

## **HOW MUCH CLEARANCE DRIVERS WANT WHILE PARKING: DATA TO GUIDE THE DESIGN OF PARKING ASSISTANCE SYSTEMS**

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This experiment examined how close to objects (such as a wall or another vehicle) people would drive when parking. The findings determined the distance at which visual and/or auditory warnings should be provided by parking assistance systems.

Sixteen drivers (8 aged 18-30, 8 over age 65) served as subjects. Data was collected for the subject sitting in the driver's seat of a 2004 Nissan Q45 (a full-size sedan) and when they were outside the vehicle (as if directing someone else to park). Data was collected for moving a simulated brick wall towards and away from the test vehicle for 8 cardinal clock positions.

The overall mean distance was 20.4 in for the 640 data points collected, ranging from 2.5 to 48.5 in. Using the regression method, 1 of the 2 developed methods, the desired distance (in) 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.

### **INTRODUCTION**

For the last year, UMTRI has been involved in supporting the design of a parking assistance system to make parking easier and safer. The system consists of an instrument panel display and several cameras that can provide close ups from various angles of the areas near the front and rear bumpers, and the side of the car.

A review of the human factors and crash data revealed that the number of crashes and property damage associated with parking are substantial, though relatively few crashes resulted in deaths (Smith, Green, and Jacob, 2004). Because many parking-related crashes occurred on private property, the number of parking crashes is probably underreported. The review also revealed the most common crash scenario involved a driver backing out of a perpendicular space and striking another vehicle.

Subsequently, baseline data was collected on how people normally park. Cullinane, Smith, and Green, 2004 reported drivers park 3 times/day on average, regardless of the day of the week, with about  $\frac{3}{4}$  of all parking being perpendicular. There were few differences in parking frequency or other factors between various age groups or between men and women. Cullinane, et. al. also provided data on the parking positioning error for drivers in Ann Arbor, Michigan, data useful for selecting test conditions and establishing baselines for parking studies.

Subsequently, UMTRI conducted experiments to examine perpendicular parking (in a parking lot) and parallel parking (simulating a street situation) with a prototype assistance system. In addition, an experiment was conducted to determine the desired clearance around a car, data needed to locate "no go" zones and other markings on parking assistance displays. That experiment is summarized here and discussed in detail in Green, Gadgil, Walls, Amann, and Cullinane (2004). Specifically, it determined

how much clearance is desired around a car as a function of 1) contact position, 2) data collection method (ascending vs. descending threshold), 3) subject location (inside vs. outside of the car) and 4) age and 5) and sex of the subject.

**METHOD**

**Participants**

Sixteen licensed drivers (8 ages 20 to 30 (mean of 22), 8 above age 60 (mean of 72)) volunteered to participate in a 1.5-hour experiment. Each age group included 4 men and 4 women. All subjects had normal or corrected vision. They were paid \$30 each.

Subjects drove relatively new vehicles and drove 9900 miles each year on average. (The U.S. mean is 10,000 miles/year). All subjects were experienced at parking, parking between 8 and 180 times each month (mean of 59)

Five subjects had been involved in at least 1 parking crash (2 of whom had 2) within the past 5 years. Four subjects had been in a non-parking crash within the last 5 years (1 of whom had 2 crashes).

**Procedure**

Subjects completed a pre-experiment questionnaire about their driving habits and also provided biographical information.

Next, a simulated brick wall was moved towards or away from the test car (2004 Infiniti Q45, a full-size sedan). Subjects said stop “when the wall was as close as they felt comfortable driving towards/away from it.” The wall (made from foam and simulated brick) was moved instead of the vehicle to reduce the data collection time and the collision risk. There were 8 test positions around the car (Figure 1). Data was collected for both the subject seated in the drivers seat and for self-selected positions from where subjects could best observe the car-wall gap (usually nearby and

perpendicular to it) as if directing someone else to park. (Parking system images could resemble what the driver could see directly or virtually, or via an off-board camera, the observer’s viewpoint.)

The 8 positions were tested in several orders, each repeated 4 times, with the start position and direction (clockwise, counterclockwise) counter-balanced across all subjects. The order of the 4 judgment conditions was fixed to minimize subject confusion, with in-car data being collected before the observer data, and ascending thresholds before the descending thresholds.

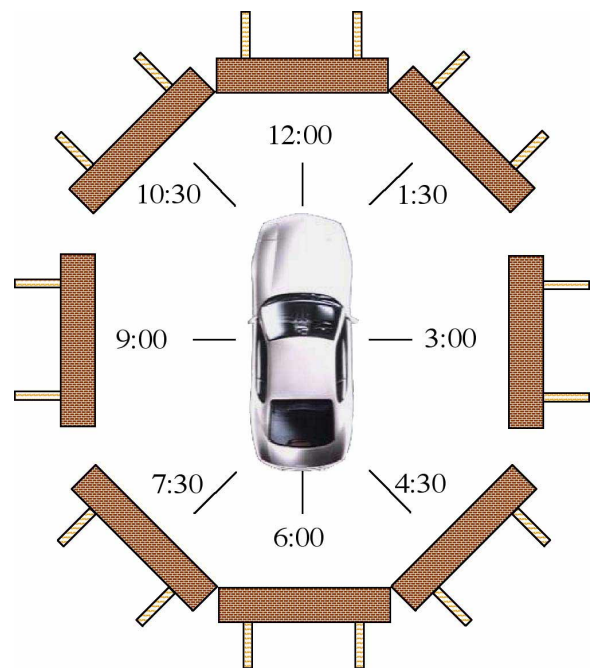


Figure 1. Wall Positions Examined

**RESULTS**

**Typical Values and Sources of Variability**

The overall mean minimum desired lateral clearance distance was 20.4 in for the 640 judgments. The overall distribution (Figure 2), which appears to be log-normal, is the aggregate of 4 distributions with similar ranges but different means (wall towards/away x driver/observer).

The location of the subject affected the results. When subjects were in the driver’s seat, the mean desired distance was 23.0 in versus 18.1 in when outside the car as an observer. The size of the inside-outside difference depended on the position around the vehicle. Observers outside the vehicle have a better vantage point than the driver, and hence move the vehicle closer to other vehicles or structures.

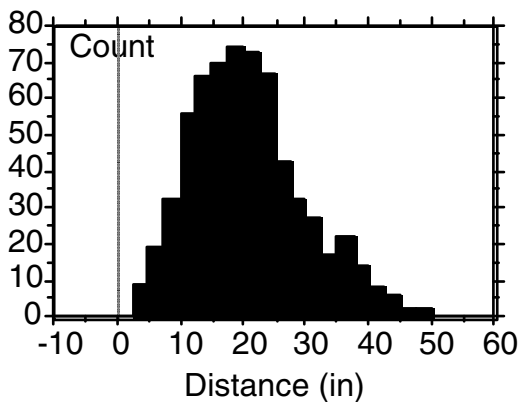


Figure 2: Overall Desired Closest Approach

Figure 3 shows the effect of the contact position around the vehicle on desired clearance. Greater clearance was desired for exiting than for just approaching (6.7 in on the left, 7.3 in on the right, to allow for a space to open the door and for a person to get out.

Also, distance from the driver to the area of interest mattered with the right front corner being somewhat greater than the front or left front (10:30). Furthermore, distances to the rear are greater than corresponding positions 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 makes 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.

To determine the factors influencing driver responses, 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, 1:30, 3 (clearance, exit), 4:30, 6:00, 7:30, 9 (clearance, exit), and 10:30). In addition, factors that were likely to interact (based on prior experience and a preliminary review of the results) were also included in the model (Age\*Sex, Subject Location\*Direction of Measurement, Position\*Subject Location, Position\*Direction of Measurement).

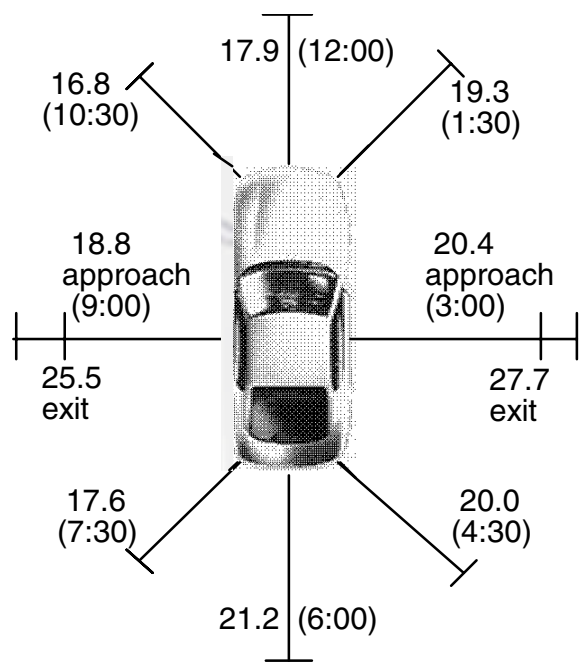


Figure 3. Desired Distance versus Position

**ANOVA Method to Predict Desired Distance**

Figure 4 summarizes the individual differences. Note that age, sex, and the age by sex interaction all achieved significance at the engineering level ( $p < .1$ ), much less significant than is typically the case. However, as is common, individual differences were highly significant. In general,

young men wanted the smallest clearances, the older men the largest (22.6 in) and the younger women and older women were in between (19.9 and 21.7 in), a pattern has been found in prior studies (Green, 2001). This reflects capabilities (young subjects can see better, older men have the poorest health) and risk acceptance (young men accept greater risk than young women). Averaging across genders, younger subjects wanted distances about 3 in less than older subjects (18.9 versus 22.1 in).

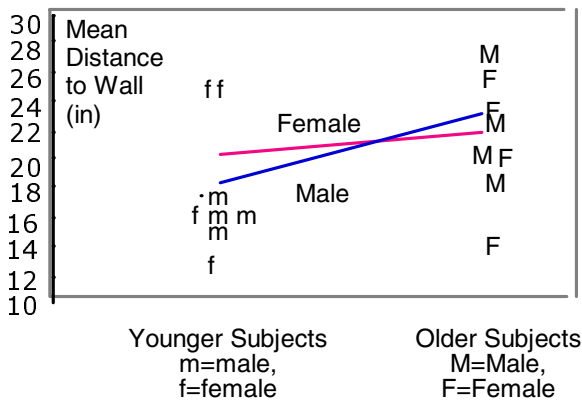


Figure 4: Individual Differences

Based on this analysis, a procedure was developed to estimate the desired clearance. It used the mean value desired by subjects for each position (8) for each of the 4 judgments (wall moving in/out x driver/observer) and then adjust that value up or down from the mean age of the subjects in the experiment to the age of the driver in question. (See Green, Gadgil, Walls, Amann, and Cullinane, 2004 for details.)

**Regression Method to Predict Desired Distance**

An alternative approach 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 toward 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 position, only front-not front and exit-approach. The resulting equation is shown in Table 1. This model assumes that some of the position variations are spurious.

Table 1. Regression Method Terms

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

As an example, suppose the distance directly in front of the vehicle was desired (12:00) for a 60-year old driver for a vehicle approaching an object. In the ANOVA method, the desired value is equal to 24.9 (the wall moving in, the driver is in the car, the wall is at 12:00, a table value) plus an adjustment for the 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. Again, that adjustment could be refined by including the gender distribution.

Using the regression method, the estimated value is the intercept plus the toward/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 in. This is 1.6 in less than the estimate from the ANOVA method, providing a sense of the accuracy of the underlying data and estimation procedure. Differences on the order of an inch or so are reasonably common. It should be noted that the standard deviation of estimates was on the order of

2.5 in, and the mean may not be the most appropriate value for a clearance.

## CONCLUSIONS

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

Drivers want about 20 in of clearance around their vehicle, or at least around a large car. The clearance depends on many factors including the position around the car, the location of the driver, the age and sex of the driver, and how the question is asked.

### ***2. How does the measurement procedure alter the recommendation?***

The desired clearance depends upon if the object to be avoided is moving towards or away from the driver (means of 23.4 and 17.7 in) and if the driver was in the vehicle (mean=23.0 in) or an outside observer (mean 18.1 in).

### ***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.

### ***Closing Thoughts***

This report provides 2 procedures to predict the minimum desired clearance when parking based on data from a U.S. driver sample responding under benign conditions. These data are sufficient to initially determine the distances at which drivers should be alerted as a function of driver age and sex, the position of the object, and the viewing situation (the camera location).

## 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.
- Green, P., Gadgil, S., Walls, S., Amann, J., and Cullinane, B. (2004). Desired Clearance Around A Vehicle While Parking or Performing Low Speed Maneuvers. (Technical Report UMTRI 2004-30), Ann Arbor, Michigan: University of Michigan Transportation Research Institute.
- Cullinane, B., Smith, D., and Green, P. (2004). Where, When, and How Well People Park: A Phone Survey and Field Measurements (Technical Report UMTRI 2004-18), Ann Arbor, Michigan: University of Michigan Transportation Research Institute.
- Smith, D., Green, P., and Jacob, R. (2004). Parking and Low-Speed Crashes: Crash Database, Literature, and Insurance Agent Perspectives (Technical Report UMTRI 2004-9), Ann Arbor, Michigan: University of Michigan Transportation Research Institute.

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