each age group included 4 men and 4 women. Their ages ranged from 20 to 76, with a mean age of 47 (mean of 22 for the younger subjects and 72 for the older subjects).

Visual acuity was measured using the Landolt Ring eye test on a Stereo Optical Optec 2000 vision tester on the Far #2 setting without a lens, and then again with an 80 cm lens. Twelve subjects had normal or corrected to corrected vision, and 4 did not. Far vision of the 16 subjects ranged from 20/13 to 20/70 with a mean of 20/26. The 4 subjects without corrective lenses had vision ranging from 20/13 to 20/18. Generally, older subjects had poorer vision, with 2 subjects having 20/40 far vision and 1 subject having 20/70, even with corrective lenses. Younger subjects generally had normal vision, with the poorest vision being 20/25 (2 subjects).

Near vision of the 16 subjects ranged from 20/13 to 20/100 with a mean of 20/46. Again, the 4 subjects without corrective lenses had relatively good near vision, ranging from 20/13 to 20/25. Older subjects had significantly poorer near vision, ranging from 20/40 to 20/100 (3 subjects), even while wearing corrective lenses.

The location of each participant's seated left eye height was measured. The horizontal coordinate originated from the interior driver's side door bracket, located 59.3 cm on the horizontal (longitudinal) axis from the center of the front wheel (which is the origin for all measurements), and the vertical coordinate originated from the laboratory floor. Figure 1, following, depicts the eye locations of all 16 participants. The correlation between the horizontal and vertical eye location was 0.54, indicating that taller drivers (as indicated by seated eye height) sat farther back. However, the overall range was about 20 cm (just under 8 in).

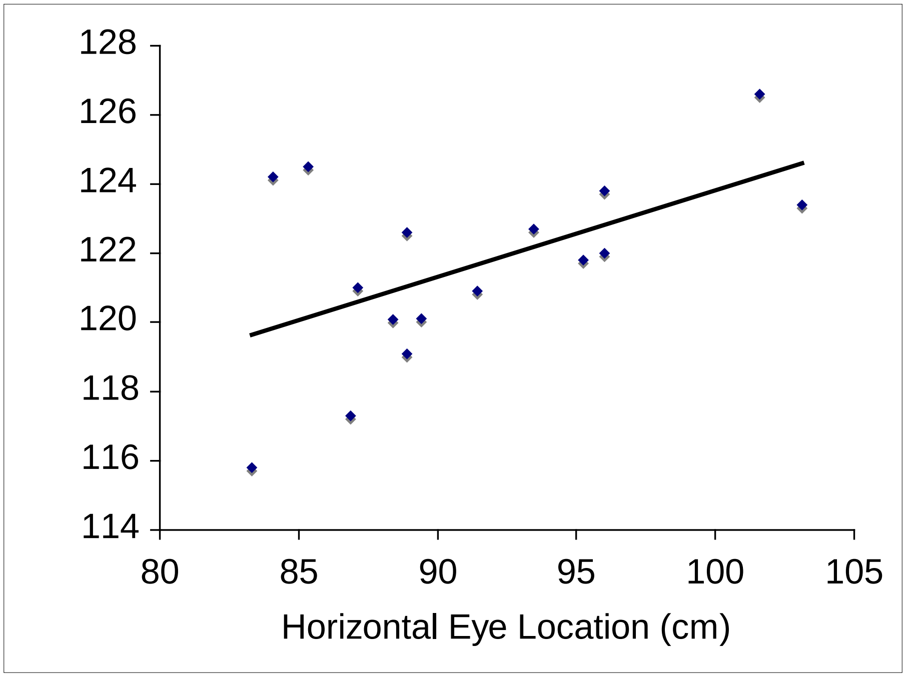


Figure 1. Seated Eye Height Correlation

In addition to seated eye height, the standing height, waist circumference, and weight of each participant were measured. These values are summarized in Table 1.

Table 1. Anthropometric Data

	Measurement Device	Mean	Range
Weight	Continental Health-O-Meter Model 230 kg	76.9 kg	52.5 – 114.7 kg
Waist Circumference	Flexible measuring tape	94.4 cm	65.0 – 132 cm
Height	210 cm Siber Hegner & Co standing anthropometer	137.3 cm	185.6 - 166.8 cm
Vertical Seated Eye Height	210 cm Siber Hegner & Co standing anthropometer	119.7 cm	89.2 – 126.6 cm
Horizontal Seated Eye Positon	210 cm Siber Hegner & Co standing anthropometer	91.2 cm	83.3 - 103.1 cm

For the U.S. adult population, the mean heights are 175.6 cm for men and 162.9 cm for women and the mean weights are 78.5 kg and 62.0 kg for women (Kroemer, Kromer, and Kroemer-Elbert, 1994). The resulting adult means are 169.3 cm for height, 70.3 kg for weight. Thus, this sample was a bit shorter and somewhat heavier than the adult population, assuming the Kroemer, et al. data are current. Readers should note that the sample was stratified by age and sex and was not selected to be anthropometrically representative of the U.S. adult population.

All of the older subjects were retired. Seven of the 8 younger subjects were students (five undergraduate and two graduate students) with the remaining young subject a middle school teacher. One of the two graduate students one was a research assistant in the Human Factors department of UMTRI. Eight of the 16 subjects had participated in previous UMTRI experiments. However, 7 of these subjects had no experience in the test vehicle. One subject (the middle school teacher) participated in the previous perpendicular parking study, which was conducted in the same test vehicle.

Subjects owned and drove relatively new vehicles. All but 1 vehicle was manufactured between 1993 and 2004, with the last vehicle being from 1964. Ten subjects drove cars, 5 drove minivans, and 1 drove a small SUV. On average, subjects drove 9,900 miles each year, ranging from 500 miles to 22,000 miles. This value is very close to the U.S. average of 10,000 miles a year.

Five of the 16 subjects had been involved in at least one parking crash (2 subjects each had 2 crashes) within the past five years. Four of these subjects were young (2 men and 2 women), and the last was an older man.

Of all subjects, 4 had been in a non-parking crash within the last 5 years (1 of whom had two crashes). Three subjects were younger (1 man and 2 women), and the last subject was an older woman.

Information about each subject's parking frequency was collected prior to entering the test car. Table 2 shows the parking frequency data, which is averaged across all users. The frequency of perpendicular parking is somewhat lower than has been found typical in prior studies (Cullinane, Smith, and Green, 2004).

Table 2. Mean Parking Frequencies by Parking Type and Time of Week

	Parallel	Perpendicular	Angular	
Weekdays	5 (9%)	25(42%)	14 (24%)	67 %
Weekends	2 (3 %)	9 (15%)	4 (7%)	33%
	12%	57%	31%	

Simulated Brick Wall

Due to the risk of a collision when moving a vehicle close to other vehicles or structures, the method used was to move a portable, difficult-to-damage wall towards and away from a fixed vehicle. The wall was 4 feet high and 8 feet wide, constructed from a plywood sheet padded with a sheet of ¾" rigid polystyrene foam insulation and completely covered with Nailite vinyl siding, patterned to look like brick, on the front wall surface. The simulated wall was placed on a rolling cart so it could be easily maneuvered around the test vehicle. The back of the wall can be seen in Figure 2.

Figure 2. Back Side of Wall with Rolling Cart

Data Collection Method

The lateral clearance experiment was conducted between July 19 and July 28, 2004, in a garage bay at UMTRI (Figure 3). The experiment lasted about 90 minutes per subject. To minimize distractions from activity in the garage bay, a "privacy zone" was created around the test area. Black plastic sheets were draped from the ceiling to the floor on all sides of the test vehicle. The curtains were at least 9 feet from the vehicle, far more clearance than any subject could have desired. All lights in the garage were turned on so the wall could be easily seen. An instrumented 2004 Infinity Q45 was used as a test vehicle.

Figure 3. Minimum Lateral Clearance Laboratory

Before entering the garage, each subject received an overview of the experiment following the script in Appendix A, and signed a consent form (Appendix B). Next, basic information and subject biographical dimensions were collected and measured using the Subject Biographical Form (Appendix C). That form included information concerning height, weight, waist circumference, type of car usually driven, number of car crashes involvements, parking frequency, and visual acuity.

Subsequently, the subject was instructed to sit in the driver's seat of the test vehicle (which was powered only in the "accessory" position) and adjust the seat to a comfortable driving position. The seated eye position coordinates (vertical and horizontal) were recorded. Next, the subject fastened the seat belt and adjusted the mirrors as if they were actually driving the vehicle.

After all of the driver adjustments were made, the experimenter explained the test procedure. There were 4 major sequences in the lateral clearance experiment. The minimum allowable distance between the test vehicle and the portable wall was measured from 8 positions around the car, 1 position at a time. These positions are illustrated in Figure 4. Eight sets of parallel tracks were laid on the floor (1 at each measurement position around the vehicle). Standard masking tape was used to mark the tracks, which served as guides to ensure that the wall was moved evenly towards or away from the car.

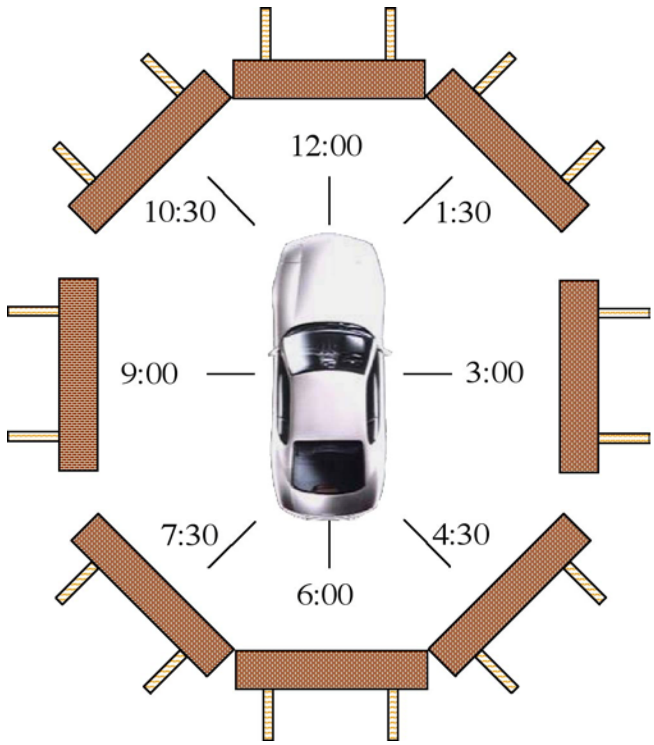


Figure 4 Testing Positions

The 8 different positions were tested in order, with the starting position and direction (clockwise or counterclockwise) counterbalanced across subjects.

For the 3 forward and 3 rear locations, only the minimum closest approach was measured. The minimum closest approach as well as minimum exiting clearance was measured for both the driver and passenger side of the test vehicle (9 o'clock and 3 o'clock positions). Both ascending and descending thresholds were measured, and the procedure was repeated twice: once with the subject sitting in the driver's seat, and once with the subject standing outside of the test vehicle. There were 6 starting positions from which the experimenters moved the wall either clockwise or counterclockwise around the vehicle. Table 3 summarizes the 8 position sequences examined. (See Appendix D for the rationale for this sequencing.)

Table 3. Starting Position and Sequence Direction of the Eight Trial Orders

Sequence	*Starting Position*	*Sequence Direction*
1	*10:30*	*Clockwise*
2	*1:30*	*Counterclockwise*
3	*3:00*	*Clockwise*
4	*3:00*	*Counterclockwise*
5	*4:30*	*Clockwise*
6	*7:30*	*Counterclockwise*
7	*9:00*	*Clockwise*
8	*9:00*	*Counterclockwise*

The experiment was broken into five parts (steps 4-8 of Table 4). First, the descending threshold was tested while the subject sat in the driver's seat. One experimenter read directions to the subject (see Appendix A) and 2 others pushed the brick wall towards the vehicle (from the starting position), along the tracks placed on the floor. When the distance between the wall and the car was as small as comfortably possible, the subject was instructed to say "Stop". The wall would stop moving and the experimenter would measure the distance from the center of the wall to a specific point on the car, which was marked discreetly with tape. Data were recorded on the form in Appendix E.

This procedure was used for each of the eight positions. To measure the minimum exiting clearance, the process was repeated with the subject being instructed to say "Stop" when the distance between the vehicle and the wall was as small as possible such that the subject could still exit the vehicle without damaging the car or wall.

After all 8 positions around the vehicle were tested for both closest approach and exit distances; the process was repeated in the same way with the driver standing outside of the vehicle. Next, the subject was asked to return to the driver's seat. The 8 positions were re-measured, this time with the wall starting out flush with the vehicle and being drawn away from it. Again, the subject was instructed to say, "Stop" when the distance between the vehicle and the wall was the minimum clearance the subject was comfortable with. The 9:00 and 3:00 positions were again tested twice, for both determining the closest approach and exiting the vehicle distances. Fourth, the subject was asked to stand outside of the vehicle again. The ascending threshold was measured in the same order as the previous 3 sections of the experiment.

Finally, the subject was asked to sit in the driver's seat with the door closed and then exit the vehicle by opening the door as little as possible. This distance was measured as an arc from points that were at equal horizontal distances when the door was closed. The subject was then asked to repeat this process on the passenger's side. After doing so, the experimenters verified that there were no missing data points and the subject was thanked for participating and compensated for their time. A listing of the experimental tasks and their durations appears in Table 4.

Table 4. Tasks and Descriptions

Step #	Task	Description	Time (min)
1	Biographical Forms	Forms were completed with information such as name, gender, height, weight, type of car usually driven, parking patterns, car crashes, and results of an eye exam.	15
2	Introduction to Car	Experimenters showed subject how to adjust the seat, measured seated eye position (horizontal and vertical), and demonstrated adjusting the mirrors.	5
3	Introduction and Explanation	Experimenters briefly described the experiment to the subject including the general task to be completed.	5
4	Descending Threshold, Subject Driving	Subject determined the desired clearance from inside vehicle while experimenters moved the wall towards vehicle.	15
5	Descending Threshold, Subject Outside	Subject determined the desired clearance from outside the vehicle while experimenters moved the wall towards the vehicle.	15
6	Ascending Threshold, Subject Driving	Subject determined the desired clearance from inside the vehicle while experimenters moved the wall away from the vehicle.	15
7	Ascending Threshold, Subject Outside	Subject determined the desired clearance from the outside vehicle while experimenters moved the wall away from vehicle.	15
8	Minimum Door Opening, Driver and Passenger Side	Subject exited driver and passenger sides while opening the door as little as possible.	5

RESULTS

What Was the Overall Distribution of the Data?

The primary measure of interest was the clearance each driver desired between the vehicle and brick wall. The overall mean distance was 20.4 in (51.8cm) for the 640 data points collected, with a range of 2.5 to 48.5 in (6.3 to 123.2 cm). There were no missing data. Figure 5 shows the overall distribution. Though the data appear log normal, as shall become apparent later, these data are actually the aggregate of 4 distributions (wall moves towards or away × driver or observer) with similar ranges but different, unevenly spaced means.

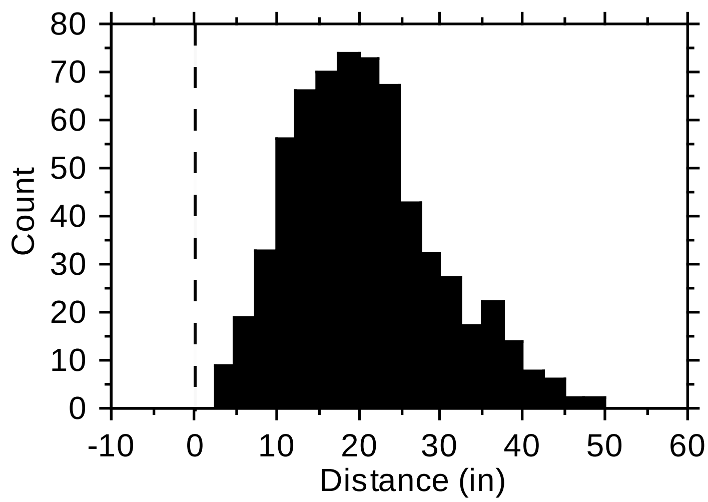
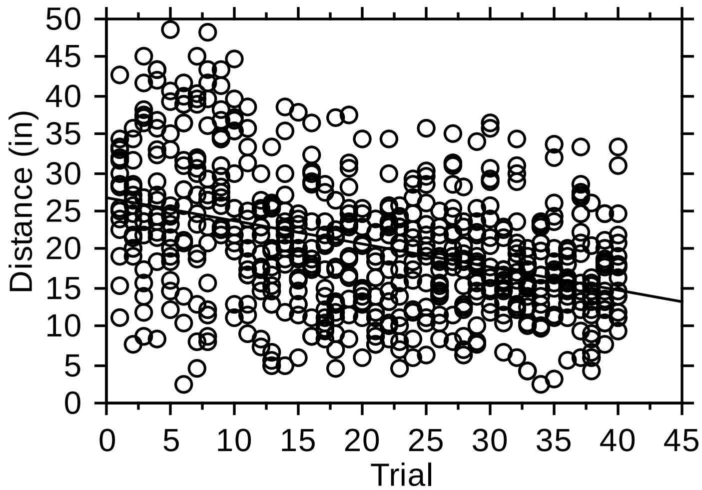


Figure 5. Overall Distribution of Desired Closest Approach Distances

Did Practice Influence the Results?

In many human factors studies, practice and fatigue effects are of concern, and that was certainly the case here. Figure 6 shows the distribution of distance responses from all 16 subjects across all 40 trials/subject. This figure suggests that the mean value decreased with practice.



Distance (in) = 26.623 - .298 * Trial; R^2 = .15

Figure 6. Distance Desired on Each Trial

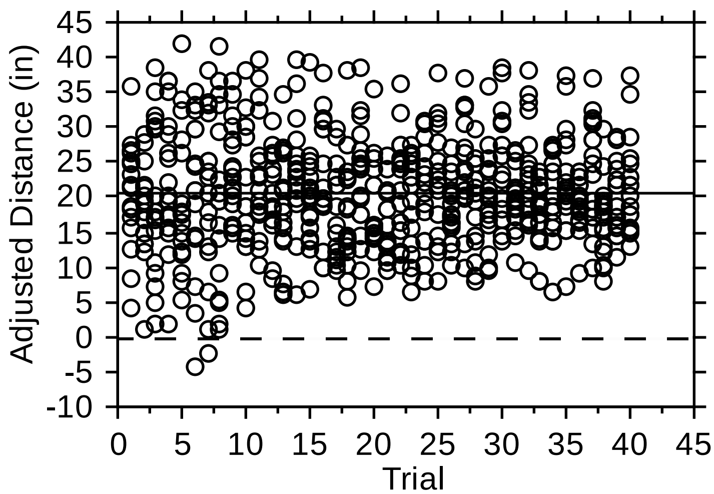
However, the order of trials was only partially counterbalanced. The order of blocks was

1. block 1 - driver sitting in the car, wall moving inward
2. block 2 - observer outside the car, wall moving inward
3. block 3 - driver sitting in the car, wall moving away
4. block 4 - observer outside the car, wall moving away.

There was concern that if the third and fourth blocks were run first, subjects would be confused by the procedure and the resulting data would be meaningless. Blocks 1 and 2 were easy to explain, and since moving the wall towards the driver was the easiest decision to understand, that condition was most appropriately completed first. Because the mean distances for these 4 blocks differ (with observers saying stop when the wall closer than drivers, and moving the wall away leading to smaller clearances than moving the wall towards), the order selected resulted in a decrease in the distance desired across the experiment.

To remove the block effect (to reflect real differences in desired clearance), the distances were adjusted by adding or subtracting the block mean for the distance measured for each subject and trial. As noted in Figure 7, there was no evidence of a practice effect in the adjusted data, in part because within blocks, the order of trials was counterbalanced. Accordingly, no adjustments were made for practice effects in any subsequent analyses.

These data do suggest the variability was slightly greater for the first few trials than subsequent trials. Therefore, future studies may consider allocating a few practice trials for subjects to become familiar with the procedure, leading to more stable results.



Adjusted Distance (in) = 20.4 + .006 * Trial; R^2 = 7.111E-5

Figure 7. Desired Distances Adjusted for Block Effects

Overall, Which Factors Significantly Affected the Desired Clearance?

To determine the factors influencing driver responses, an ANOVA was used. The independent variables were age, sex, subject nested within age and sex, subject location (driver, outside observer), direction of measurement (moving in, going out), and position around the vehicle (12:00, 1:30, 3:00 (clearance, exit), 4:30, 6:00, 7:30, 9:00 (clearance, exit), and 10:30). In addition, factors that were likely to interact based on prior experience and a preliminary review of the results was also included in the model (age × sex, subject location × direction of measurement, position × subject location, position × direction of measurement). Table 5 shows the resulting ANOVA. ANOVAs that included additional interaction terms added no significant terms and resulted in only small changes to significance levels.

Table 5. ANOVA of Closest Approach Distances

Source	**df**	**F**	**p**
Age_Group	1	126.19	0.10
Sex_Group	1	4.94	0.03
Age_Group × Sex_Group	1	3.54	0.06
Subject #[Age_Group,Sex_Group]	12	14.60	<.0001
Position	9	17.25	<.0001
In/Out of Car	1	83.84	<.0001
Towards or Away from Vehicle	1	113.07	<.0001
In/Out of Car × Towards or Away from Vehicle	1	30.76	<.0001
Position × In/Out of Car	9	1.50	0.14
Position ×Towards or Away from Vehicle	9	3.54	0.06

Figure 8 summarizes the individual differences. Note that while the age, sex, and the age by sex interactions all achieved significance at the engineering level, the degree of significance was much less than is typically. However, as is common, individual differences were highly significant. In general, young men wanted the smallest clearances (18.0 in or 45.7 cm), older men wanted the largest (22.6 in or 57.4 cm), and younger women and older women were in between (19.9 and 21.7 in or 50.5 and 55.1 cm respectively). This pattern of means and significances has been found in many prior UMTRI studies (for example, Green, 2001).   This outcome reflects capabilities (young subjects can see better, older men have the poorest health) and risk acceptance (young men accept greater risk than young women). To put this into perspective, averaging across genders, younger subjects wanted distances about 3 in less than older subjects (18.9 versus 22.1 in).

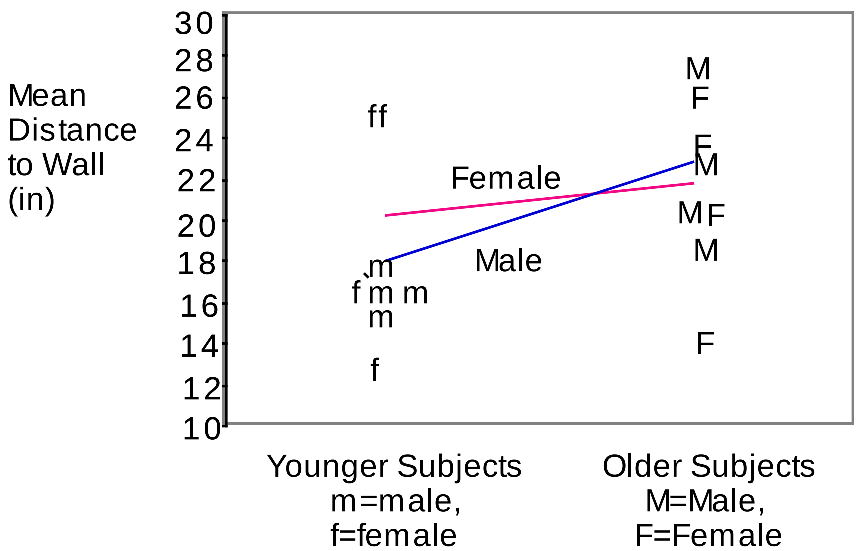


Figure 8. Individual Differences

The location of the subject clearly affected the results. When subjects were in the driver's seat, the mean desired distance was 23.0 in versus 18.1 in (58.4 cm versus 45.9 cm) when subjects were outside the car as observers. This is a practically and statistically significant difference of 4.9 in (12.5 cm). The size of the inside-outside difference depended on the position around the vehicle, as indicated by the interaction. When observers outside the vehicle are guiding a driver to position a vehicle, they have a much better vantage point than the driver, and hence are willing to move the vehicle closer to other vehicles or structures.

Also, the direction of movement of the obstruction (the wall) had a statistically significant effect on the desired minimum clearance. When moving the wall towards the vehicle the mean was 23.4 in (56.4 cm) versus 17.7 in (44.9 cm) when moving away, which is a 5.7 in (14.5 cm) difference.

Figure 9 shows the effect of the clock position around the vehicle on minimum clearance.   There is some logic to the differences. First, greater clearance is needed for exiting than for just approaching (6.7 in on the left, 7.3 in on the right) to allow for enough space to open the door and for a person to get out.

Second, distance from the driver seems to matter with the right front corner being somewhat greater than the center front or left front (10:30). Furthermore, distances to the rear are greater than corresponding locations in the front, with the right rear (4:30) and the center rear (6:00) being much greater than their front counterparts. This may be because the high rear window in the test vehicle made it difficult to see those corners directly. Interestingly, the side values for clearance are comparable to the rear. Thus, distance to the driver seems to matter, though there also seems to be a substantial front-rear difference, some of which may be attributable to whether the wall was in direct view. However, that explanation does not account for the large values on the sides.

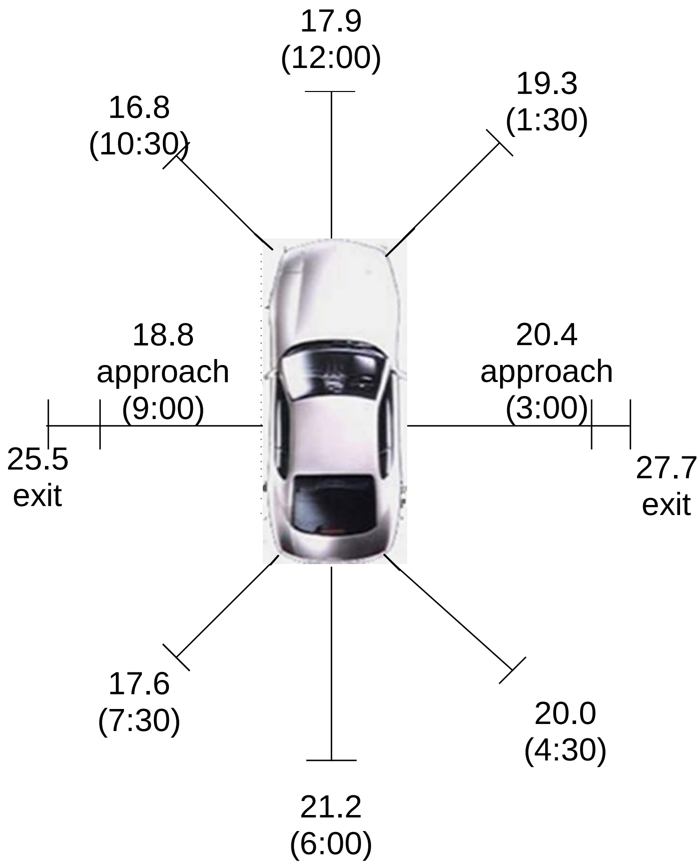


Figure 9. Mean Minimum Clearance Desired around the Vehicle for Each Position

During the initial planning, there was discussion of examining the search strategy drivers used to determine when objects are too close, especially for the rear where vision is particularly challenging. However, recording and analyzing such data was beyond the scope of this effort. Therefore, at a gross level, the overall search strategy used by each subject was recorded. As noted in Table 6, older drivers were more likely to use their mirrors and younger drivers were more likely to turn or look out the window, primarily because they were more mobile. However, there are too few responses to make inferences relating search strategies to desired distances.

Table 6. Rear View Method

Method	Young	Old	Total
Mirror	2	5	7
Mirror + Turn	2	2	4
Mirror + Turn + Out the Window	2	1	3
Turn	1	0	1
Turn + Out the Window	1	0	1
Total	8	8	16

Readers are reminded that the purpose of this experiment was to determine the distance at which parking assistance systems should inform drivers of being too close to obstructions. Table 7 shows values on which that information could be based. The full table (showing the standard deviation, etc.) appears in Appendix F. As a rough approximation, the mean was about 2.5 times standard deviation.

Table 7. Mean Clearance Values (in)

	Wall Moves Toward Vehicle		Wall Moves Away	
Position	Driver	Outside Observer	Driver	Outside Observer
10:30	**24.9**	14.7	13.8	13.7
12:00	**27.5**	15.8	14.4	13.9
1:30	**30.2**	17.0	16.7	13.4
3:00 (approach)	**26.4**	18.9	18.4	17.9
3:00 (exit)	**32.6**	26.9	27.2	23.8
4:30	**29.0**	19.1	17.5	14.2
6:00	**28.8**	20.3	20.2	15.5
7:30	**22.8**	17.4	16.2	14.1
9:00 (approach)	**22.6**	18.7	17.5	16.5
9:00 (exit)	**27.7**	25.4	24.8	24.1

How Can Desired Clearance Be Estimated?

For a system used by a driver inside a vehicle to determine when an external object is too close, the minimum desired distance could be based on the data in the first column of Table 7 (wall moves toward vehicle, driver). One could argue that providing a camera-based view of some portion of a vehicle is equivalent to an outside observer. This distinction is not merely an intellectual disagreement, but one with significant practical implications, as values in the 2 columns (wall moves towards) differ by anywhere from 2.3 to 13.2 in (5.8 to 33.5 cm). Furthermore, one could also argue that the wall moving out conditions represent the threshold for a driver with extensive parking experience who knows precisely the boundaries of the vehicle.

For the sake of discussion, assuming the bold column is appropriate and ignoring the exit case, the range is about 22.5 to 30 in (57.2 to 76.2 cm). However, those values represent the mean distances, which will be too close for some and too far for others. Given that the standard deviation is about 40 percent of the mean (1/2.5), the 95 percentile would be 1.8 times the mean or 40.5 to 54 in (102.8 to 137.2 cm), which are rather large values. Consideration of the 95 percentile is appropriate in this case.

Another potential adjustment to the data is for driver age. For example, a product might be targeted for a particular market segment/age bracket. Note that the mean distance for younger subjects was 18.9 versus 22.1 in (48.0 versus 56.1 cm) for older subjects, a 3.2 in difference. The mean age was 22 for the young group and 70 for the older group, or a difference of 48 years. Assuming the increase in distance is linear with age, this leads to an increase of 0.0667 in/year above age 22. When computing age adjustments, keep in mind that the values in Table 7 are for the mean age of the sample (46), so, for example, computing the desired distance for someone age 36 would require subtracting .7 (approximately 10 years × .667 in/year) from the values shown. Should both age and sex data be available, the means for each age × sex combination could be used for even more specific adjustments.

Those making predictions about the desired distances for particular situations and driver samples should not go beyond the accuracy of the original data. Desired preferences were measured to the nearest inch. Data here are to the nearest 0.1 in to provide the full accuracy available, but presentation in that manner can suggest more accuracy than is intended. Furthermore, there were only 4 subjects in each age × sex group, which is a somewhat small group for strong predictions about a subset of the population, but an adequate sample size given the resources available.

Finally, the clearance data to be used with video and other systems have errors in terms of how distance is measured and presented, and their expected system accuracy and precision is unlikely to be within a fraction of an inch. The precision and accuracy of the driver-related data should be consistent with the system performance.

An alternative approach to determining recommended minimum distances is based on a stepwise regression analysis of the data. In that analysis, the factors considered for the model were a code for forward/non-forward (including side) locations, a code for exit locations, a code for moving towards or away from the driver, a code if the subject was a driver or observer, driver age, a code for sex, and an age × sex interaction. In the ANOVA, all of the terms except for sex and age × sex were in the model. The model only accounts for 32% of the variance of the data, in part because the model did not include effects for each location, only for front-not front and exit-approach. The resulting equation coefficient is shown in Table 8.

Table 8. Regression Prediction for Minimum Clearance

Term	Coefficient	Comment
Intercept	9.5	
Forward/Rear code	1.6	Add if side or rear
Exit code	6.7	Add if exit
Toward/away code	5.7	Add if toward
Driver/observer code	4.9	Add if driver
Age	.07	Multiple by age

To provide an example, suppose the distance directly in front of the vehicle (12:00) was desired for a 60-year-old driver for a vehicle approaching an object. In the ANOVA method, the desired value is equal to 24.9 in (63.2 cm) plus an adjustment for driver age. That adjustment is equal to the driver's age minus the mean age of the sample (60-46) times the age increment (.07 in/yr) or (60– 46) × .07 for a total of 25.9 in (65.8 cm), approximately. Again, that adjustment could be refined by considering the gender.

Using the regression method, the estimated value is the intercept plus the towards/away code (the wall moves towards) plus the driver code (the subject is a driver) plus the age adjustment times the drivers age or 9.5 + 5.7 + 4.9 + (0.7 × 60) = 24.3. This is 1.6 in (4.1 cm) less than the estimate from the ANOVA method. Estimates for other situations generated both ways provide a sense of the accuracy of the underlying data. Differences on the order of an inch or so are reasonably common. Again, readers are reminded that the standard deviation of estimates was on the order of 2.5 in (6.4 cm), and the mean may not be the most appropriate value for a clearance.

What Were Desired Door Clearances?

Also of interest was how the driver's size related to the door opening space desired. The clearances gathered here were for a particular sample of drivers that was not selected to be statistically representative of the girth of the driving population.

Table 9 shows the relationship between the anthropometric measures and the maximum door opening desired, pooling together data for the driver and passenger sides. As a footnote, there was no practical difference between the driver (mean=18.5 in, range 14.3 to 23.3 in) and passenger values (mean = 18.9 in, range 15.5 to 26.0 in).

Table 9. Correlation of Anthropometric Measures with Maximum Opening

	Max Opening	Waist	Weight	Height
Max Opening	1.00			
Waist	.76	1.00		
Weight	.64	.91	1.00	
Height	-.38	-.16	.00	1.00

Note that there was a reasonably good correlation with waist circumference and with weight. However, the absence of any correlation of height and weight was unusual. A correlation of about 0.6 in is typical.

In a stepwise regression analysis, the maximum opening (in) was predicted as 19.5 + .040 × waist circumference (in) - .024 × height (in); that is, opening size is primarily determined by girth. This model accounted for 62 percent of the variance of the opening preferences, which is quite good.

However, these opening preferences were unrelated to any of the other distances measured. For example, Figure 10 shows that there appears to be no relationship between the clearance distance and the maximum opening desired (for the exit data only).

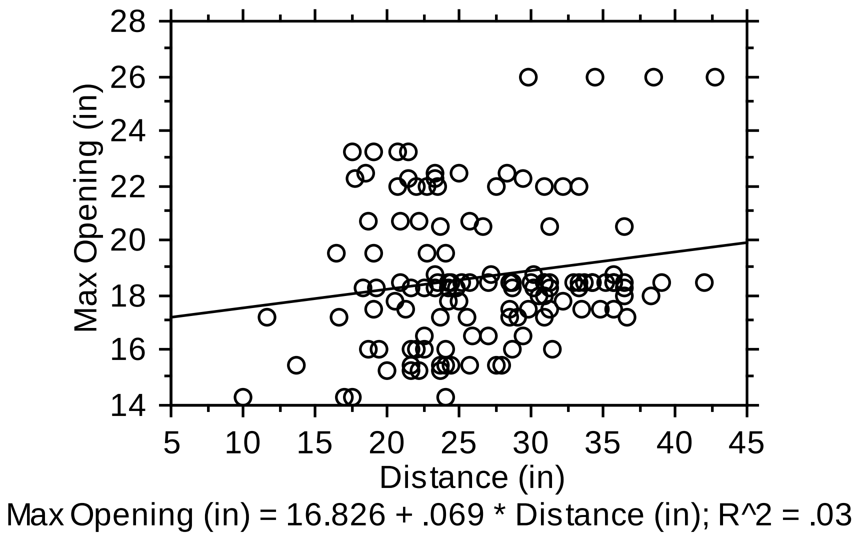
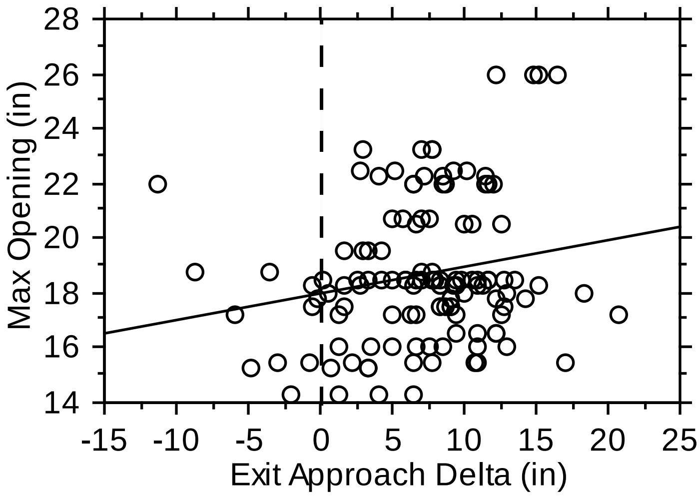


Figure 10. Exit Distance Versus Opening Desired

Similarly, a comparison of the exit minus the approach distance with the exit desired (Figure 11) again shows the absence of a relationship.



Max Opening (in) = 17.977 + .098 * Exit Approach Delta (in); R^2 = .039

Figure 11. Adjusted Distance Versus Opening Size

This lack of a connection is probably due to variability in the manner in which the data were collected. Starting with the wall placed at a far distance, subjects indicated when the wall was close enough for an exit. The wall was then withdrawn to the starting point and then moved towards the car to determine the approach distance. One would expect the 2 values to differ by reasonably stable amounts given they were determined in successive trials. As shown in Figure 12, the differences were quite variable (mean = 7.1 in, range of -11.3 to 20.8 in), including trials where the approach value was larger than the value for opening the door (so the difference was negative). The maximum opening values are much larger (mean = 18.7 in, range 14.3 to 26 in). The unusual distribution in Figure 13 results from the combination of 2 underlying distributions, 1 for younger drivers (mean = 17.0 in, range of 14.3 to 19.5 in) and 1 for older drivers (mean 20.3 in, range 17.3 to 26.0 in).

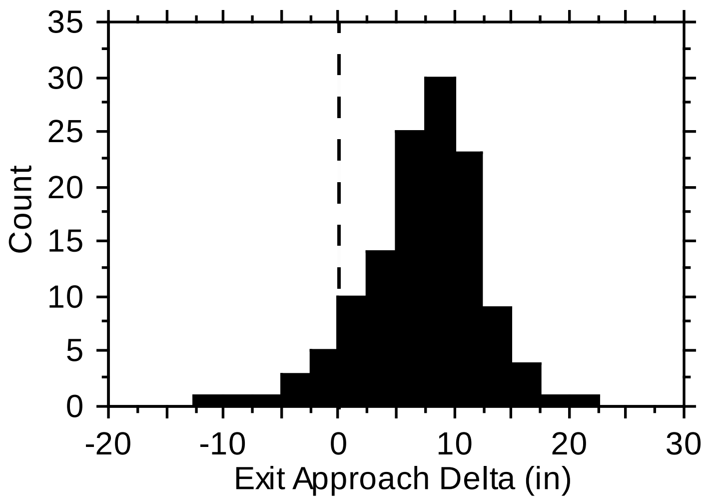


Figure 12. Distribution of Exit Minus Approach Distances

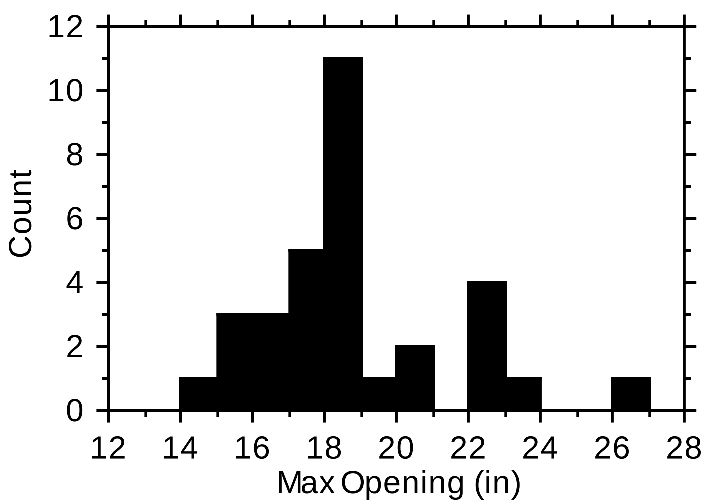


Figure 13. Distribution of Maximum Opening Values

CONCLUSIONS

1. In general, how much clearance is desired around a car when parking?

On average, drivers want about 20 in of clearance around their vehicle, or at least around a large vehicle similar to a 2004 Nissan Q45. The clearance depends on many factors. Figure 14 shows how the mean desired clearance varies with the position around the car and the task (just approach, allowing for exit space to open the door).

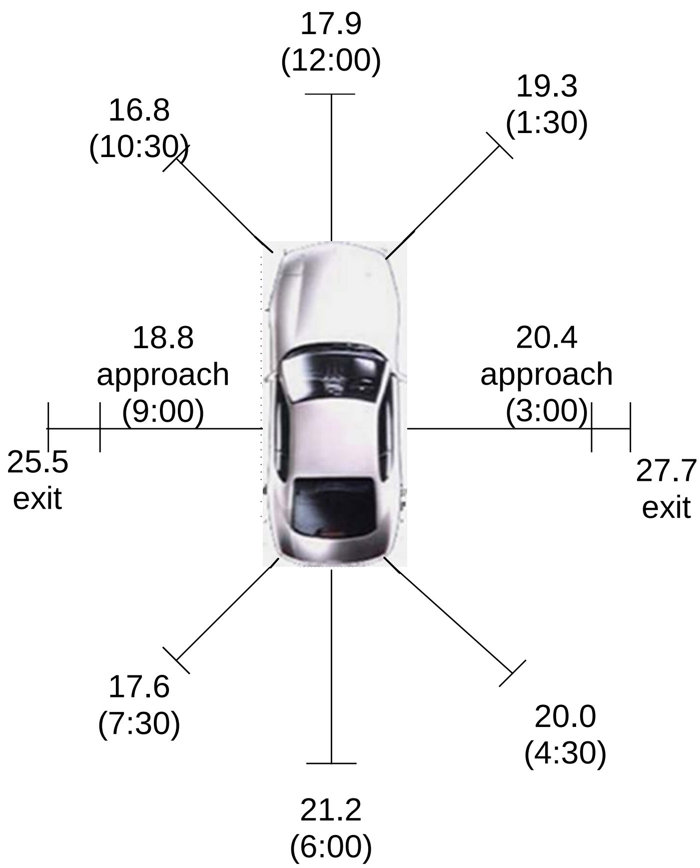


Figure 14. Mean Minimum Clearance Desired Around the Vehicle for Each Position

2. How does the measurement procedure alter the recommendation?

The desired clearance depends on whether the boundary is moving towards or away from the driver (means of 23.4 in (59.4 cm) and 17.7 in (44.9 cm)) and whether the driver is in the vehicle (mean of 23.0 in (58.4cm)) or an outside observer (mean of 18.1 in (45.9cm)).

3. How does the desired clearance vary with driver age and sex?

There were major differences due to age (young mean = 18.9 in, old mean = 22.1 in), some differences due to sex, and indications of an age × sex interaction, with young men wanting the smallest clearances and old men wanting the largest clearances.

4. How can the desired clearance be predicted?

The report suggests 2 procedures to predict desired clearance. The ANOVA procedure begins with the appropriate column of clearance values from Table 10. For example, for the case of a driver in a vehicle approaching an object, the bold column is appropriate. Next, determine a typical age for a user of the interface and adjust the value by .0667 times the age difference from 46-year-old drivers (the mean of the sample in the experiment). For example, for a 42-year-old driver, subtract 4 times .0667 or approximately 0.3 from the bold values. So, at 12:00 (straight ahead), the desired clearance is 27.2 in (= 27.5 – 0.3).

Table 10. Mean Clearance Values (in) for Drivers, Average Age 46

	Wall Moves Toward		Wall Moves Away	
Position	Driver	Outside Observer	Driver	Outside Observer
10:30	**24.9**	14.7	13.8	13.7
12:00	**27.5**	15.8	14.4	13.9
1:30	**30.2**	17.0	16.7	13.4
3:00 (approach)	**26.4**	18.9	18.4	17.9
3:00 (exit)	**32.6**	26.9	27.2	23.8
4:30	**29.0**	19.1	17.5	14.2
6:00	**28.8**	20.3	20.2	15.5
7:30	**22.8**	17.4	16.2	14.1
9:00 (approach)	**22.6**	18.7	17.5	16.5
9:00 (exit)	**27.7**	25.4	24.8	24.1

The regression procedure uses the coefficient in Table 11 to estimate the value. For the example given, the value is 9.5 + 5.7 + 4.9 + (42 × 0.07) = 23.0 in.

Table 11. Regression Prediction for Desired Clearance

Term	Coefficient	Comment
Intercept	9.5	
Forward/Rear code	1.6	Add if side or rear
Exit code	6.7	Add if exit
Toward/away code	5.7	Add if toward
Driver/observer code	4.9	Add if driver
Age	.07	Multiple by age

Readers should keep in mind that these data are based on a limited sample (16 drivers), so that a particular age-sex combination has only 4 subjects. Furthermore, repetitions within drivers were not collected, so that variability is unknown. Finally, the predictions are for the mean, and there may be alternative statistics to consider.

5. Is the size of the person exiting a vehicle related to the clearance desired for opening the door?

The size of the door opening desired was well correlated with driver girth, with the maximum opening being approximately 19.5 + .040 × waist circumference (in) - .024 × height (in). This value was obtained with drivers actually trying to exit the vehicle. However, there was essentially no relationship between moving a wall towards or away from the subjects, simulating driving, or being driven near an obstruction.

Closing Thoughts

This report provides 2 procedures to predict how close to walls and other vehicles drivers would like to drive when parking. These procedures consider the location around the vehicle, vantage point of the driver, and the age of the intended driver. These procedures are based on data from a small sample of U.S. drivers responding under benign conditions of simulated parking. The data are sufficient to provide reasonable initial estimates for guidance and warning thresholds (alerts for auditory interfaces, yellow and red lines for displays) for parking assistance systems.

REFERENCES

Green, P. (2001). Variations in Task Performance Between Younger and Older Drivers: UMTRI Research on Telematics. Paper presented at the Association for the Advancement of Automotive Medicine Conference on Aging and Driving, Southfield, MI.

Kroemer, K., Kroemer, H., and Kroemer-Elbert, K. (1994). Ergonomics, Englewood Cliffs, .N.J.: Prentice Hall.

APPENDIX A – INSTRUCTIONS TO SUBJECTS

Hello <Subject's Name>, my name is <Your Name>, and I am going to get you set up for this study. The first thing we need to do is to get some paperwork out of the way. So please fill out this form

Give subject participation form to fill out

This form basically states that you are aware of the type of study being conducted, you know how long the study will take, and that the study takes place in a car that you will be sitting in while the car is turned off.

Do you have any questions? Then please print and sign your name where appropriate, and when you are finished, please hand the form to me.

Because this study involves simulating parking, we need to know how good your eyesight is, so we will now do a brief vision test. May I please see your driver's license?

Verify validity of license, and make sure birth date is correct.

Ok, please have a seat at the eye test machine.

Clean head pad with alcohol swab.

Ok, for the entire test, please keep looking straight ahead. Can you see that in the first diamond one of the circles is complete, but the other three are incomplete? For each diamond, please tell me its number, and the location of the complete circle, top, bottom, left, or right.

Perform visual acuity test Far #2 without lenses in place.

Ok, good. Now we are going to do a similar test. Again, please tell me the number of the diamond, and the location of the complete circle.

Perform visual acuity test Far #2 with 80 cm lenses

Because your position within the car will be important we need to get some biographical dimension data from you. The first measurement that we need to take is your weight. Please remove your shoes, and empty your pockets of their contents. Please also remove any watches, cell glasses or any other objects you may be carrying. This is also a good time to turn off any cell phones or pagers that you have.
Measure and record weight.

Next we need to measure your height, so step off the scale and stand up straight next to our measuring device with your head level to the ground.

Measure and Record height.
We also need to measure waist circumference.

Ok, we are ready to go out to the test vehicle. Go ahead and put your shoes back on, and gather your belongings. This will also be the last time to use the restroom or to get a drink until the conclusion of the study. If you need to use the restroom or get a drink, please do so now.

This is <Experimenter Name>, and <Experimenter Name>, they will be helping with the study from here. Please have a seat in the car, and adjust the seat so you are comfortable. There are controls on the bottom left side of the seat to control the seat position.

Show subject controls.

When you feel that you are in a comfortable driving position, please place your hands on your lap, so we may measure your seated eye height. This measurement is important so we can tell what your field of view was like while in the vehicle.

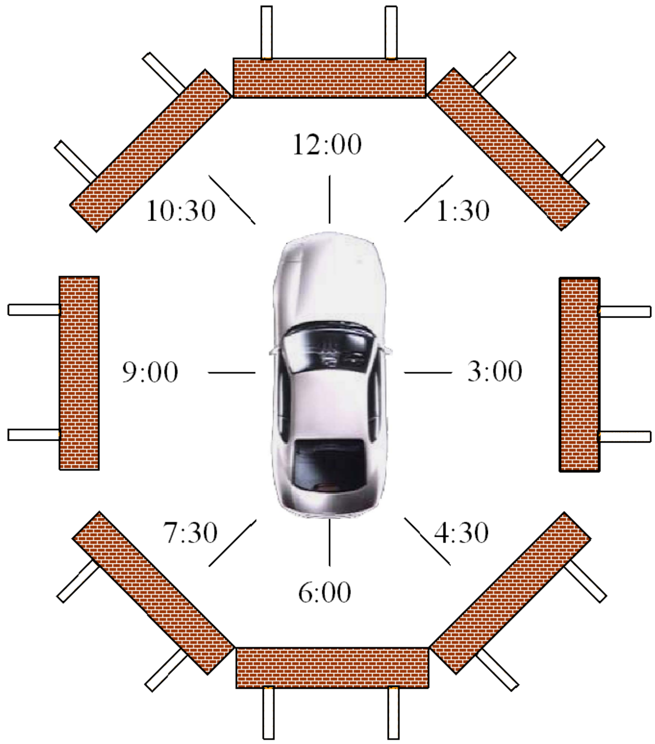
Measure seated eye height, height first (vertical distance), and then distance from car reference (horizontal distance).

Very good. We are now going to begin the study. Please close the door, and adjust your mirrors to your needs.

Show subject control for side mirrors.

Minimum Clearance Instructions for AVM Project Version of June 11, 2004 revised
Note: This task is done without the AVM to determine normal, desired clearance.
Part 1. Wall moves in (Descending Threshold), Subject driving

In the first part of the experiment, please sit in the driver's seat and buckle up. The purpose of this part of the experiment is to determine the minimum distance away from other cars or walls drivers feel comfortable parking or maneuvering. In each sequence, we will be moving a wall towards or away from the car from 8 locations, 1 at a time. Pretend that instead of the brick wall moving, that you were driving this car towards the wall while parking. We are collecting data this way to minimize damage to the car and wall. Assume this expensive car is brand new and it is your car.



Forward locations (10:30, 12 o'clock, 1:30). Counterbalance the order across subjects
Move the wall to the first forward location.

The wall is now in the first position. Pretend you are entering a parking spot and driving towards a wall. Say stop when the wall is as close as you would feel comfortable driving towards it. Ready?

Starting 5 feet from the car (or 3 feet if on the sides), move the wall to the driver very slowly, 1 inch/second or less, except at the beginning when a slightly faster speed may be ok. Stop when the subject says "Stop". If they say "too far," move the wall back to the start point and start over. Record the distance at which they stop. Do not say the distance aloud. Subjects may naturally engage in a dialog as you do this. (Ok, you are getting close…). Even when they do, try to keep the approach speed consistent. Be careful not to bias subjects to be consistent with other subjects. If you are unsure of something, ask the subject, do not guess.

If the subject asks for the distance, say that you will provide the values at the end of the experiment. Also, do not tell them how their data compares with others.

Move the wall to the second forward location.

We are going to move the wall. Again pretend you are driving towards the wall. Say stop when the wall is as close as you would feel comfortable driving towards it. Ready?

Move wall towards the car.
Record the distance where they say stop.
Move the wall to the third forward location.

Ok, again, the wall will approach. Say stop when the wall is as close as you would feel comfortable driving towards it.

Move wall towards the car.
Record the distance where they say stop.
Side locations (3 and 9 o'clock)
Move the wall to the first side location. The order is counterbalanced across subjects.

For the next 2 locations, you need to say stop twice. The first time to say stop, which we will do now, is when you feel that the wall is as close as possible to the car so that you could still open the door and get out without damaging the door or wall. In other words the minimal distance that you would need to get out of the car without damaging the wall or the car. Ready?

Move wall towards the car.
Record the distance they say stop

Ok, this time, pretend you are driving next to a wall, like in a parking garage. Say stop when you feel the wall is as close as you would want to drive near it. Ready?

Move the wall towards the car.
Record the distances where they say stop.
Move the wall to the second side location.

Ok, let's repeat the process again on this side, saying stop twice. The first time is minimal distance that you would need to get out of the car without damaging the wall or the car, and the second time is for driving by the wall. Ready?
Move wall towards the car.
Record the distance where they say stop first.

And now for the second stop. Ready?

Move wall towards the car.
Record the distance where they say stop second.
Rear locations (4:30, 6, 7:30). Similar to front, order counterbalanced.
Move the wall to the first rear locations.

We are now going to collect data for the rear of the car. When drivers back up, some use their mirrors, some turn their heads, some people open the door, and some use a combination of these methods. Do whatever you would normally do to see the wall behind the car when backing out of a parking spot. Again, say, "Stop" when the wall is as close as you would want to back towards it.

Move wall towards the car.
Record the distance where they say stop.
Move the wall to the next rear location.

And now for the next rear location. Ready?

Repeat

Part 2. Wall moves in (Descending Threshold), Subject outside

Ok, for this part of the experiment, you need to be outside of the car, so go ahead and get out now. In this set of trials, pretend someone else is parking your car and you want to be absolutely sure they do not run into the wall. Assume it is someone you do not know, so you do not know how well they park. You would like to aid them in parking your car, but all you can do is say stop when they reach your comfortable distance. Think of this as being a situation where, to protect your car, you decide how close others can get to the wall as if you were standing behind the car and being their eyes. Feel free to move around to get a good angle, but you cannot guide them in, for example by saying “your are getting close.” You can only say stop. Understand?

Forward locations (10:30, 12 o’clock, 1:30). Counterbalance the order across subjects
Move the wall to the first location.

We will now do the forward locations.
Just as before for front, say stop when the car is as close to the wall as you would want someone else to park it. Ready?

Move wall towards the car.
Record the distance where they say stop.
Move the wall to the next forward location.

And now for the next forward location. Ready?

Move wall to next forward location.
Repeat
Side locations (3 and 9 o’clock)
Move the wall to the first side location. The order is counterbalanced across subjects.

We will now do the side locations.
For the sides, you will again say stop twice. The first time is minimum distance that you feel they would need to get out of the car without damaging the wall or the car. Assume they are of your body type, build, and agility. For the second stop again say stop for the distance you would feel comfortable seeing them drive by the wall. Ready?

Move wall towards the car.

Record the distance where they say stop first.

And now for the second stop. Ready?

Move wall towards the car.
Record the distance where they say stop second.
Move the wall to the second side location.

Ok, let's repeat the process again for this side, saying stop twice. The first time is minimum distance that you feel they would need to get out of the car without damaging the wall or the car, and the second stop is for the distance you would feel comfortable seeing them drive by the wall.
Ready?

Move wall towards the car.
Record the distance where they say stop first.

And now for the second stop. Ready?

Move wall towards the car
Record the distance where they say stop second.
Rear locations (4:30, 6, 7:30). Similar to front, order counterbalanced.
Move the wall to the first rear location.

We'll now do the rear of the car again.
Again, say, stop when the wall is as close as you would want someone else to back towards it.

Move wall towards the car.
Record the distance where they say stop.
Move wall to next rear location.

And now for the next rear location. Ready?
Repeat

Part 3. Wall moves out (Ascending Threshold), Subject driving

Ok, we are now going to go back to the situation where you are driving, so please re-enter the car, and buckle your seat belt. In this next part of the experiment, we are going to repeat the process, only instead of the starting with the wall far away, the wall will be touching the car and we will move it away slowly. It may seem odd to think about approaching the wall while the car is going the other way but don't think about the wall moving; rather think about the distance between the car and the wall.

Forward locations (10:30, 12 o'clock, 1:30). Counterbalance the order across subjects
Move the wall to the first location.

We will now do the forward locations just as before.
Pretend you entering a parking spot and driving towards a wall. Say stop when the wall is as close as you would feel comfortable driving towards it. Ready?

Move wall towards the car.
Record the distance where they say stop.
Move the wall to the next forward location.

Ok, again, the wall will pull back. Say stop when the wall is as close as you would feel comfortable driving towards it.

Move wall towards the car.
Record the distance where they say stop.
Move wall to next forward location.
Repeat
Side locations (3 and 9 o'clock)
Move the wall to the first side location. The order is counterbalanced across subjects.

We will now do the side locations.
For the sides, you will again say stop twice, however, because the wall is now pulling away, the first stop will be for the distance you would feel comfortable driving by the wall. The second stop will now be the minimal distance that you feel you would need to get out of the car without damaging the wall or the car. Ready?

Move wall towards the car.
Record the distance where they say stop first.

And now for the second stop. Ready?

Move wall towards the car.
Record the distance where they say stop second.
Move the wall to the second side location.

Ok, let's repeat the process again for this side, saying stop twice. The first stop is the distance you would feel comfortable driving by the wall and the second stop is the minimal distance that you would need to get out of the car without damaging the wall or the car.
Ready?

Move wall towards the car.
Record the distance where they say stop first.

And now for the second stop. Ready?

Move wall towards the car.

Record the distance where they say stop second.
Rear locations (4:30, 6, 7:30). Similar to front, order counterbalanced.
Move the wall to the first rear location.

We are now going to test the rear of the car again. Use any method that you would use normally to see the back of the car. Again, say, “Stop” when the wall is as close as you would feel comfortable backing towards it. Ready?

Move wall towards car.
Record the distance where they say stop.
Move the wall to the next rear location.

And now the next rear location. Ready?

Repeat

Part 4. Wall moves out (Ascending Threshold), Subject outside

Ok, for this part of the experiment, we again need to be outside of the car, so lets get out now. In this set of trials, just as before, pretend someone else is parking your car and you want to be absolutely sure they do not run into the wall. Feel free to move around to get a good angle, but you cannot guide them in, you can only say stop. Understand?

Forward locations (10:30, 12 o’clock, 1:30). Counterbalance the order across subjects
Move the wall to the first forward location.

We will now do the forward locations.
Say stop when the car is as close to the wall as you would want someone else to park it.

Move wall towards the car.
Record the distance where they say stop.
Move the wall to the next forward location.

And now the next forward location. Ready?

Repeat
Side locations (3 and 9 o’clock)
Move the wall to the first side location. The order is counterbalanced across subjects.

We will now do the side locations.
For the sides, you will again say stop twice, however, because the wall is again pulling away, the first stop will be for the distance you would feel comfortable having them driving by the wall. The second stop will now be the minimal distance that you feel they would need to get out of the car without damaging the wall or the car. Ready?

Move wall towards the car.
Record the distance where they say stop first.

And now for the second stop. Ready?

Move wall towards the car.
Record the distance where they say stop second.
Move the wall to the second side location.

Ok, let's repeat the process again for this side, saying stop twice. The first stop is the distance you would feel comfortable having them drive by the wall and the second stop is the minimal distance that you feel they would need to get out of the car without damaging the wall or the car.
Ready?

Move wall towards car.
Record the distance where they say stop first.

And now for the second stop. Ready?

Move wall towards car.
Record the distance where they say stop second.
Rear location (4:30, 6, 7:30). Similar to front, order counterbalanced.
Move the wall to the first rear location.

And now for the rear locations.
Again, say, stop when the wall is as close as you would want someone else to back towards it. Ready?

Move wall towards car.
Record the distance where they say stop.
Move the wall to the next rear location.

And now the next rear location. Ready?

Repeat

There are 2 final tasks. First, please sit in the driver's seat. In a moment, please get out of the car as if there was an imaginary wall very close to the driver's door. To ensure that this imaginary wall does not scratch the door, you will need to hold the door and open the door as little as possible as you try to squeeze out. Try to get out of the car, and when you are certain that you could exit the car with that amount of space, let me know. I will hold the door at the position and you can get back into the car as we measure the opening of the door. Ready? Please exit.

Record the maximum opening from the car body.

Good. Now the second task is the same thing only on the passenger side, so please go around to the passenger side and sit in the seat. Now we are going to repeat the process, simulating the situation of a wall close to the car, so you open the door as little as possible. Ready? Please exit.

Record the maximum opening from the car body.
Verify there are no missing data points on the data collection sheets and everything written is legible. If something in uncertain, cross out the value and write the correction next to it, do not erase or write over data.

APPENDIX B – SUBJECT CONSENT FORM

UMTRI
University of Michigan
Transportation Research Institute
2901 Baxter Road, Ann Arbor, MI 48109-2150

Participant number: _____

Parking and Low Speed Driving – Inside Subjects
Investigators: Paul Green (763 3795) UMTRI Human Factors

An automotive manufacturer is developing devices to help people park and drive at low speeds. To design this device, they need to know how close to objects outside the car people are willing to drive while parking. To gather this information, you will sit in a test car as well as stand outside the car. The car may either be parked outside or in a garage. A simulated wall will slowly be moved to and away from the car, and your task is to say when it is too close. We will record what you say and may videotape the process.

The results of this study, summarized in a report for the sponsor and public, will be used to make future vehicles easier and safer to drive.

There are no risks associated with this experiment that we can think of, especially since there is no driving involved. You may withdraw from this study at any time without penalty. The study should take about an hour. You will be paid $30 for your time.

I HAVE READ AND UNDERSTAND THE INFORMATION PRESENTED ABOVE. MY PARTICIPATION IN THIS STUDY IS ENTIRELY VOLUNTARY.

______________________________	________________________________
Print your name	Date
______________________________	________________________________
Sign your name	Witness (experimenter)

I agree to be videotaped in this study and realize my face will appear on the tape. I understand that segments from the tapes may be used in presentations to explain the results. My name will not be disclosed with the tape. The raw tapes will be erased 10 years after the project is completed.

[Optional] Sign your name ___________________________________

Segments from videotapes of my sessions may be used by the media (e.g. on TV) to help explain this research to the public.

[Optional] Sign your name ____________________________________

Should you have questions regarding your participation in research, please contact Kate Keever:
Human Subjects Projection Office, IRB Behavioral Sciences, 540 East Liberty Street, Suite 202, Ann Arbor, MI 48104-2210, Ph: 936-0933, fax: 647-9084, email: Irbhsbs@umich.edu, web: http://www.irb.research.umich.edu

APPENDIX C – SUBJECT BIOGRAPHICAL FORM

University of Michigan Transportation Research Institute

Subject: ____________

Around View Monitor Study Biographical Form

Date: ____________

Name: ______________________________________

Male **Female** (please circle) **Date of Birth:** ____/____/____
mm / dd / yy

Waist Circumference (in.) ________ **Weight (lbs)** ________ **Height (in.)** ________

Seated Eye Height (in.) ________ **Occupation** ____________________

What kind of motor vehicle do you drive the most?

year: ________ make: ____________ model: ________

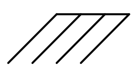
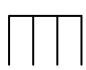
Miles you drive per year: ______________

During the past 5 years, in how many:

Parking crashes have you been involved? ____________

Non-parking crashes have you been involved? ____________

How many times per month do you park in:

		On Weekdays:	On Weekends:
Angular spaces:		________	________
Parallel spaces:		________	________
Perpendicular spaces:		________	________

In how many previous UMTRI studies have you participated? ________

Have you ever driven a car with an in-vehicle parking camera? ________

If you were driving on a 3-lane highway, what lane would you typically drive in?

Left Center Right

For Experimenter:

Vision Correction: Yes (Eye Glass, Hard Contact Lens, Soft Contact Lens), No

Titmus Vision: (Landolt Rings)

1	2	3	4	5	6	7	8	9	10	11	12	13	14
T	R	R	L	T	B	L	R	L	B	R	B	T	R
20/200	20/100	20/70	20/50	20/40	20/35	20/30	20/25	20/22	20/20	20/18	20/17	20/15	20/13

1	2	3	4	5	6	7	8	9
B	L	B	T	T	L	R	L	R
12	5	26	6	16				

APPENDIX D – EXPERIMENT DESIGN RATIONALE

Decision	Rationale
Forward locations first	Subjects may have difficulty in understanding why the wall moves and not the car. The forward case is easiest to understand, so it should be done first. However, varying which of the 3 is selected should balance out order effects.
2 criteria for sides	Approach and exit are likely to be different values
Exit criteria	Remind them not to damage the door and to allow space for themselves to they do not confuse closest with exit. Data on a comfortable exit is not being collected because some would interpret that to mean opening the door to the maximum allowed by the hinge (fully open), and that is not the data point desired.
Ordering of inside-outside trials	If ascending and descending are done in succession, memory may lead them to chose the same value twice, so the judgments will not be independent.
Someone else perspective	In some sense this is like watching someone park near you and you cannot tell them what to do, but you are concerned they will hit your car.
Repetition	It is important to keep the language consistent thought the experiment so the judgment does not change, even when paraphrasing. Hence, always use the phrase "as close as you would feel comfortable driving towards it" or "as close as you would feel comfortable having someone else park your car."

APPENDIX E – SAMPLE DATA COLLECTION FORM

Desired Clearances Data Collection Sheet 2 Subject Name: ______________
Page 1 of 2 Date: ___________________________

Trial	Sequence		Location (clock)	Judgment type	Distance (cm or in tbd)
1	Wall moving towards car, Subject driving	Front	12	Closest approach	
2			1:30	Closest approach	
3			10:30	Closest approach	
4		Sides	3	exit	
5			3	Closest approach	
6			9	exit	
7			9	Closest approach	
8		Back	7:30	Closest approach	
9			4:30	Closest approach	
10			6	Closest approach	
11	Wall moving towards car, Subject outside	Front	1:30	Closest approach	
12			10:30	Closest approach	
13			12	Closest approach	
14		Sides	3	exit	
15			3	Closest approach	
16			9	exit	
17			9	Closest approach	
18		Back	7:30	Closest approach	
19			4:30	Closest approach	
20			6	Closest approach	

Comments:

Minimum Clearances Data Collection Sheet 2 Subject Name: _____________

Trial	Sequence		Location (clock)	Judgment type	Distance (cm or in tbd)
21	Wall moving towards car, Subject driving	Front	1:30	Closest approach	
22			10:30	Closest approach	
23			12	Closest approach	
24		Sides	3	Closest approach	
25			3	exit	
26			9	Closest approach	
27			9	exit	
28		Back	7:30	Closest approach	
29			4:30	Closest approach	
30			6	Closest approach	
31	Wall moving towards car, Subject outside	Front	1:30	Closest approach	
32			10:30	Closest approach	
33			12	Closest approach	
34		Sides	3	Closest approach	
35			3	exit	
36			9	Closest approach	
37			9	exit	
38		Back	7:30	Closest approach	
39			4:30	Closest approach	
40			6	Closest approach	

Maximum door opening-driver side:

Maximum door opening, passenger side:

Comments:

APPENDIX F - MINIMUM DESIRED DISTANCE FOR EACH CONDITION

	Mean	Std. Dev.	Std. Error	Count	Minimum	Maximum	#
Missing Distance (in), Total	20.521	8.890	.351	640	2.500	48.500	0
Distance (in), 10:30, In, Away	13.781	5.225	1.306	16	4.500	23.500	0
Distance (in), 10:30, In, Toward	24.906	11.293	2.823	16	10.250	41.750	0
Distance (in), 10:30, Out, Away	13.719	5.203	1.301	16	4.000	26.000	0
Distance (in), 10:30, Out, Toward	14.797	6.704	1.676	16	5.000	33.500	0
Distance (in), 12:00, In, Away	14.422	4.344	1.086	16	6.000	20.250	0
Distance (in), 12:00, In, Toward	27.484	11.739	2.935	16	4.500	45.000	0
Distance (in), 12:00, Out, Away	13.859	5.294	1.323	16	2.500	24.500	0
Distance (in), 12:00, Out, Toward	15.844	8.499	2.125	16	5.000	38.500	0
Distance (in), 1:30, In, Away	16.656	6.725	1.681	16	8.000	30.500	0
Distance (in), 1:30, In, Toward	30.219	12.649	3.162	16	8.750	48.500	0
Distance (in), 1:30, Out, Away	13.438	4.574	1.143	16	3.250	20.000	0
Distance (in), 1:30, Out, Toward	16.969	7.765	1.941	16	5.500	38.000	0
Distance (in), 3:00 approach, In, Away	18.438	4.470	1.117	16	10.000	24.500	0
Distance (in), 3:00 approach, In, Toward	26.438	7.692	1.923	16	14.750	39.250	0
Distance (in), 3:00 approach, Out, Away	17.922	5.668	1.417	16	10.500	32.000	0
Distance (in), 3:00 approach, Out, Toward	18.938	5.475	1.369	16	11.500	29.750	0
Distance (in), 3:00 exit, In, Away	27.203	4.630	1.157	16	21.500	35.750	0
Distance (in), 3:00 exit, In, Toward	32.641	6.212	1.553	16	22.500	42.750	0
Distance (in), 3:00 exit, Out, Away	23.875	6.427	1.607	16	11.750	33.750	0
Distance (in), 3:00 exit, Out, Toward	26.938	6.496	1.624	16	16.500	38.500	0
Distance (in), 4:30, In, Away	17.484	6.814	1.703	16	6.250	25.750	0
Distance (in), 4:30, In, Toward	28.984	11.278	2.820	16	8.000	48.250	0
Distance (in), 4:30, Out, Away	14.281	4.877	1.219	16	4.000	21.000	0
Distance (in), 4:30, Out, Toward	19.141	8.226	2.057	16	7.000	37.000	0
Distance (in), 6:00, In, Away	20.156	8.697	2.174	16	7.750	35.000	0
Distance (in), 6:00, In, Toward	28.812	10.921	2.730	16	7.750	43.500	0
Distance (in), 6:00, Out, Away	15.469	4.807	1.202	16	6.000	22.250	0
Distance (in), 6:00, Out, Toward	20.312	8.251	2.063	16	8.500	37.500	0
Distance (in), 7:30, In, Away	16.156	5.789	1.447	16	7.000	26.000	0
Distance (in), 7:30, In, Toward	22.828	10.132	2.533	16	2.500	39.750	0
Distance (in), 7:30, Out, Away	14.078	4.693	1.173	16	5.500	21.500	0
Distance (in), 7:30, Out, Toward	17.375	7.691	1.923	16	4.500	34.500	0
Distance (in), 9:00 approach, In, Away	17.469	5.810	1.453	16	8.750	34.000	0
Distance (in), 9:00 approach, In, Toward	22.641	7.200	1.800	16	11.000	35.250	0
Distance (in), 9:00 approach, Out, Away	16.531	4.668	1.167	16	9.750	24.500	0
Distance (in), 9:00 approach, Out, Toward	18.719	4.821	1.205	16	11.000	25.250	0
Distance (in), 9:00 exit, In, Away	24.766	6.669	1.667	16	10.000	36.500	0
Distance (in), 9:00 exit, In, Toward	27.656	5.666	1.416	16	20.750	38.250	0
Distance (in), 9:00 exit, Out, Away	24.156	5.965	1.491	16	13.750	34.250	0
Distance (in), 9:00 exit, Out, Toward	25.359	5.514	1.379	16	17.500	33.250	0