

DRIVER PERFORMANCE EVALUATION OF TWO REAR PARKING AIDS

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ABSTRACT

Four levels of parking aids were tested using 32 participants in two age groups with equal numbers of men and women. Levels of parking aid were: no aid, ultrasonic rear park assist (URPA) with an auditory/visual distance to an object interface, a video view to the rear, and a combination of URPA with video view. Using a sport-utility vehicle, eighteen participants between 45 years and 55 years, and 14 participants 60 years and older performed five parking tasks: entering and exiting a parallel space, entering and exiting a perpendicular space, and backing to a trailer hitch. Participants reported higher scores of parking quality and judging distance to other objects with the video system than without. Objective measures including time to park, final position and angle in parking space showed differences based on parking aid system (URPA versus video). Age groups and replication number also showed differences. Total eye glance times to different areas of the vehicle showed differences based on parking aid system.

INTRODUCTION

Devices intended to assist drivers while parking vehicles are becoming increasingly common. URPA systems which detect objects to the rear of a vehicle while backing have been on the market for some time. Rear video systems which make use of an in-dash display to provide the driver with a view of the area to the rear potentially permit the driver to evaluate the type of objects and location more fully than is possible with URPA systems. A number of questions exist related to rear video systems. How will drivers make use of these systems? Do the systems impact the driver's current backing and search behavior? Is the user able to interpret the wide angle view typical of the systems? Will the user accept these systems? Will performance with these systems be comparable or better than other parking aids? The following study investigates these

questions through questionnaire data and driver performance data.

METHODS

Research Site

The parking and trailer hitching tasks were conducted on a closed section of roadway with occasional vehicle and pedestrian traffic. Figure 1 shows the layout of the space and the starting point for the participant vehicle. The parallel space was located to the right of a lane of travel. The space was 22 ft 6 in (6.9 m) long and 8 ft 2 in (2.5 m) wide with a 6 in (15 cm) curb located on the right side of the space. Artificial cars constructed of wood frame and surfaced with foam board were placed with their bumpers 3 ft 3 in (1 m) from the ends of the space.

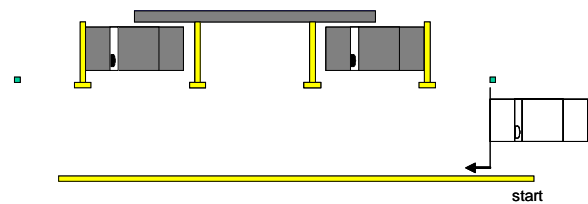


Figure 1. Parallel space and starting point.

Figure 2 shows the layout of the perpendicular space and the starting point for the participant vehicle. The perpendicular space included the space boundary lines to create an interior space dimension of 19 ft (5.8 m) deep by 8 ft 7 in (2.6 m) wide. Artificial cars were located 1 ft 4 in (40 cm) to the outside of the space boundary on both sides of the space and 1 ft 6 in (46 cm) behind the back of the space.

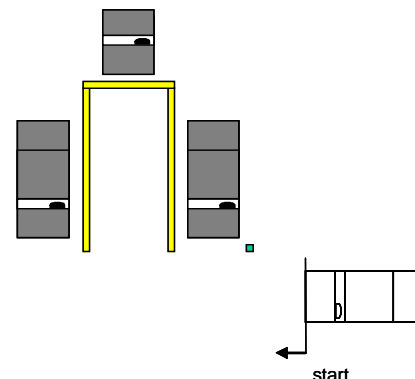


Figure 2. Perpendicular space and starting point.

Figure 3 shows the trailer and starting orientation of the participant vehicle. An artificial flatbed type trailer, similar to that used for pulling personal water

craft, was constructed of wood and foam board. The trailer was 4 ft 10 in (1.5 m) wide, 7 ft (2.1 m) long, and 2 ft 6in (76 cm) tall. The trailer location provided essentially an unrestricted area of pavement for maneuvering the vehicle to the hitch.

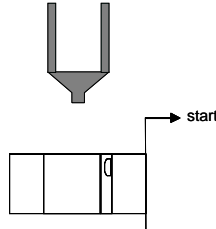


Figure 3. Trailer hitch and starting point.

Research Vehicle

The research vehicle was a 2002 Cadillac Escalade. Vehicle instrumentation included interior camera views of the participant’s foot and the pedals, the participant’s face viewed from a camera adjacent to the rear video display, and the participant’s face viewed from a camera located on the A-pillar. These three views were multiplexed with a view from the rear video camera. The figure below illustrates the multiplexed three interior views and the rear video view.



Figure 4. Multiplexed interior views and rear video view.

Additionally, four camera views were made of each bumper corner of the vehicle. By using a grid overlay method, these views were used to measure the final location of the vehicle in the space during post-drive analysis.

Gear position, longitudinal acceleration, speed, and task time were also recorded at 10 Hz and synchronized with the videos.

Experimental Design

The experimental design was a 2x4x5 mixed factor design. The between-subject variable was Age. Equal numbers of men and women were placed in each age group. The within-subject variables were Parking Aid (four levels) and Parking Tasks (five levels). Each of these variables is described in more detail in the following section.

Participant Vehicle Type

Participants were selected to emphasize current drivers of SUVs or large vehicles. 72% of the participants reported that their primary vehicle was a SUV, truck, or van. 19% reported their secondary vehicle was a SUV, truck, or van. The remaining 9% did not currently drive a SUV, truck, or van.

Independent Variables

Age

Two age groups were included in the study. The middle-aged group included individuals between 45 years and 55 years of age. The older group were individuals 60 years or older. 18 participants were included in the middle-aged group and 14 in the older group.

Parking Aid

Four levels of parking aid were used by the participants.

Traditional – No parking aid system was used so drivers used mirrors and over the shoulder glances for this baseline level.

Ultrasonic Rear Park Assist (URPA) - A system using ultrasonic sensors with an interface located on the passenger side rearmost pillar was used. This system operates as follows: at 5 ft a chime sounds and one amber light is lit; at 40 in both amber lights are lit; at 20 in a continuous chime is sounded and all three lights (amber/amber/red) are lit; and at 1 ft a continuous chime is sounded and all three lights flash. Figure 5 shows the URPA visual interface with all of the lights illuminated.



Figure 5. Passenger side rearmost pillar URPA visual interface.

Rear Video (RV) – When the vehicle was put in reverse, this system provided a 131 degrees wide view of the rear bumper and area behind the vehicle. Figure 6 shows the location of the RV display and a view of a lane with a pylon located behind the vehicle.



Figure 6. Parking aid experimental rear video display system.

URPA + RV – This level of parking aid used a combination of the URPA system and the RV system. When placed in reverse, the participant was provided with the video view to the rear and the lights and auditory signals of the URPA system.

Parking Task

The participants were all required to execute five parking tasks with each of the four levels of parking aid. The five tasks were (1) backing into a parallel space, (2) backing out of a parallel space, (3) backing into a perpendicular (straight in) parking space, (4) backing out of a perpendicular space, and (5) backing up to a trailer hitch.

Dependant Variables

In-vehicle questionnaire

After completion of each task, the participant was asked to respond to the following five statements with either a strongly agree, agree, disagree, or strongly disagree response:

1. I know the vehicle is well parked (statement used for parking tasks) / I know the vehicle is within 2 inches of the trailer hitch (statement used for trailer task).
2. While driving, I knew where the vehicle was and how far it was from other objects.
3. I was aware of the surrounding environment while performing the task.
4. This system was helpful in addition to my normal methods (not asked for in traditional method condition).
5. I was comfortable using [this system] to perform the task.

Post-drive questionnaire

A post-drive questionnaire investigated user perceptions of the rear video system by querying participants about areas of confusion, difficulties, problems, and their overall preferred system for each of the parking tasks.

Objective measures

Objective measures used were as follows:

- Vehicle position and angle in parking space
- Distance from hitch
- Time to park
- Time in reverse
- Number of gear changes
- Glance behavior

Experimental Procedure

After arriving at the facility, the participant completed pre-drive paperwork as well as a pre-drive questionnaire. The participant was then oriented to the vehicle and verbally provided the procedures for the study and the URPA and rear video systems were explained. The participant was instructed that he or she should be aware of his or her surroundings and that other traffic and personnel would be on the road. The participant then drove to the first area for four practice trials. The practice trials involved backing toward a row of pylons with each level of the parking aid systems and providing a response to the five statements discussed previously.

During the main experimental portion of the study, the participant conducted each of the five parking tasks with the same parking aid level before

completing the tasks with additional parking aid levels. Each of the tasks ended with the participant indicating they were done. In the trailer hitching task, the participant was allowed to exit the vehicle twice to check his or her progress. After completing each task, the participant responded to each of the five in-vehicle questionnaire statements.

Order of tasks and parking aid levels were counterbalanced between subjects. Following completion with the final parking aid level, the participant performed a replication of the five parking tasks with the parking aid level he or she had experienced first.

After the last trial, a ruse was used where while the experimenter spoke to an individual outside the vehicle, the vehicle was blocked from forward travel by two objects (cone and folding chair) while a plastic pylon was (unbeknownst to the participant) placed behind the vehicle. The participant was then told he or she could return to the building. At this time, the participant would either back into the pylon or detect it. The participant was debriefed after the ruse. The participant then returned to the building and completed a post-drive questionnaire, after which he or she was paid and released.

RESULTS

In-vehicle questionnaires

Participant scale responses to the in-vehicle statements were analyzed for differences among parking aid levels. The following discussion indicates where differences were found at $p \leq 0.05$.

Results from the parallel parking task are shown in Table 1. The URPA, RV, URPA+RV systems showed advantages over the traditional condition when considering the participants responses to the statements related to knowing they were well parked. RV and URPA + RV showed advantages over the traditional condition in evaluating how far they were from other objects.

Table 1. Questionnaire responses for parallel parking.

Parallel	Traditional	URPA	RV	URPA+RV
Well parked	-	+	+	+
How far from other objects	-	±	+	+
Awareness of surroundings	o	o	o	o
Helpful	na	o	o	o
Comfortable	o	o	o	o
-, +, ++, +++ indicates statistically different groups from lowest scored to highest scored. ± could be either from the - or + group o indicates no differences. na - statement did not apply to parking aid level.				

Results from the perpendicular parking task are shown in Table 2. RV and URPA + RV seemed to help people feel they knew how far they were from other objects. URPA made people more comfortable than the traditional condition.

Table 2. Questionnaire responses for perpendicular parking.

Perpendicular	Traditional	URPA	RV	URPA+RV
Well parked	o	o	o	o
How far from other objects	-	±	+	+
Awareness of surroundings	o	o	o	o
Helpful	na	o	o	o
Comfortable	-	+	±	±
-, +, ++, +++ indicates statistically different groups from lowest scored to highest scored. ± could be either from the - or + group o indicates no differences. na - statement did not apply to parking aid level.				

Results from the trailer hitching task are shown in Table 3. Both the RV and URPA + RV showed clear preferences in the trailer hitching task, receiving higher evaluation in all of the questions than either the traditional condition or URPA.

Table 3. Questionnaire responses for trailer hitching.

Trailer	Traditional	URPA	RV	URPA+RV
Well parked	-	-	+	+
How far from other objects	-	-	+	+
Awareness of surroundings	-	-	+	+
Helpful	na	-	+	+
Comfortable	-	+	+++	++

-, +, ++, +++ indicates statistically different groups from lowest scored to highest scored.
± could be either from the - or + group
o indicates no differences.
na - statement did not apply to parking aid level.

Objective Measures

Time in Reverse

When parallel parking, mean time spent in reverse was 36.5 s in the traditional condition. This time was shorter than the corresponding times for URPA and URPA + RV ($p = 0.01$), which had mean times of 46.1 s and 47.3 s, respectively.

Gear Changes

The mean number of gear changes required during the trailer hitching task using the RV (mean=4.5 changes) and the URPA + RV (mean=4.8 changes) were lower than the mean number of gear changes in the traditional condition and with the URPA system (mean=6.4 changes) ($p=0.05$).

Parallel Parking Position

When parallel parking, there was no difference in the mean longitudinal position in the space across parking aid levels. Mean final position was 6.5 in (16.5 cm) rear of the longitudinal center. However, there was a statistically significant difference ($p=0.04$) in the lateral position in the space across parking aid levels. When using URPA, the mean lateral position was 1 cm right of lateral center. When using RV alone, mean lateral position was 9 cm right of lateral center (closer to curb). There was no difference between the traditional condition or URPA + RV condition and any other conditions.

In the parallel parking task, there was also a main effect of replication on final lateral position ($p=0.05$). This effect is best understood by examining the statistically significant Parking Aid x Replication effect ($p=0.03$). Participants who replicated the parallel parking task with RV or URPA + RV parked

closer to the curb during the first replication as compared to participants who replicated the parallel parking task with URPA alone or the traditional condition.

There was a statistically significant difference across parking aid levels for final angle in the space ($p=0.01$). Maximum angle deviation possible is about 9 degrees. 97% of trials were less than 5 degrees angle deviation. When using URPA only, the mean angle was approximately 0.2 degrees left of straight. When using a RV or URPA + RV, mean angle was approximately 1.2 degrees left of straight. The left of straight orientation indicates the front of the vehicle being closer to the lane of traffic than the rear of the vehicle.

There was an Age X Parking Aid interaction for longitudinal final position in the parallel space ($p=0.047$), which is shown in Figure 7. No statistically significant difference in longitudinal position was found for the older group across parking aid levels, whereas the middle-aged group were further rearward when using URPA, RV, or URPA + RV than when in the traditional condition. The middle-aged group parked further rearward than the older group in the URPA or URPA + RV conditions.

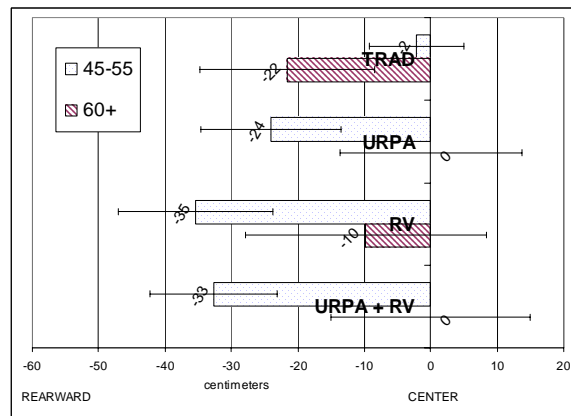


Figure 7. Age by Parking Aid effects on longitudinal position in Parallel Parking Task.

Perpendicular Parking Position

When perpendicular parking, there was no difference in the mean lateral deviation across parking aid levels. The mean lateral position in the space across all parking aid levels was 4.5 in (11.5 cm) left of center. There was a statistically significant difference across parking aid levels for longitudinal final position in the space ($p=0.01$). When using RV or URPA + RV, mean final position was approximately 4.7 in (12 cm) from the back of the

space, whereas in the traditional condition, the mean position was approximately 1 ft 2.1 in (36 cm) from the back of the space.

Trailer Hitching Task

There was a main effect for system on the final distance to the hitch ($p=0.0001$). When using RV or URPA + RV, participants were able to place the ball closer to the trailer hitch by almost 7.9 in (20 cm) than when using URPA alone or when in the traditional condition.

There was a main effect of replication on the approach angle ($p=0.02$). In the first replication of the trailer hitching task, the mean approach angle of the participants was 18 degrees to the driver’s side. In the second replication of the trailer hitching task, the mean approach angle was 26 degrees to the driver’s side.

Task Time By Replication

There was a main effect of replication on the time it took to complete each task ($p=0.007$). Figure 8 shows the mean time in seconds for each task and replication. Differences between the mean first and second replication times for parallel, perpendicular, and trailer tasks were 20 s, 25 s, and 47 s respectively.

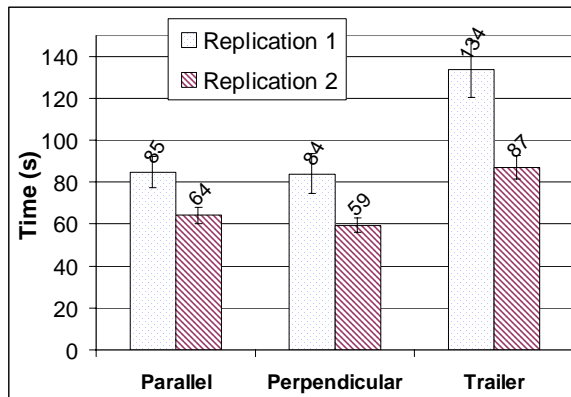


Figure 8. Mean time for each task by replication (time in seconds).

Glance Analysis

A glance analysis was performed to investigate time spent looking at different locations in and around the vehicle while parking. The following locations were used:

1. Front windshield
2. Rear view mirror
3. Instrument Panel (IP)
4. Rear video display
5. Right mirror
6. Left mirror
7. Right front window
8. Left front window
9. Right rear windows
10. Left rear windows
11. Back window

In the glance time charts below, the vertical axis shows the mean total time (sec) that participants glanced at the specific location during execution of that task for the four levels of parking aid. Glance time to all eleven locations was analyzed, but only the locations showing statistical differences are reported here. Differing letters above each bar indicate significant post-hoc testing differences ($p < 0.05$) found between parking aid levels for total glance time to that glance location.

In all tasks, participants clearly spend time looking at the rear video system when it is available.

Parallel Parking

In the parallel parking task, Figure 9 shows that the time spent looking out the back window was less when using RV than in the other conditions. Time looking in the rear view mirror was higher for the URPA condition than the other conditions (Note: the URPA visual display was visible in the rear view mirror). Time looking in the driver’s side mirror was less in the RV condition than in the other conditions.

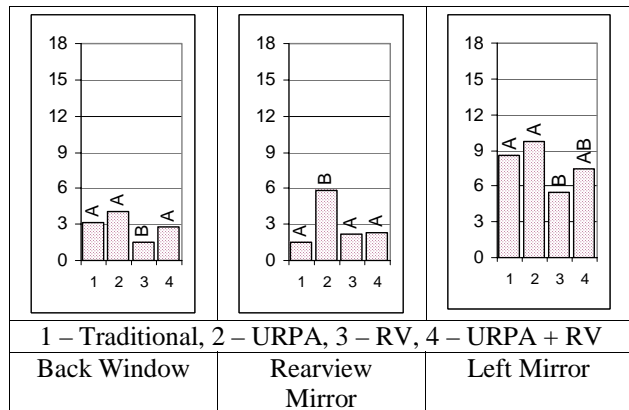


Figure 9. Locations showing differences in mean total glance time when parallel parking (time in seconds).

Perpendicular Parking

Figure 10 shows that when perpendicular parking, participants looked at the back window less in the RV and URPA + RV conditions than when in the URPA or traditional conditions. Time spent looking at the video display was less in the URPA + RV condition

than time looking at the video display in the RV alone condition. The rear view mirror was used more in the URPA condition than for the other three conditions when perpendicular parking.

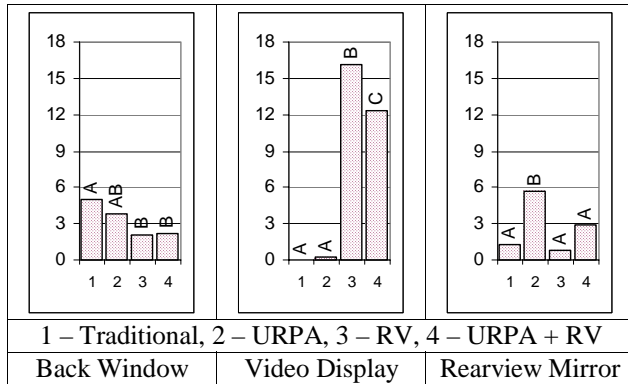


Figure 10. Locations showing differences in mean total glance time when perpendicular parking (time in seconds).

Exiting a Perpendicular Space

Exiting the perpendicular space provided a scenario where a glance to the left rear window and right rear area of the vehicle was appropriate to ensure no crossing traffic or pedestrians were approaching. The right rear area could be seen with either a glance to the right rear window or back window, so these locations were combined for analysis. An ANOVA indicated no statistical difference in the number of glances to the left rear, or combined right rear and back window locations across the parking aid conditions.

A secondary analysis was performed to determine if participants would forego glances to the left rear or combined right rear and back window locations when parking aids were used as compared to the traditional condition. A nonparametric sign test (pairing each parking aid level) on the number of participants with zero glances to the left rear or combined right rear and back window locations indicated no statistical difference between any of the parking aid conditions versus the traditional condition. However, as shown in Figure 11, the URPA + RV condition (10 participants) was statistically different from the number of participants not looking to the combined right rear and back window locations in the URPA (3 participants) and RV (3 participants) conditions. No difference was found for the number of people not glancing at all to the left rear window location.

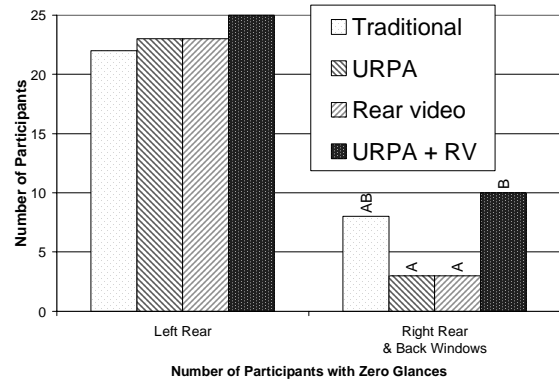


Figure 11. Number of participants who did not glance to the left rear, or combined right rear and back window locations while backing from a perpendicular space.

Trailer Hitching

Figure 12 shows that in the trailer hitching task, time spent looking at the left mirror and left front window was lower for the RV and URPA + RV conditions than for the URPA and traditional conditions. Time spent looking to the right front, right rear windows, and back window was less with RV and URPA + RV than with URPA alone.

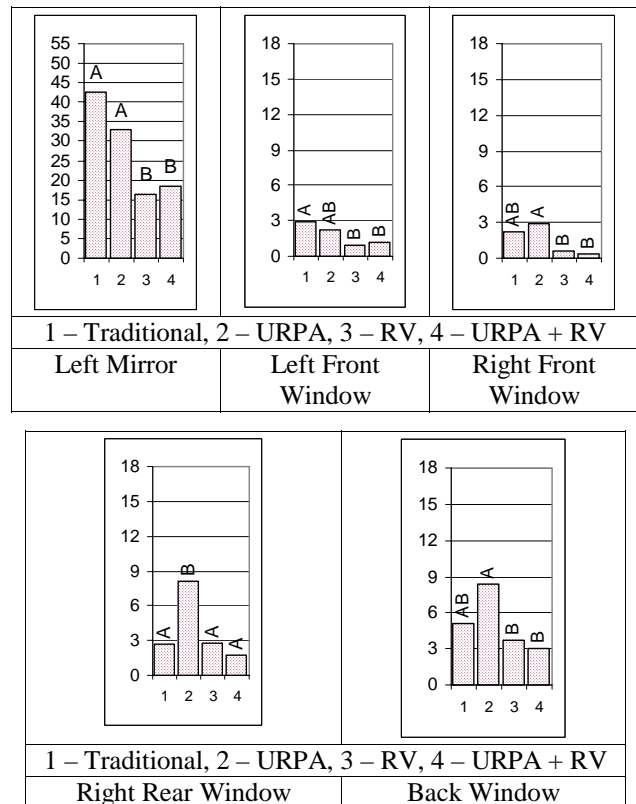


Figure 12. Locations showing differences in mean total glance time when hitching a trailer (time in seconds).

Post-Drive Questionnaire

After completing the driving portion of the study, participants were administered a post-drive questionnaire. Questionnaire data for three additional participants who completed the protocol without numerical data permitted use of 35 respondents for the following analysis.

When asked if anything about RV confused them, 22 participants said no and 13 participants said yes. Of the 13 reporting confusion, the items mentioned by more than five participants were: difficulty relating display to actual locations/distances (six participants), and shadows in the display (five participants). 23 participants did not indicate any surprises from the system. No specific surprises were mentioned by more than five participants. When asked to list any difficulties which arose while using RV, 14 participants did not indicate any difficulty. More than five participants indicated difficulty with shadows in the display (nine participants).

Figure 13 shows which parking aid condition participants indicated was most preferred for each of the tasks. The RV or URPA + RV conditions were most preferred for the trailer hitching task. The URPA + RV condition was the most preferred for both of the other parking task types.

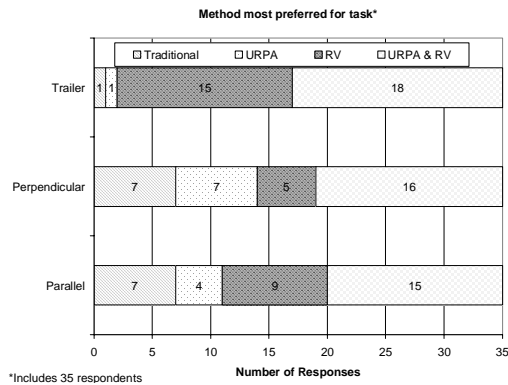


Figure 13. Participant preferences for systems.

Ruse

The ruse was set-up and executed successfully for 29 participants. The number of participants exposed to the ruse for the traditional, URPA, RV, and URPA + RV conditions was seven, seven, nine, and six, respectively. 24 of the participants hit the obstacle leaving five who avoided hitting the obstacle. Of the five participants who did not hit the obstacle: three saw the obstacle using the RV (two in the RV condition, one in the URPA + RV condition), one

saw the obstacle in their mirror (in the URPA + RV condition), and one saw the obstacle out the back window (in the RV condition).

CONCLUSIONS

The rear video system was particularly useful to the participants in the trailer hitching task. This was demonstrated through their improved accuracy when backing to the hitch, as well as their preference for either the RV or URPA + RV when executing this task as indicated in the in-vehicle and the post-drive questionnaires.

When perpendicular parking, the middle-aged group located the vehicle further to the rear, but still within, the parking space. This could be caused by greater ability to find the back of the space or by perceiving the gap to the back of the space as larger than it actually was.

All of the parking aid systems received higher in-vehicle task evaluations than the traditional method when parallel parking. As participants backed at an angle into the parallel space, RV and URPA + RV appeared to help them get closer to the curb, especially for people unfamiliar with the vehicle, but tended to leave them at a slight angle. As the participant backed into the space, URPA alone may have been used to make use of the entire length of the space while parking, but not to get closer to the curb.

Glance behavior indicated that drivers were using both the URPA and the RV systems when available. The passenger side rearmost pillar URPA location did draw the eyes to the rear view mirror or the back window directly. In the parking tasks, glance time to the back window tended to reduce when RV was available, but in general, time to other areas did not show statistically significant changes.

There was no significant difference in the number of participants who did not glance to the back and back-right windows during the task of exiting a perpendicular space between the URPA + RV condition and the traditional condition. However, a significantly larger number of participants in the URPA and RV alone conditions did look at least once to this area during that maneuver. One explanation for this is that the limited additional information over traditional methods provided by each of these parking aid systems alone may lead the driver to look for more complete information. With URPA alone, a traditional glance may be used to check for clear area, and with RV alone, a traditional glance may be used to confirm the distances to objects.

The trailer hitching task was very difficult due to the small size of the trailer. In the traditional condition, as participants got close, the trailer disappeared from mirrors and window views. Time spent searching these views was reduced when the video view was present.

It appears users will make use of these systems and are able to interpret the wide viewing angles present in the RV system. Some experience may be required to achieve the same proficiency in time, but these results suggest that users will be able to park more easily and in some cases closer to the curb or back of a space than with traditional methods. Glance behavior did change to include more time to the RV system rather than to the mirrors and back window, but participant visual scan of other locations around the vehicle appeared to continue similar to that observed with no parking aid system. Participants took more time to park with all of the parking aid systems than with the traditional method.

In an unplanned backing task as presented in the ruse, participants generally proceeded without fully checking the area to the rear. 83% of the participants hit the pylon placed close behind the vehicle during the ruse. For those five participants who did not hit the pylon, it is interesting to know that all had the rear video view available, although only three of these five avoided the pylon by viewing it in the video display. It should also be noted that this experimental design did not address drivers' long term usage patterns and behavior with parking aid systems.