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Exploratory Study of Early Adopters, Safety-Related Driving with Advanced Technologies

Final Report

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16. Abstract

Exploratory work was undertaken to study driver real world experiences associated with the use of advanced technologies currently available in production automobiles (e.g., Adaptive Cruise Control, night vision, park aid, and navigation systems). The effort involved identifying and interviewing so called "early technology adopters" (owners of recently introduced in-vehicle technologies) in order to provide insights into driver acceptance and adaptation to these types of systems. Although the current effort included a substantial data collection effort, its primary role was as a feasibility study intended to determine successful methods and approaches for identifying and contacting system owners which could be successfully used in future large-scale and representative data collection efforts. A total of 480 vehicle owners were recruited to participate, resulting in 691 completed interviews. Evidence suggests that some form or degree of driver behavioral adaptation occurred for each of the systems examined. Some changes represented improvements (e.g., enhanced ability to detect obstacles at night or behind the vehicle, etc.) while others lead to potentially riskier driving practices (e.g., longer glances away from the forward roadway, etc.). Many drivers were found to hold misconceptions about the performance capabilities of their advanced systems, suggesting that drivers' mental models of how these systems function do not always match reality. Information gathered can lead to improved designs and educational programs to ensure that drivers understand device functions, capabilities and limitations, and can also serve as an early indication of the safety benefits or problems that new technologies may bring when they are more fully deployed in the light vehicle fleet.

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EXECUTIVE SUMMARY

The availability of in-vehicle systems (e.g., Adaptive Cruise Control, navigation, park aid, night vision systems) is increasing. An inventory of factory-installed systems found that in-vehicle navigation and route guidance systems, in particular, are the most prevalent technology currently available to U.S. consumers; over 90 vehicle models offer this feature. Park aid systems, designed to assist drivers in executing backing and parking maneuvers, are also emerging as a popular feature currently being offered in 44 2004 model year vehicles. Adaptive Cruise Control (ACC) systems are relatively new introductions into the U.S. market and are offered in a limited number of vehicle models (17 different models); these tend to be higher-end luxury vehicles. Only two manufacturers have introduced night vision systems, both are offered as optional equipment.

Owners of advanced in-vehicle technologies were surveyed in a telephone interview intended to assess driver behavioral adaptation (changes in behavior over time), as well as driver acceptance (ease-of-use, effectiveness, desirability, etc.) associated with four types of commercially available in-vehicle systems (Adaptive Cruise Control, night vision, parking/backup aids, and navigation and route guidance systems). The information gathered can lead to improved designs and educational programs to ensure that drivers understand device functions, capabilities and limitations, and can also serve as an early indication of the safety benefits or problems that new technologies may bring when they are more fully deployed in the light vehicle fleet. Although the current effort included a substantial data collection effort, its primary role was as a feasibility study intended to determine successful methods and approaches for identifying and contacting system owners which could be successfully used in future large-scale and representative data collection efforts. Six unique recruitment methods were used to solicit participation in the survey, these included: mail-outs to lists of registered vehicle owners; newspaper recruitment ads; Internet recruitment ads; magazine recruitment ads; direct calls to registered vehicle owners, and participation from automobile dealerships.

A total of 480 vehicle owners were recruited to participate, resulting in 691 completed interviews (Since some vehicles were equipped with multiple systems or respondent had more than one vehicle with different systems, respondents were allowed to complete up to two interviews addressing different systems). The sample of vehicle owners ranged in age from 23 to 87 years of age with a mean age of 56 years. Approximately 15% were between the ages of 23-39 (younger); 38% between the ages of 40-59 (middle aged); and 47% above age 60 (older). The sample was heavily represented by males (67%) versus females (33%). The overwhelming majority of drivers in the sample (94%) purchased or leased the equipped vehicle themselves. Over 98% of the vehicles owned were 2002 or later models, and were driven an average of 15,606 miles since they were purchased or leased. A substantial percentage of the sample (25%) had driven the vehicle 7,000 miles or less; the top 25% of the sample had driven the vehicle over 20,000 miles since it was purchased.

Results suggest mail-outs and follow-up telephone calls to registered vehicle owners were the most effective recruitment methods examined, providing 81% of the valid completed interviews. Further, although different levels of monetary incentives were examined ($25 versus $50), both yielded a similar response rate, suggesting that the added incentive did not appreciably increase the response rate above the base level. Thus, for this particular population, the real incentive to participate in this type of survey may not be monetary, but simply the opportunity to influence the design of systems and have their opinions heard by an authoritative organization (e.g., NHTSA). Future recruitment materials therefore should be specifically designed to highlight the uniqueness of these drivers and appeal to their status and ability to offer insights based on their experience with the systems. Mail-outs should be designed to increase the likelihood that individuals will open, read and respond to the letters (e.g., use of stick-on postage stamps, department logos, toll-free numbers, etc.). The relatively large number of invalid cases experienced during this pilot effort highlights the importance of recruitment and screening procedures and suggests that future survey efforts should conduct more aggressive screening and/or limit the use of Internet and magazine recruitment.

Systems were generally well received and liked by drivers. Most drivers felt comfortable using their system within the first few days of use with system trust and usage increasing over time. For example, ACC systems were perceived to be very useful and effective with a majority of drivers (85%) indicating they would recommend the system to a friend. Most drivers (84%) felt the system improves safety over conventional cruise control, and many (43%) indicated that the system reduces their likelihood of being involved in a crash. Although a majority of night vision system owners felt the system improves comfort and reduces stress, perceived usefulness and safety of the system was mixed and strongly related to experience with more frequent usage leading to higher perceived usefulness and safety. Many drivers were disappointed with the system's ability to display recognizable images and felt the system made it difficult to accurately judge distances to obstacles and objects. Nevertheless, the ability to recognize objects appeared to improve with experience.

Evidence also suggests that some form or degree of driver behavioral adaptation occurred for each of the systems examined. Some changes represented improvements (e.g., enhanced ability to detect obstacles at night or behind the vehicle, adoption of safer following distances, etc.) while others lead to potentially riskier driving practices (e.g., less reliance on vehicle mirrors while backing, longer glances away from the forward roadway, etc.). Some adaptations were more widespread than others, and experience with the system tended to moderate these behavioral changes to some degree. ACC system owners, for example, tend to use the system more frequently than conventional cruise control, tend to adopt the same or greater headways when using the system, and are likely to use the system under a wider range of environments (including heavy traffic). For most drivers, park aid systems serve as supplements or enhancements to their vision when parking and backing with no change to their reliance on direct glances/mirror use. However, evidence suggests that some drivers may come to over-rely on park aid systems effectively altering their behavior when parking and backing. Changes in driver scan patterns, particularly with camera-based systems, and over-reliance on the park aid system appear to be key concerns. About one in five users reported a decreased reliance on the vehicle's mirrors and on direct glances while backing with the system. Use of camera-based systems also appeared to result in behavioral changes with 28% of drivers reporting that they rely on the in-dash display more so than the mirrors or direct glances (4% reported that they rely on the in-car display exclusively while backing).

The availability of night vision systems can be expected to increase willingness to drive at night for some drivers (about 33% of those in our sample), increase nighttime driving speed for a small percentage of drivers (about 14% of drivers in our sample), and is not likely to negatively affect mirror usage. The system also appears to enhance driver's ability to detect obstacles at night with one-third of drivers experiencing a situation in which the system helped them avoid hitting an object they otherwise might not have seen in time. The presence of a navigation system may increase the number and duration of glances away from the road for some drivers (particularly younger drivers who tend to rely on the visual display), and increase willingness to drive in unfamiliar areas for some drivers.

Many drivers held misconceptions about the performance capabilities of their advanced systems, and in many cases, experience with the system over time does not appear to alter these misconceptions. For example, nearly all ACC system owners did not know that the system ignores stopped vehicles. Similarly, 41% of park aid system owners did not know that the system warning is tied solely on the distance to objects and does not take into account their closing speed. This suggests that drivers' mental models of how these systems function and perform do not always match reality, and additional efforts are needed to increase driver understanding of how these systems operate. This is particularly important for safety-related misconceptions. The report also highlights various driver experience and age effects, and provides some recommendations for enhancing system interface designs. For example, ACC displays could be more effectively designed to communicate specific information items including distance and speed settings, and operational modes to drivers. Although the information collected is based on a limited sample of system owners and relies exclusively on driver self-reports, the data provide insights into how drivers view and use these systems, and how usage patterns are influenced by driver age and experience. Findings from these interviews can be used to guide future research and development efforts.

INTRODUCTION

Exploratory work was undertaken to study driver real world experiences associated with the use of advanced technologies currently available in production automobiles (e.g., Adaptive Cruise Control, night vision, park aid, and navigation systems). The effort involved identifying and interviewing so called "early technology adopters" (owners of recently introduced in-vehicle technologies) in order to provide insights into driver acceptance and adaptation to these types of systems. Early adopters of advanced technologies represent a unique population of users and can play a key role in determining the success of systems in the marketplace, serving to gauge consumer demand for advanced in-vehicle technologies as well as guide their design (e.g., interface aspects and features). Manufacturers can respond to feedback from early adopters to enhance performance and improve their product designs. If systems are not embraced or accepted when they are first introduced, they may not succeed or penetrate fully into the market. In addition, information gathered from early adopters can provide an indication of the safety benefits or problems that new technologies may bring when they are more fully deployed in the commercial and passenger vehicle fleet.

Drivers have been shown to change their driving behavior as a result of perceived changes in the risk of driving brought about by the introduction of a new safety system, or experience. This type of change in behavior has been called "behavioral adaptation" and refers to the response of drivers to the introduction of a new technology (including in-vehicle telematics systems), or change in the roadway system. Assessing driver behavioral adaptation spans both driver attitudes as well as behaviors and involves examining how drivers feel about and come to understand the performance capabilities and utility of in-vehicle devices, as well as how these systems impact driving style and performance (both initially and after extended use and experience). The changes in behavior can be positive, negative or neutral in terms of their effect on safety. Furthermore, different adaptations can occur in the short and long term. In the short term, drivers may respond to the novelty of the device but in the long term may find it annoying and thus ignore it or turn it off. All of these behaviors play a role in the real world effectiveness of newly introduced technologies.

While behavioral adaptation is not a new phenomenon, the introduction of advanced and sometimes complex in-vehicle systems (e.g., Adaptive Cruise Control, night vision, park aid, navigation) may significantly increase the opportunity for adaptations through widespread use and penetration into the vehicle fleet. NHTSA is interested in both the potential safety benefits and possible safety problems that these in-vehicle technologies may afford drivers as well as how system designs affect driver performance. Advanced in-vehicle technologies may supplement drivers' limited sensory and information processing capabilities and thus, enhance their abilities to detect and respond to critical driving situations. Night vision systems, for example, may substantially improve a driver's ability to detect and respond to in-path obstacles, and reduce the stress sometimes associated with nighttime driving. Park aid systems can significantly reduce backing and parking related crashes by alerting drivers to the presence of an obstacle or guiding their low speed maneuvers. Opportunities also exist for negative adaptations to occur through misunderstanding, misuse, over-reliance on the system, or changes in attention and distraction from the driving task (interactions with the device or display, or other non-driving tasks). ACC systems, for example, are designed to ignore stopped or slow moving vehicles in order to limit the frequency of false alarms. Failure to understand this fundamental operational characteristic could lead to rear-end crashes or delays in responding to a stopped lead vehicle. Assessing drivers' mental model of how systems operate, the control/display interface features that determine ease of operation, and even the driver's overall acceptance of in-vehicle devices is an important part of understanding driver behavioral adaptation to in-vehicle telematics devices. Since many of these systems represent new and unique devices, ensuring that drivers understand how the system operates and functions (their mental model) is an important factor in evaluating these systems

The insights obtained as part of this effort are expected to help shape future research, including obtaining more objective measures of behavioral adaptation collected through vehicle instrumentation studies. Understanding how drivers modify their behavior resulting from the use of these types of systems can lead to improved designs and educational programs to ensure that drivers understand device functions, capabilities and limitations. A key question is whether the technologies have a positive or negative impact on driver safety. While ongoing field operational tests can provide useful insights into these types of safety and operational issues, additional data from a broader range of fleets, drivers and geographic areas can supplement those tests and provide more reliable data based on long-term use. This particular study gathered information from a range of system users, characterizing their real world experiences and interactions with several types of advanced in-vehicle technologies. The sample included drivers with a range of system experience levels which allowed trends in behavior and system use to be identified and characterized over time.

Objectives & Scope

This research effort served two distinct purposes. First as an opportunity to collect data, based on real world system experience and use, intended to assess driver acceptance and adaptation to advanced technology currently available in production automobiles. Secondly as a feasibility study intended to determine successful methods and approaches for identifying and contacting system owners and obtaining the necessary information from them. The primary emphasis was on identifying and developing effective protocols, data collection instruments and methods to capture this information which could be successfully used in future large-scale and representative data collection efforts. Thus, although the current effort included a substantial data collection effort (useful in assessing each targeted technology in terms of such parameters as acceptability, usability, and reported influence on safety-related driving behavior), its primary role was as a feasibility study to lay the foundation for larger and more representative data collection efforts.

Four types of commercially available in-vehicle systems were targeted: Adaptive Cruise Control, night vision, parking/backup aids, and navigation and route guidance systems. These represent emerging systems that are currently in production; some have been available for several years (e.g., navigation and night vision) while others are newly introduced (e.g., ACC and park aid). In all cases widespread penetration into the light vehicle fleet has not occurred, and studying driver interaction with these systems can provide meaningful and useful information. Moreover, many systems within a class vary in their interface designs providing an opportunity to understand how different implementations impact driver experience, use and understanding. The specific research objectives undertaken as part of this work included:

- Providing insights into the potential safety impacts of advanced in-vehicle technologies (both safety benefits and potential safety concerns). Includes the initial and long-term impact these technologies are having on driver behavior.
- Exploring how acceptance and use of the technology is influenced by system interface characteristics, operation, and performance.
- Identifying driver/system interaction problems and potential safety issues that need to be addressed in future research using more objective measurement methodologies.
- Determining the implications of the findings for assessing the benefits of the technologies, possible countermeasures for any problems identified (including human factors guidelines and standards), and research needs.
- Assessing the relative effectiveness of the various methods that can be used to address the above issues.

Project tasks included documenting available in-vehicle devices (Task 1), examining self-report methods and approaches for collecting user experience data (Task 2), developing and implementing data collection instruments and analyzing the data (Task 3), and developing a plan to empirically measure driver interactions with advanced vehicle systems (Task 4). This report documents the activities associated with both Task 1 and Task 2. The section entitled, "In-Vehicle System Inventory" provides a detailed inventory of adaptive cruise control (ACC), park aid, night vision, and navigation systems. The inventory was restricted to the U.S. light vehicle market as of the 2004 model year. Information gathered as part of this task was intended to document and describe interface aspects and features for the various products, including system displays and controls, as well as the intended functional range and operating environments of the system. The section entitled, "Survey Development and Administration" addresses the development and administration of the survey to a sample of system users and presents the survey results.

IN-VEHICLE SYSTEM INVENTORY

This section provides a detailed inventory of adaptive cruise control (ACC), park aid, night vision, and navigation systems available in the U.S. light vehicle market as of the 2004 model year. Interface aspects and features for the various products inventoried are also detailed, including system displays and controls, as well as the intended functional range and operating environments of the system. Information on individual systems was largely gathered from available documentation (e.g., vehicle owner's manuals, and automotive reviews and articles). Safety and usability related items were emphasized in the review as were system capabilities and limitations. The information captured during the inventory was used to help guide questionnaire items (and/or dimensions to explore), and provided a basis for interpreting any observed differences in driver behavioral adaptation and acceptance.

Overview of Available Systems

As shown in Figure 1, among the systems explored, in-vehicle navigation and route guidance systems are the most prevalent factory-installed technology currently available to U.S. consumers; over 90 vehicle models offer this feature. Park aid systems, designed to assist drivers in executing backing and parking maneuvers, are also emerging as a popular feature currently being offered in 44 2004 model year vehicles. Adaptive Cruise Control (ACC) systems are relatively new introductions into the U.S. market and are offered in a limited number of vehicle models; these tend to be higher-end luxury vehicles. Only two manufactures have introduced night vision systems, both are offered as optional equipment.

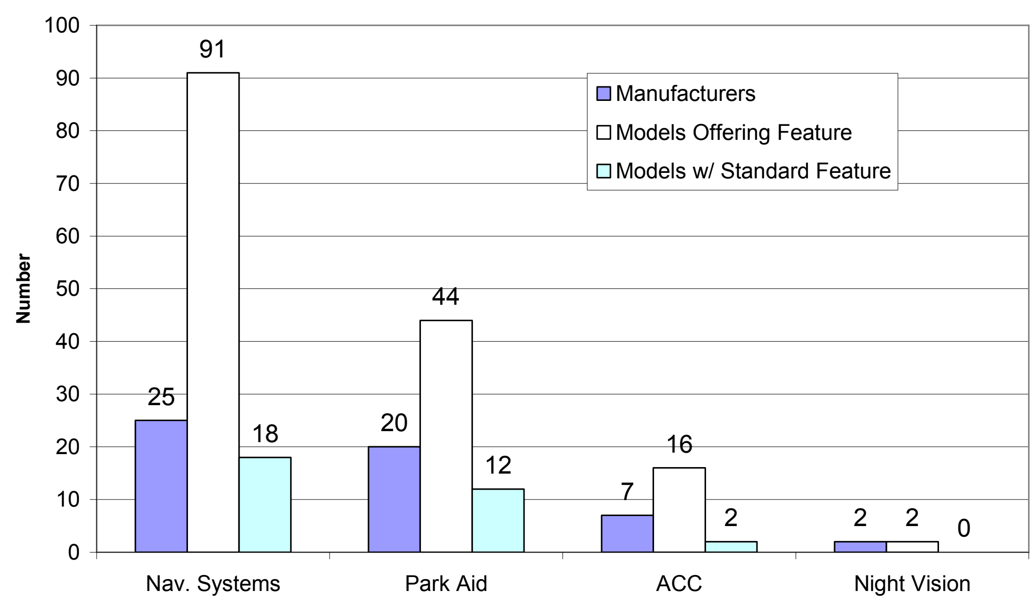

Figure 1. Availability of Navigation, Park Aid, Adaptive Cruise Control, and Night Vision Systems in the U.S. Market

Adaptive Cruise Control Systems

At the time of this review (April, 2004), there were seven manufactures (vehicle makes), and 16 different models, offering Adaptive Cruise Control (ACC) Systems in the U.S. market. Only two vehicle models offer ACC as a standard feature (Cadillac XLR and Toyota Sienna XLE Limited); all others offer ACC as an option (Refer to Figure 2). Mercedes-Benz provides the most extensive line-up, offering ACC as an option on seven different vehicle model lines. Until recently, the market for ACC equipped vehicles in the U.S. has been limited to luxury car brand sedans and convertibles (e.g., BMW, Lexus, Cadillac, Mercedes-Benz, etc.). The recent introduction of ACC on Toyota's Sienna (a minivan), is one notable exception. Table 1, lists the availability of ACC equipped passenger vehicles in the U.S. by vehicle make, model, year.

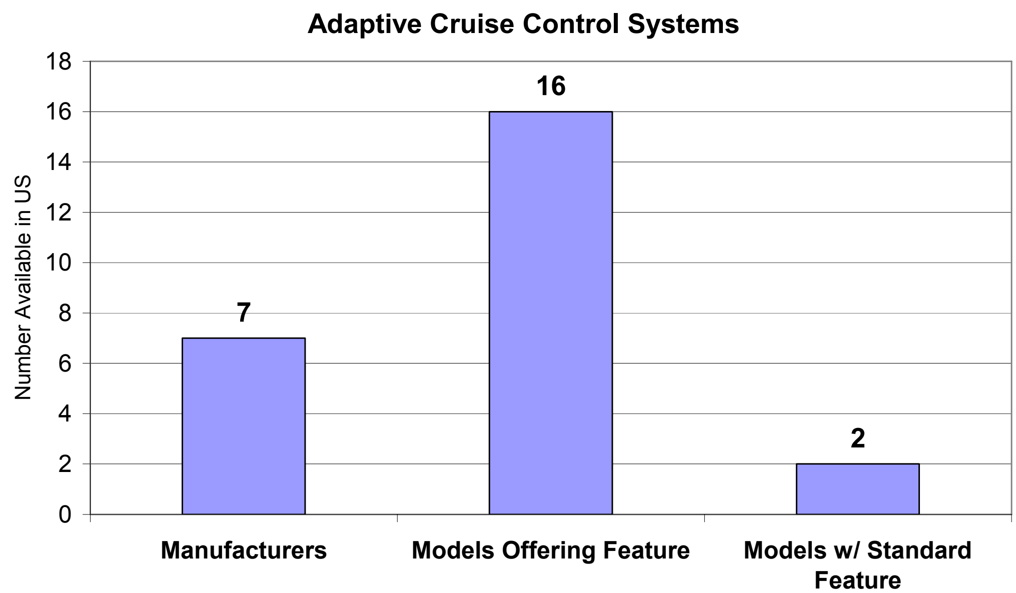

Figure 2. Availability of Adaptive Cruise Control Equipped Vehicles in the United States

Table 1. List of ACC Equipped Vehicles By Make, Model and Year

Vehicle Make	Vehicle Model	Model Year	Option/Standard	Marketed As
BMW	7 Series	2001	Optional	Active Cruise Control
BMW	5 Series	2003	Optional	Active Cruise Control
Cadillac	XLR	2004	Standard	Adaptive Cruise Control
Infiniti	Q45	2000	Optional	Intelligent Cruise Control
Infiniti	FX	2004	Optional	Intelligent Cruise Control
Jaguar	XKR	2003	Optional	Adaptive Cruise Control
Lexus	LS 430	2000	Optional	Dynamic Cruise Control
Lexus	RX	2004	Optional	Dynamic Laser Cruise Control
Mercedes-Benz	SL	2000	Optional	Distronic Adaptive Cruise Control
Mercedes-Benz	CL		Optional	Distronic Adaptive Cruise Control
Mercedes-Benz	S-Class	2001	Optional	Distronic Adaptive Cruise Control
Mercedes-Benz	CLK-320	2003	Optional	Distronic Adaptive Cruise Control
Mercedes-Benz	CLK-500 Coupes		Optional	Distronic Adaptive Cruise Control
Mercedes-Benz	E320 Sedans		Optional	Distronic Adaptive Cruise Control
Mercedes-Benz	E500 Sedans		Optional	Distronic Adaptive Cruise Control
Toyota	Sienna (XLE Limited)	2004	Standard	Dynamic Laser Cruise Control

Manufacturers market these systems under different names, including Adaptive Cruise Control, Active Cruise Control, Intelligent Cruise Control, Dynamic Cruise Control, and Distronic. Despite their different naming conventions, the ACC systems sampled here are functionally very similar. They operate at or above 25 mph, and automatically disengage and warn the driver when the speed falls below the minimum operating speed. Controls and displays allow drivers to input and view set speed and distance settings, and disengage the system using alternate methods including a brake tap. All systems provide a vehicle detected signal or icon, and have some type of approach warning (using both audible and visual cues) to indicate when driver intervention is required. As discussed later, work conducted by ISO and SAE technical standards committees appears to have contributed to the "standardization" of key system functions and interface characteristics. Nevertheless, some aspects are not necessarily uniform across systems. For example, systems appear to vary with regard to the location and placement of the controls and displays, maximum deceleration authority, range and levels of headway settings (the minimum headway settings appears to be at or above 1.0 second), use of warning symbols and sounds, and integration with conventional cruise control. Some systems provide unique features such as the ability to lock-out access to the ACC system when the windshield wipers are operating, and provisions for warning drivers of forward obstacles even when the ACC system is disengaged. One system (equipped on the Cadillac XLR) automatically reduces the vehicle's speed in tight curves (irregardless of whether a lead vehicle is present).

Owner's manuals tended to provide perhaps too many warnings and cautionary information items; the concern is that important information will get lost or buried within the vast array of warnings. This practice may discourage drivers from reading the manual, or may make it difficult for users to quickly access and extract important information. For example, one critical characteristic of most ACC systems is that these systems do not react to stationary or slow moving vehicles. Drivers must be alerted to this characteristic. While all manuals included this information, it was often included within larger segments of text within a warnings box making it less conspicuous.

<u>BMW Active Cruise Control</u>

BMW offers an optional Active Cruise Control system on their 5 and 7 Series vehicles. The radar-based system provides four different headway settings, with stalk-mounted controls for activating and setting headway distances. The system operates at speeds between 25-110 mph and automatically disengages when the vehicle's speed falls below 20 mph (drivers are notified of the disengagement via a gong sound and message in the Check Control). A graphic display, located within the speedometer, provides system status and operational information including the set speed and distance settings (see Figure 3). The system issues an alert to drivers when the braking capacity has been reached and intervention by the driver is required. This is communicated by both an audible and visual warning (the vehicle icon flashes and a chime sounds). The vehicle icon graphic illuminates when the radar has detected a forward vehicle, providing an indication to drivers that the system has captured a target (if no vehicle is detected, the graphic icon shown in the display appears as an outline). The system also automatically activates the vehicle's brake lamps when decelerating as an added safety feature. The manual includes approximately 7 pages dedicated to the system, but includes surprisingly little technical detail about the ACC system's capabilities (e.g., specific headway setting values, maximum braking authority, sensor detection range, etc.). Numerous warnings and system limitations are provided in the manual, including: notifications that the system is not intended as a collision warning device; situations when the system will deactivate or lose targets, conditions under which to avoid use, as well as the systems inability to detect slow or stopped vehicles or decrease the vehicle's speed under large differences in speed. As with conventional cruise control, the ACC system can be deactivated by applying pressure to the brake pedal.

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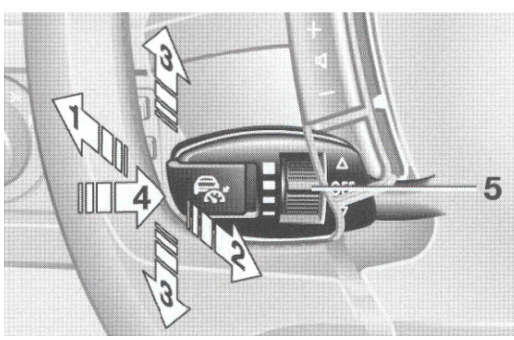
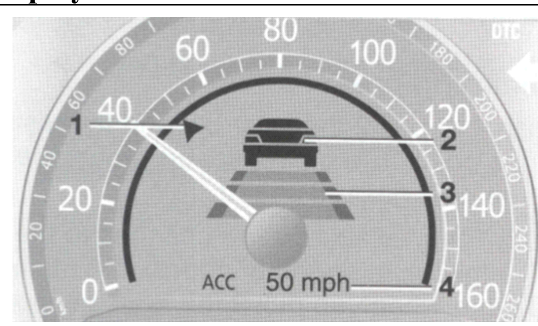
<tr><td>
</td><td>
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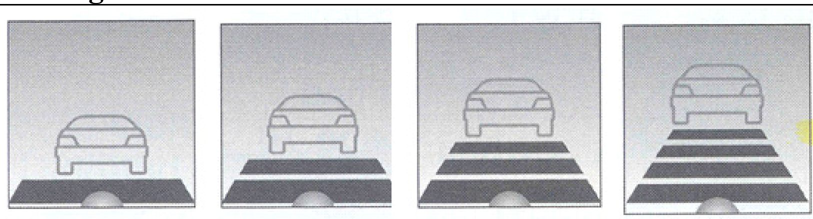
<tr><td colspan="2"></td></tr>
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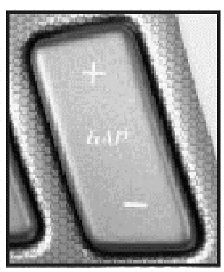
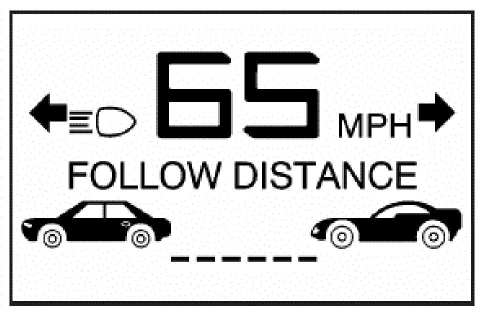
Figure 3. BMW Active Cruise Control Interface Elements

Cadillac Adaptive Cruise Control

Cadillac's Adaptive Cruise Control system is only offered on the XLR model (comes standard). According to GM, approximately 1,731 XLR's were produced in calendar year 2003; 875 were sold as of December 2003. The radar-based system operates at speeds above 25 mph, has a detection range of 328 feet, and is capable of applying 0.3 g's (2.95m/sec2) of braking force. Controls for activating the system and setting a speed are located on a multifunction stalk-mounted control, while a separate steering wheel-mounted control allows drivers to select one of six discrete distance settings ranging from 1 to 2 second headways (see Figure 4). A Head-Up Display (HUD) provides information on system status and operational settings, including set speed. Since much of the ACC system information is communicated via the HUD, the HUD must be on and properly adjusted in order for drivers to receive the information (the manual cautions drivers to ensure the HUD is on and adjusted, otherwise they may forget the set speed or miss critical information). Following distance is displayed using a graphic depicting two vehicles which move closer or farther apart based on the selected following distance. A variety of icons are also presented on the HUD in addition to the main graphic display. For example, drivers are notified that the ACC system has been activated by a graphic symbol (uses the ISO symbol). A "Vehicle Ahead" symbol depicting a car silhouette is displayed on the HUD to notify the driver that a lead vehicle has been detected by the system. Finally, an alert symbol is displayed when driver interaction is required (the symbol will flash and a warning beep sounds). This may occur under a range of conditions such as when the ACC system cannot apply sufficient braking, or the vehicle speed drops below 20 mph (in which case the system will automatically deactivate).

Cadillac XLR Controls	**Display**
 	
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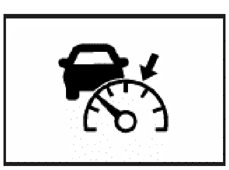
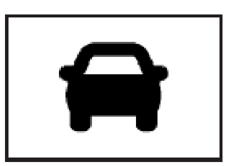
  	

Figure 4. Cadillac XLR Adaptive Cruise Control Interface Elements

Incidentally, the alert symbol used by this system is one of the symbols developed under the Crash Avoidance Metrics Partnership (CAMP) program, and considered for use as a forward collision warning icon. In this application, it is used to communicate a need for driver intervention for the ACC system (the owners manual indicates the ACC system is “not a safety system”).

The manual devotes approximately 13 pages to describing ACC system functions, controls, displays, and system limitations and capabilities. Eleven separate cautionary warning boxes are included in the ACC section of the manual. Cautionary statements warn drivers of system limitations and operating characteristics, including: system’s inability to respond to stopped (or slow moving) vehicles, pedestrians or animals; and the potential loss of targets in curves and low visibility conditions (rain, snow, fog). The manual also graphically presents several driving scenarios illustrating ACC system performance capabilities and limitations. This is currently the only system (of those reviewed) that uses a Head-up display. The system activates the vehicle’s brake lamps when ACC braking is applied. The ACC system automatically reduces the vehicle’s speed in tight curves (irregardless of whether a lead vehicle is present); a “tight curve” message is displayed on the HUD to notify drivers.

Infiniti Intelligent Cruise Control

Infiniti offers their Intelligent Cruise Control system as an optional feature on two of their models, the Q45 and FX. The system was introduced first in the Q45 2000 model year, and is now available in the 2004 model year FX (both of the reviewed systems are for the 2004 model year vehicles). Although functionally similar, there are some system interface differences across the two models (see Figure 5). Nevertheless, both systems use lasers to detect objects with a range of 390 feet, operate at speeds between 25 and approximately 90 mph, and can provide up to 25% of the vehicles braking authority. The system automatically disengages when the vehicle speed falls below 20 mph (a warning buzzer sounds to indicate this to the driver). The system also issues various warnings to drivers under conditions requiring driver intervention or action. These warnings normally include a warning buzzer and various visual indicators, the configuration of which are used to communicate the particular type of problem (it may be difficult for drivers to quickly distinguish and interpret the various types of warning conditions). Both systems include steering wheel-mounted controls for activating the system, setting cruise speed, and following distances. Three discrete following distances are offered corresponding to short, middle and long headways. There is some variation in the time headway values between the two models. The Q45 uses time headways of 1.19, 1.70, and 2.21 seconds, while the FX uses headway values corresponding to 1.02, 1.47, and 2.21 seconds. The system defaults to the long headway value each time the vehicle is started.

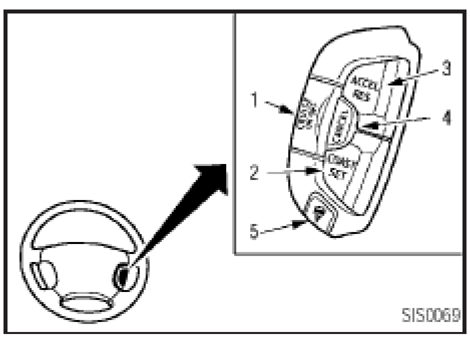
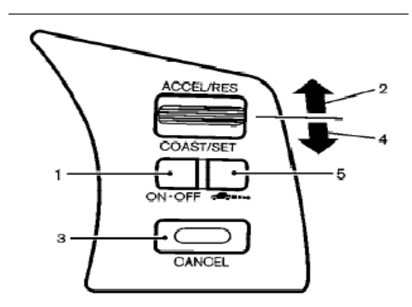
Infiniti Q45 (2004) Controls	**Infiniti FX (2004) Controls**
	

Figure 5. Infinity Intelligent Cruise Control System Controls

Both models provide an in-dash (instrument panel) display to present system information, including set speed and distance settings using graphics. Both the Q45 and the FX displays provide functionally similar information (a vehicle detection indicator, set distance indicator, host vehicle indicator, a set speed, a system on/off indicator, and an ICC warning light). However, the specific graphics used to communicate this information and its format differs across the two models. The Q45 uses a car icon (viewed from the rear) to denote the presence of a vehicle and series of distance bars located below the car icon to indicate set headway or following distance (the largest and closest bar includes an indicator to denote the host vehicle). The resulting graphical display provides an orientation which is consistent with the true underlying spatial relationship between the host car and the lead vehicle (see Figure 6). The FX also uses a car icon, but it depicts a profile view of the entire vehicle to denote a lead vehicle detected. A series of distance bars are also provided, but they are located to the right of the car icon (an indicator located to the right of the bars is used to represent the host vehicle). Unlike the Q45, this display format does not preserve the underlying spatial relationships between the host vehicle and lead vehicle (it requires some mental rotation of the image). The set speed indicator (item #1 in the figure below) blinks when the vehicle speed exceeds the set speed.

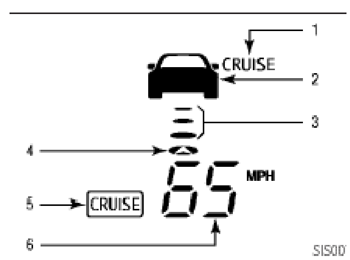
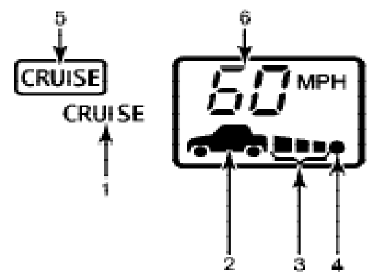
Infiniti Q45 (2004) Display	**Infiniti FX (2004) Display**
	

Figure 6. Infinity Intelligent Cruise Control System Displays

Two relatively unique system features are designed into the Infiniti ICC system. First, the FX integrates conventional cruise along with the more capable Intelligent Cruise Control system. Drivers can select which system (or cruise mode) is activated based on how they press the ON/OFF switch. Depressing the switch quickly activates the ICC, while pushing and holding the switch for longer than 1.5 seconds activates the convention cruise control system. The display provides as indication of which system is activated (the graphic portion of the display with set speed, following distance and car icon are not presented under conventional cruise control). Further, once a cruise control mode (either conventional or ICC) is selected, it cannot be changed unless the driver turns off the system. Secondly, the ICC system in both vehicles automatically disengages (or is locked-out) when the windshield wipers are set to the high intermittent, low, or high setting effectively preventing ACC use during rainy or some inclement weather conditions. Another safety feature common to both models, and seen in other ACC systems, is the illumination of the vehicle's brake lamps whenever the ICC system performs braking (the brake pedal also automatically depresses). The Q45 manual devotes approximately 15 pages to the ICC system, and the FX 19 pages to the ICC system. Both include numerous warning and cautionary messages to drivers. They include notification that the system is an aid and not a collision warning system; intended for straight, dry open roads with light traffic; system will not automatically stop the vehicle; and system may not detect the vehicle ahead under certain conditions (bad weather, sharp curves, strong direct light in front of the vehicle, etc.). Both manuals also provide graphic illustrations of road and traffic situations where system performance may be degraded or reduced.

Jaguar Adaptive Cruise Control

The Jaguar XK's radar-based Adaptive Cruise Control system operates at speeds between 20 and 110 mph; the system automatically deactivates at speeds below 18 mph. Six steering-wheel mounted controls allow drivers to set time gap (using a rocker switch for increasing or decreasing following distance to one of four discrete settings), speed, resume set speed, and cancel to temporarily turn off the ACC without erasing system memory. An in-dash multifunction display message center is used to provide system status information including gap setting (when in follow mode), and set speed (when in cruise mode). A warning light (dummy light) on the instrument cluster illuminates when a lead vehicle has been detected and the system enters into "follow mode." The system warns drivers when manual intervention is required (e.g., ACC predicts maximum braking level will not be sufficient); an audible warning sounds, a red warning light illuminates, and the message "DRIVER INTERVENTION" is displayed in the message center. The displays and message center are located on the lower portion of the speedometer. A unique system feature is the forward alert which warns drivers of objects ahead (through audible and visual signals only, no braking) even when the ACC system is not engaged. Drivers can adjust the sensitivity of the forward alert using the ACC gap setting controls, and can turn the feature on or off using a switch located on the lower left of the steering column (on the lower outboard knee bolster).
The ACC also system uses a master warning approach to highlight priority messages presented on the driver message center (using separate red and amber lights). The manual devotes 6 pages to the ACC system and is laid out with noticeably fewer warning than many other owners' manuals; however, it does caution drivers against use when entering/existing freeways, and warns drivers that the system is not a collision warning system and will not detect stationary or slow moving vehicles, pedestrians, or oncoming vehicles.

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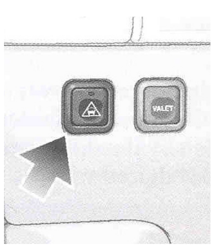

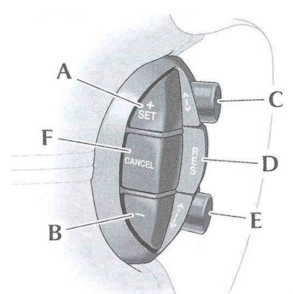

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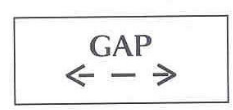

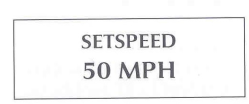

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Jaguar 2004 XK Adaptive Cruise Control System Controls and Displays

Lexus Dynamic Laser Cruise Control

Lexus offers two vehicles equipped with an optional Dynamic Laser Cruise Control system, the LS 430 and the RX. This write-up addresses the LS 430 system, although both are likely functionally similar. The laser-based system operates at speeds between 28-85 mph, and has a detection range of 400 feet. The system automatically disengages if the vehicle's speed falls below 25 mph (the driver is altered via a warning tone). The system also disengages (or prevents activation) and notifies the driver when the windshield wipers are operated at low/high speed. The manual also overviews other situations in which the system will automatically disengage (e.g., antilock system engages, sensor malfunction, etc.). Stalk-mounted system controls allow drivers to activate the system and input the desired cruise speed. Steering wheel controls are used to set following distance (see Figure 7). The system features an integrated conventional cruise control mode, as well as Adaptive Cruise Control. Drivers can select either conventional or dynamic laser cruise control by using the stalk-mounted control lever (pressing the main switch at the end of the lever engages the dynamic laser cruise; moving the lever towards the dash for longer than 1 second after pressing the main switch changes modes to the conventional cruise). The display provides an indication of which operating mode has been selected (conventional or dynamic laser cruise, the display area is blank under conventional cruise). Once the dynamic laser cruise has been activated and used, drivers cannot change into conventional cruise mode without first turning off the system; this guards against accidental changes in mode.

<table>
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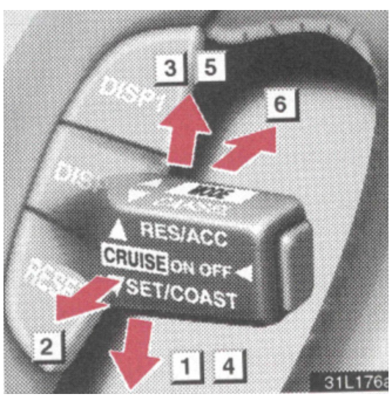
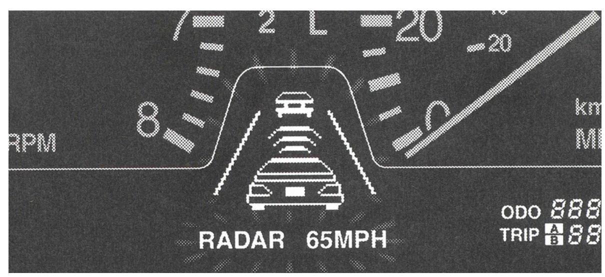
<tr><td>
</td><td>
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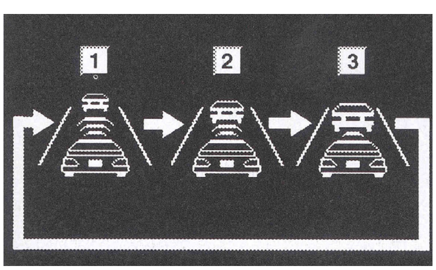
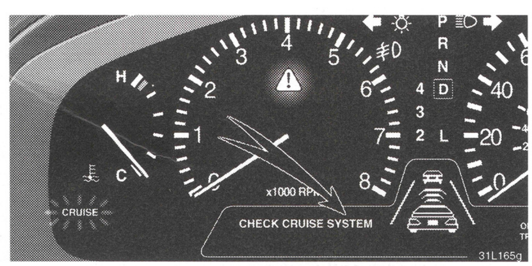
<tr><th>Headway Setting Indicators</th><th>Warning Indicators/Messages</th></tr>
<tr><td>
</td><td>
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Figure 7. Lexus LS 430 Dynamic Laser Cruise Control System Interface Elements

Drivers can select one of three discrete distance settings corresponding to 1.24, 2.04, and 3.03 second headways using the steering wheel mounted buttons. The system defaults to the longest distance setting (3.03 sec) whenever the dynamic laser cruise system is first activated. A multi-information display on the instrument panel presents set speed, detected vehicle, following distance, and various text messages regarding system status. The graphic display contains icons depicting the host vehicle as well as any detected lead vehicles, and preserves the spatial relationship through its vertical orientation. Whenever the system brakes to slow the vehicle, the vehicle's rear brake/stop lamps are illuminated; the brake lights of the icon representation of the host vehicle pictured in the display also illuminates as an additional cue to the driver that braking is occurring. A variety of audible and visual warnings are provided by the system. An approach warning, alerts drivers to situations where intervention (manual braking by the driver) is required (e.g., vehicle ahead decelerates rapidly causing inadequate braking). Under these conditions, the multi-informational display flashes and beeps. This feature is only active when the dynamic laser cruse control system is on (no alerts are provided if conventional cruise is active, or if the cruise system is off). If there is a system failure while the system is operating, the cruise indicator light on the instrument panel flashes, a master warning light illuminates, and a warning tone sounds. In addition, a text message is presented detailing the nature of the problem (e.g., clean radar, check cruise system, etc.).

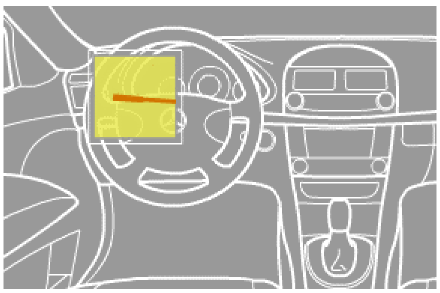
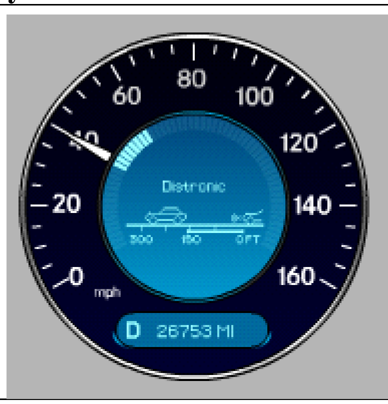
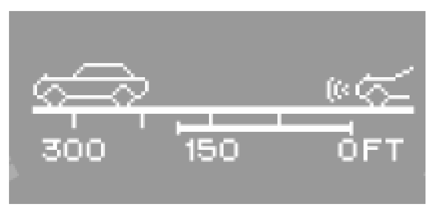
The manual devotes approximately 19 pages to the dynamic laser cruise control system; a DVD is also available but it only briefly describes the system and is more of a marketing tool. Most pages in the manual contain some form of warning or cautionary statement referencing system capabilities and limitations. Drivers are cautioned against using the system on freeway on/off ramps, bad weather, heavy traffic, roads with sharp curves, on slippery road surfaces, and hilling roads. Drivers are cautioned to "pay special attention" to slow or stopped vehicles, and that under certain conditions (e.g., cut-ins with drastic speed differences) the system "will neither warn you nor decelerate." Many situations are graphically illustrated in the manual.

Mercedes-Benz Distronic

Mercedes-Benz has perhaps the most extensive line of ACC equipped vehicles in the U.S., offering Distronic in seven different vehicle models, including the SL, CL, S-Class, CLK-320, CLK-500 Coupes, E320 Sedans, and E500 Sedans. Their website provides a very good overview and demonstration of the Distronic system with interactive capabilities (Access the demo at www.mbusa.com, use the search feature to find Distronic adaptive cruise control feature spotlight). The radar-based system operates at speeds between 25-110 mph, has a range of 300 feet, and is capable of providing up to 20% of the vehicle's braking power (maximum of 6.5ft/sec2, or 2m/sec2). The brake pedal also automatically depresses, when activate braking is being performed by the system. Drivers can activate the system and program the set cruising speed using conventional steering column mounted controls. Advanced controls for setting following distance and turning on/off a distance warning function (discussed later) are located on the lower section of the center console, next to the shift lever. A thumbwheel is used to increase or decrease the distance setting, varying headway from between 1-2 seconds. Each end of the thumbwheel is labeled with an icon; moving the wheel forward decreases headway, while moving the wheel towards the back increases headway.

A multi-functional display, located in the Instrument Panel (inset within the speedometer), is used to provide system status information (see Figure 8). The speedometer presents both the set or desired speed programmed into the Distronic system, and the actual vehicle speed. The driver's set speed is displayed for about 5 seconds when the system is activated (or when a new set speed is entered); lighted segments on the speedometer continuously indicate the set speed. Lighted segments inset within the speedometer show the difference between the set speed and the vehicle's current actual speed. The multi-functional display graphically illustrates both the desired headway (set following distance) and actual distance from lead vehicles. The graphic display uses car icons to represent detected lead vehicles as well as the host vehicle (both using car profiles); the display is horizontally oriented. If the system detects a situation in which a collision with a lead vehicle is likely (e.g., system is incapable of slowing the vehicle sufficiently and driver intervention is required), a warning is issued. The warning consists of an intermittent warning sound and illumination of a red warning lamp (located in the instrument cluster); the warning terminates when the "necessary distance to the vehicle ahead is again established," or when the driver depresses the brake pedal. This distance warning function is operational even if the Distronic system is deactivated, notifying the driver of collision threats resulting from stationary objects or slower moving vehicles. An over-ride switch is provided (located on the lower section of the center console) which allows drivers to turn-off the distance warning function. Drivers can assess the status of the distance warning function by an icon (loudspeaker symbol) located on the multi-functional display (the icon is illuminated when the system is active); the indicator lamp on the switch itself also illuminates when the distance warning function is on. The system can be deactivated by applying pressure to the brake pedal. If the vehicle speed falls below 25 mph, the system automatically disengages and notifies the driver (signal sounds and the message "Distronic Off" is presented for 5 seconds on the multi-function display).

The owner's manual devotes approximately 12 pages to the Distronic system, and includes a variety of warnings and special informational items (15 specific warning notices/boxes, and 8 helpful hints segments). Drivers are advised that the system is intended as a convenience system; that it should not be used in fog, heavy rain, snow or sleet; and that the system can be dangerous on winding roads or heavy traffic. Warnings that the system does not react to stationary objects is referenced repeatedly throughout the manual. Problem driving scenarios (e.g., turns and bends, offset driving, lane changing, etc.) are graphically illustrated in the manual to help drivers understand system performance capabilities and limitations.

Controls	
	 
Display	
	
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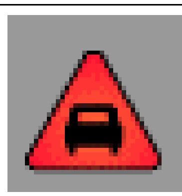
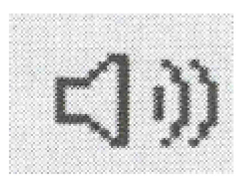
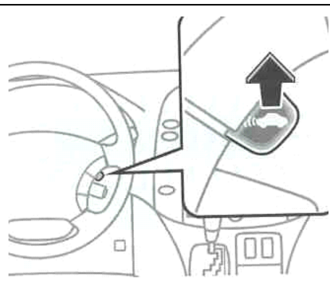
	

Figure 8. Mercedes-Benz Distronic System Interface Elements

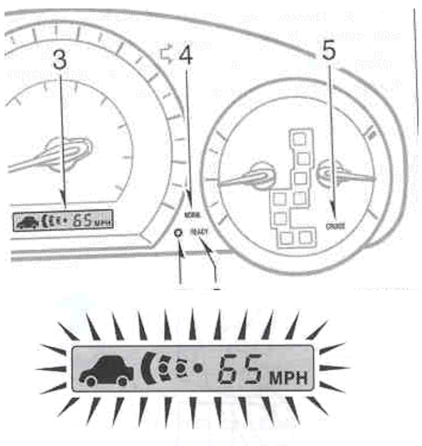
Toyota Sienna

Currently, the Toyota Sienna is the only minivan offering Adaptive Cruise Control in the U.S. market; moreover, the system comes as standard equipment in the 2004 XLE Limited model. As with its more expensive counterpart produced by Toyota, the Lexus LS 430, the Sienna's Dynamic Laser Cruise Control system uses laser-radar to detect objects out to a range of 400 ft., operates between speeds of 28 to 85 mph, offers drivers three discrete distance settings, and integrates conventional cruise control along with Adaptive Cruise Control. Like the Lexus LS 430, the system also prohibits use when the windshield wipers are operated on low or high settings (if the cruise control is engaged, the system automatically cancels when wipers are set to these positions). System controls are located on the steering wheel and on a conventional stalk off the steering column (see Figure 9). The multi-axis, stalk-mounted control is used to input most system functions, including turning on/off the system, setting a cruising speed, and selecting the operational mode – either adaptive cruise control ("vehicle-to-vehicle distance control") or conventional ("fixed speed") mode. Drivers use the steering-wheel mounted distance switch to select one of three following distances (long, middle, and short), corresponding to headways of approximately 3.03, 2.04, and 1.23 seconds. The graphic display, located on the lower portion of the speedometer, represents these following distances (in addition to set speed) using bars and a car icon. Unlike the Lexus, the graphic display used to depict following distance is oriented horizontally.

Pressing the On/Off button automatically activates the system in its advanced vehicle-to-vehicle distance control mode; an additional step is required to change to the conventional "fixed speed" mode (the lever must be pushed in the mode direction for longer than 1 second). Visual display indicators and elements are used to inform drivers about which mode has been selected. When ACC is engaged (vehicle-to-vehicle distance control mode), the graphic display, presents a vehicle icon, distance bars, and set speed. Only set speed is presented when operating in convention cruise mode. In addition, a dedicated indicator light labeled, "NORM", is presented on the instrument cluster when operating in convention cruise mode. Once the ACC mode has been used, drivers cannot change to conventional cruise mode without first turning off the system. Drivers can, however, change from conventional cruise mode to ACC mode directly without turning off the cruise system (requires pushing the lever in the mode direction for longer than 1 second).

Controls	
	

Displays



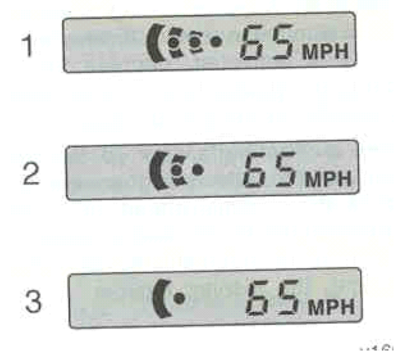


Figure 9. Toyota Sienna Dynamic Laser Cruise Control Interface Elements

When engaged, the system warns the driver (through an audible beep flashing display) when system braking is insufficient to handle the closing distance to the vehicle ahead, and manual braking by the driver is required. This approach warning is only active in vehicle-to-vehicle distance mode (does not function when using conventional cruise, or when the system if off). A master warning light is also used to indicate problems with the Dynamic Laser Cruise Control, as well as problems with other systems; warning codes are presented on a display to reference the specific problem. The manual dedicates 13 pages to the Dynamic Laser Cruise Control system and includes 10 specific dialog boxes providing cautionary information and statements. Drivers are warned, for example, that the system may not issue a warning, nor decelerate under certain conditions such as a stopped lead vehicle.

Compliance To Recommended Practices & Standards

Both the International Standards Organization (ISO) and the Society of Automotive Engineers (SAE) have been developing standards (or recommended practices) for the design of Adaptive Cruise Control systems in an effort to standardize important system functions. Both organizations provide specifications and guidance on driver interface issues and features in an effort to develop systems with consistent interface characteristics. Table 2 highlights key ACC interface design issues and compares/contrasts how these have been implemented for our sample of systems.

Table 2 Compliance With SAE J2399 Recommended Practice (SAE, 2003)

Interface Design Elements	SAE Recommended Practice	BMW	Cadillac	Infinity FX	Jaguar	Lexus	Mercedes-Benz	Toyota
Minimum Operating Speed	24.5 mph (11.2 m/s, +-10%)	25 mph	25 mph	25 mph	20 mph	28 mph	25 mph	28 mph
Minimum Headway (Following Distance)	1.00 sec.		1.00 sec.	1.02 sec.		1.24 sec.	1.00 sec.	1.23 sec.
Maximum Deceleration (in g's and m/s2)	0.306 g's (3.00)		0.3 g's (2.95)				0.20 g's (2.00)	
Illumination of Stop Lamps	Yes, deceleration greater than 0.7 m/sec2	YES	YES	YES	YES	YES		
Notification of Automatic Disengagement	Yes, under transition from automatic to manual control	YES	YES	YES	YES	YES	YES	YES
Brake Pedal Disengagement	Yes, includes brake taps.	YES	YES	YES	YES	YES	YES	YES
Time Gap Selection Indicator	At a minimum, display when system is activated or when selection changes.	YES	YES	YES	YES	YES	YES	YES
Set Speed Indicator	At a minimum, display when system is activated or when selection changes.	YES	YES	YES	YES	YES	YES	YES
Vehicle Detected Signal	Yes	YES	YES	YES	YES	YES	YES	YES
Warns System Ignores Stationary Vehicles	Inform at least in owner's manual (OM)	YES (OM)	YES (OM)	YES (OM)	YES (OM)	YES (OM)	YES (OM)	YES (OM)
Approach Warning	Not Specified	YES	YES	YES	YES	YES	YES	YES
Locks-Out in Rain	Not Specified			YES		YES		

Park Aid Systems

There are currently 20 manufactures (vehicle makes), and 44 different models offering Park Aid systems in the U.S. market; twelve vehicle models offer ACC as a standard feature (Refer to Figure 10). These systems are intended to help drivers avoid obstacles when executing low speed parking and backing maneuvers. Unlike ACC systems, Park Aid devices are being introduced across a wider range of vehicle classes including sport utility vehicles, minivans, pick-up trucks, as well as luxury car brand sedans. Table 3 lists the availability of Park Aid equipped passenger vehicles in the U.S. by vehicle make, model, year. These systems are being introduced under a variety of names, including Park Distance Control, Rear Parking Assist, Reverse Park Aid, Parktronic, and Reverse Sensing Warnings, among others. With the exception the Extended Rear Park Assist system (offered in the Lincoln Navigator and Towncar), available Park Aid systems are proximity-based aids providing coverage over the rear (and in some cases front) zones. They are intended to help drivers determine how close an object is to their bumper within a limited operating range and at low speeds. These proximity-based systems are not designed to function as back-up warning devices which are intended to warn drivers of the presence of unexpected or unseen objects behind their vehicles at relatively higher backing speeds. Some vehicles also offer a back-up camera with an in-vehicle monitor to provide drivers with an indirect view out the rear of the vehicle; camera systems are passive in sense that they do not directly alert the driver to the presence of an in-path obstacle.

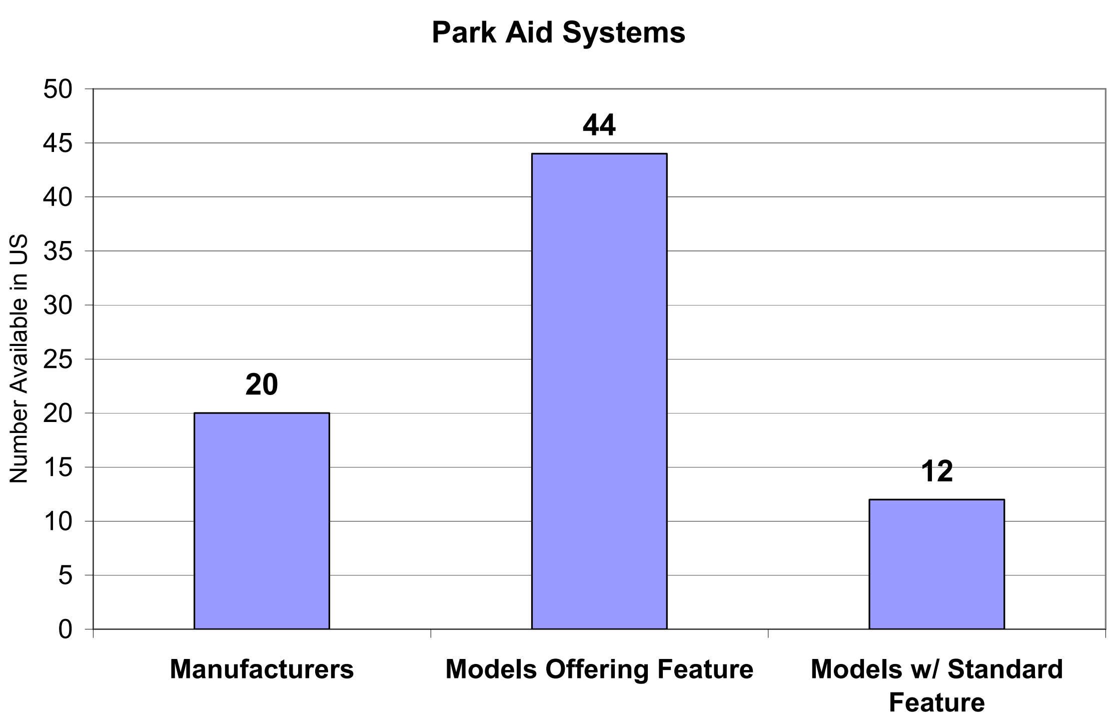


Figure 10. Availability of Park Aid Equipped Vehicles in the United States

Table 3. List of Park Aid Equipped Vehicles By Make, Model and Year

Vehicle Make	Vehicle Model	Model Year	Option/Standard	Marketed As
Acura	MDX	2004	Standard	
BMW	3 Series		Optional	Park Distance Control
BMW	5 Series		Optional	Park Distance Control
BMW	7 Series		Optional	Park Distance Control
Buick	Park Avenue	2001	Optional	Ultrasonic Rer Parking Assist
Buick	Rendezvous	2004	Optional	Ultrasonic Rer Parking Assist
Cadillac	Deville	2000	Optional	
Cadillac	Escalade (ESV & EXT)	2000	Optional	
Cadillac	Seville		Optional	
Cadillac	SRX		Optional	
Cadillac	XLR		Optional	
Chevrolet	Venture (LS and LT)	2001	Optional	
Ford	Escape (Limited)	2003	Optional	Reverse Park Aid
Ford	Excursion	2000	Optional	Reverse Park Aid
Ford	Expedition (XLT)	2000	Optional	Reverse Park Aid
Ford	Expedition (Eddie Bauer)	2000	Standard	Reverse Park Aid
Ford	F-150 Pickup (XLT, FX4, Lariat)	2004	Optional	Reverse Park Aid
Ford	Freestar	2004	Optional	Reverse Park Aid
Ford	Windstar (Limited)		Standard	Reverse Park Aid
Ford	Windstar (SE & SEL)		Optional	Reverse Park Aid
Honda	Pilot	2004	Optional	
Infiniti	FX			
Infiniti	Q45	2004	Optional	Rear View Monitor
Jaguar	S-Type	2001	Standard	Reverse Park Control
Jaguar	XKR		Optional	Reverse Park Control
Land Rover	Range Rover (HSE)	2004	Standard	Park Distance Control
Land Rover	Discovery (HSE)	2003	Standard	Park Distance Control
Lincoln	Aviator	2004	Standard	Reverse Sensing System
Lincoln	Navigator	2003	Optional	Extended Rear Park Assist
Lincoln	Towncar	2003	Optional	Extended Rear Park Assist
Lexus	LS 430 (Ultra Luxury package)		Standard	Inuitive Park Assist
Lexus	LX 470	2004	Standard	
Lexus	RX		???	
Mercedes-Benz	S600		Standard	Parktronic
Mercedes-Benz	S-Class		Optional	Parktronic
Mercedes-Benz	CL		Optional	Parktronic
Mercury	Mountaineer	2003	Optional	Reverse Sensing System
Nissan	Quest	2004	Optional	
Oldsmobile	Silhouette (GLS and Premier)		Standard	Rear Parking Aid
Pontiac	Montana		Optional	Rear Parking Assist
Saab	9 3		Optional	
Saab	9 5		Optional	
Toyota	Sienna (XLE Limited)	2004	Standard	
Volvo	XC90		Optional	Reverse Warning System

The sections that follow highlight interface and operating characteristics for a sample of eight Park Aid systems; the sample is intended to provide a representative range of systems. Appendix C provides a quick reference and summary of key interface aspects for the reviewed systems. Although many systems provide some form of visual display, the primary means of communicating distance information appears to be through audible signals to drivers. Of the eight system reviewed, all provide audible signals to indicate distance and five (62%) provide both audible and visual signals. The majority of audible signals take the form of tones or beeps which increase in frequency as the distance between the vehicle and the obstacle decreases; these become steady or continuous to indicate that the minimum distance has been achieved. No common threshold for this minimum distance (or final stage warning) appears to have emerged. For some systems, the "final stage" warning occurs when the distance to the object is 10 inches, others have set the final warning at 18 or 21 inches. Of the eight systems reviewed, six of them issue the final stage warning at or under 12 inches. For vehicles including both front and rear coverage, systems tended to provide visual displays to code direction and/or directionally code the auditory signals using the vehicle's speaker system. Staged alerts were a common warning approach. System operating ranges were somewhat variable, between 3 and 20 mph. Most systems (6 of 8) were intended to function at or below 6 mph - consistent with low-speed parking and backing situations. Most systems activate automatically and include a control or switch for manually turning off or overriding the system. Owner's manuals tended to caution drivers that systems were intended as aids when parking to avoid large obstacles and damage to the vehicle. Few, if any, effectively made the distinction between a park aid and a collision warning system.

Most available systems are proximity-based and designed to prevent backing into stationary obstacles, as opposed to pedestrians, children, and pets. A few manufacturers (Acura MDX, Honda Pilot, Infinity Q45, Lexus LS 430, Toyota Sienna, etc.) offer rear-view camera systems to allow drivers to more reliably detect unexpected and unseen obstacles such as children and pets while backing. Nevertheless, such systems are not themselves active warning systems, and require direct glances to an in-vehicle display which is often located outside of a driver's typical line of site when backing; rear images are usually displayed on existing multi-functional displays (located on the center console) used to provide navigation and other vehicle system information.

BMW Park Distance Control

BMW's Park Distance Control system (reviewed as part of the 2004 7-Series model) provides both front and rear coverage using sets of four ultrasonic sensors in both bumpers (see Figure 11). The front and two rear corner sensors have a range of approximately 2 ft., while the rear middle sensors have a range of approximately 5ft. The system is automatically activated when the car is placed into reverse gear, and is automatically deactivated once the vehicle travels approximately 165 ft., or speed exceeds 20 mph. A manual override is also provided allowing the driver to manually activate or deactivate the system. Audible signals are used to indicate the distance to the nearest obstacle; these signals are directionally coded using the vehicle speaker system. The frequency of the tones increase as the distance decreases; the signal tone becomes continuous when the nearest object less than 12 inches. Drivers can also configure the system to provide a graphic visual display showing direction and distances to objects. The visual display indicates the presence of objects in green before they are close enough to generate a signal tone. The manual cautions drivers that the system is intended as a parking aid, and to avoid approaching objects at high speeds since this may result in a warning that is issued too late.

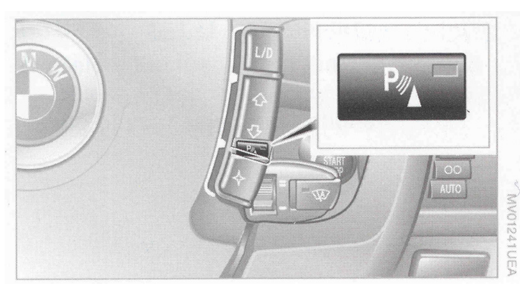
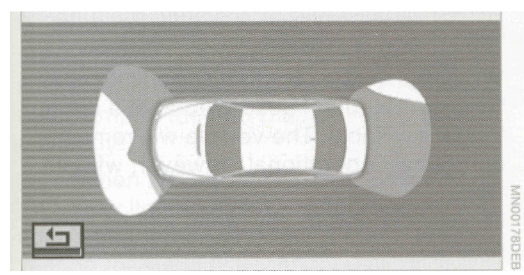
Controls (Manual Override Switch)	**Visual Display**
	

Figure 11. BMW Park Distance Control Interface Elements

Cadillac Ultrasonic Rear Parking Assist

The Ultrasonic Rear Parking Assist system (as equipped on the 2004 Cadillac XLR and DeVille) automatically engages when the shift lever is set to reverse and the vehicle is traveling under 3 mph. No manual override is provided. Four ultrasonic sensors located on the rear bumper, warn drivers of objects out to 5 ft. (the system can detect objects 3 inches and wider and at least 10 inches tall). The visual display, consisting of three LEDs, is located inside the vehicle, below the rear windows and can be viewed thru the rearview mirror, or directly over the shoulder (see Figure 12). A series of staged warnings are provided to the driver using audible tones and the visual display. When objects are detect at 5 ft, an initial alert is provided - a chime sounds and one amber light illuminates. At approximately 3 ft (40 inches), two amber lights on the display illuminate. At approximately 1.5 ft (20 inches) a continuous chime sounds and all three LEDS (two amber and one red) illuminate. The last stage is provided when the object is 1ft. away - the chime continues to sound and all three LEDS flash. The system does not operate at speeds above 3 mph; the display flashes red to denote an over speed condition. The manual cautions drivers that the system does not detect objects beyond 5 feet away, and to check carefully before backing up.

Visual Display

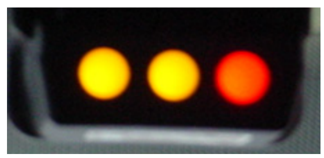


Figure 12. Cadillac Ultrasonic Rear Parking Assist Visual Display

<u>Ford Reverse Sensing System</u>

Ford's Reverse Sensing System (as equipped on the 2004 Windstar & Freestar) provides rear coverage (out to a range of approximately 6 ft.) while executing low-speed backing maneuvers using ultrasonic sensors located on the rear bumper of the vehicle. The system issues an audible tone when in reverse gear and an obstacle is detected. The rate of the tone increases as the distance between the vehicle and object decreases; the tone becomes steady when the obstacle is less than 10 inches from the rear bumper. A manual override control allows drivers to turn off the system; a visual indicator located on the control itself illuminates when the system is disabled (see Figure 13). The system defaults to an on position every time the reverse gear is selected. The owner's manual states that the Reverse Sensing System is not effective at speeds greater than 4 mph, and that the system "may not detect certain angular or moving objects." It also warns drivers that the system is intended to help prevent damage to the vehicle, and that it is not intended to prevent contact with small or moving objects, particularly those close to the ground. Ford's system also warns of a moving object approaching at 3mph or less, if the vehicle is in reverse gear but is not moving backwards.

Manual Override Control

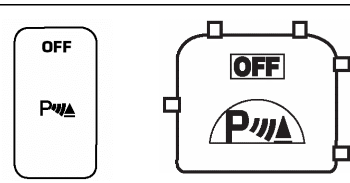


Figure 13. Ford's Reverse Sensing System Override Control

Lexus Park Assist

The Lexus Park Assist system (as equipped on the 2003 Lexus LS 430) provides both front and rear coverage zones to aid in parking maneuvers. A series of ultrasonic sensors located on the front and rear bumpers detect objects out to a distance of 3 ft (and up to 1.5 feet for objects located to the side corners of the bumpers). The system operates at speeds less than 6 mph when the shift lever is set to any setting other than "Park." Drivers must activate the system by pressing a main switch on the instrument console (see Figure 14). Location and distance to objects are communicated using both an audible signal and a visual display. A graphical visual display (presented on a multi-informational display located on the instrument cluster) uses indicators bars located on the front, rear, and corners of the vehicle to represent objects and their distance. The number of bars on the display areas indicate the distance to the obstacle; the bars start to disappear one-by-one as the distance between the vehicle and obstacle becomes smaller. Beeps are also presented and the beep interval becomes shorter as the distance to objects decreases. Four levels or stages of alerts are provided. The initial alert is presented when objects are approximately 1.5 to 3 ft. away (e.g., four indicator bars appear to the rear and beeps sound), and the final stage is presented when objects are about 10 inches (0.8 ft) away using a single flashing indicator bar and continuously sounding beeps. The volume of the beeps can be adjusted, and the beeps themselves can also be activated or deactivated (the steps for doing this are not included in the owner's manual). The system allows for multiple obstacles to be detected; if more than one obstacle is detected in the same direction, indicators for the nearest obstacle will be activated. The owners' manual does not indicate whether drivers can choose to blank-out the visual display and just rely on the audible cues. It does indicate that the park assist graphic display will appear in both the multi-informational display and the main display screen for vehicles equipped with navigation systems.

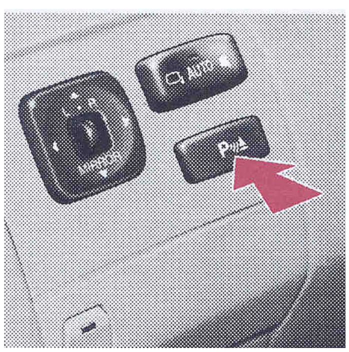
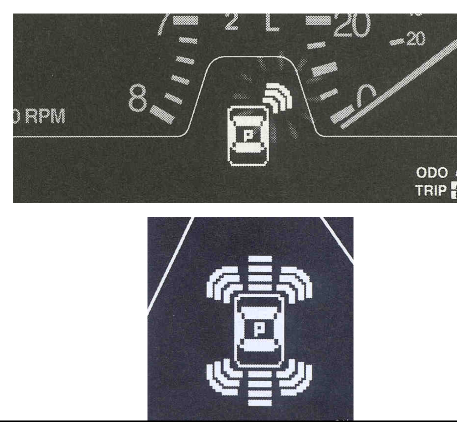
Controls	**Visual Display**
	

Figure 14. Lexus Park Assist Interface Elements

Lincoln Extended Rear Park Assist

Lincoln's Extended Rear Park Assist system (available on the 2004 Navigator and Towncar) is unique since it represents a hybrid using both radar and ultrasonic sensors to detect obstacles during backing maneuvers at speeds below 6mph (the system uses Delphi's Forewarn® Back-up Aid). Use of radar affords the system a longer detection range, and provides the opportunity to provide a warning to the driver that is based on vehicle approach speed and not simply proximity to the obstacle. The system operates much as Ford's Reverse Sensing system, providing audible tones which increase in rate with decreasing distance to the obstacle, and is engaged automatically when the vehicle is in reverse gear. However, the Lincoln system has a much greater detection range capable of detecting obstacles up to 20 ft behind the rear bumper. The system is unique in that it provides a warning to drivers when it detects high rates of closing distances requiring immediate braking by the driver. The waning consists of a "very high rate tone" which is distinct from the standard tone. The owner's manual indicates that if the warning tone is heard, "the driver is advised to slow down immediately until the tone either changes to a slower rate or stops." The system also automatically adjusts the radio volume when issuing alerts (this feature can be overridden by drivers), and provides the capability for drivers to disable the system using a control located on the message center. The system provides audible cues only, with no visual display.

Mercedes-Benz Parktronic

The Parktronic system (as reviewed for the 2004 S-Class) provides front and rear coverage using 12 ultrasonic sensors (6 in both the front and rear bumpers) to detect obstacles out to a range of 3.3 ft (forward) and 4ft (rearward); corner coverage ranges between 2 to 2.6 ft. The system automatically activates when the ignition is on and the parking brake is released, and deactivates at speeds above 11 mph. A manual override switch (located in the upper section of the center console) can be used to turn off/on the system - the system defaults to the on state each time the ignition is turned on and the parking brake is released (see Figure 15). Both audible and visual cues are used to communicate object location and distance. Three visual warning indicators (displays) are used: two for forward objects (one located above the left air vents, and the other in the dashboard above the center air vent); the third visual display provides coverage for the rear area and is integrated in the rear trim (owner's manual does not specific exact location). The position of the gear selector determines which warning indicators are activated (Drive activates the front area only, Reverse or Neutral activates front and rear areas). Visual displays provide graded warnings using 8 color-coded segments (6 yellow and 2 red). As the distance to objects decreases, segments in the visual display illuminate; the final stage of the warning (signifying the minimum distance between the vehicle and object has been reached) is achieved when the last red segment illuminates. An acoustical warning is also provided during the last two stages of the visual display: an intermitted sound is issued when the first red segment is illuminated, and a constant warning sound is issued when the last red segment is illuminated. Both audible warnings are presented for a maximum of 3 seconds. The owners manual devotes 5 pages to the system, and includes several warnings cautionary statements such as the need to pay special attention to objects above or below the height of the sensors, and that the distance to objects will not be indicated by the system once the minimum distance has been achieved (the minimum distance for the center front and rear sensors is 8 inches). An animated demonstration of the system is provided on the Mercedes-Benz website, www.mbusa.com, use the search feature to find Parktronic feature spotlight).

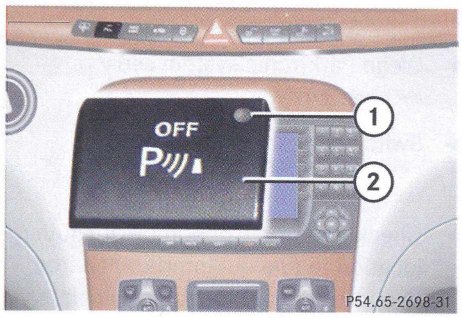
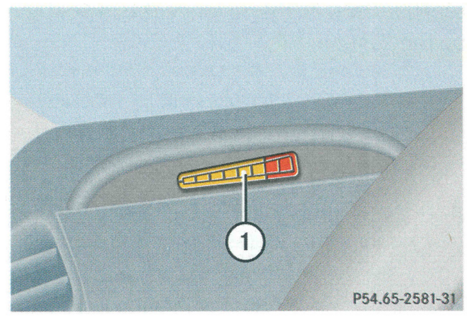
Controls	Visual Display
	

Figure 15. Mercedes-Benz Parktronic Interface Elements

Nissan Rear Sonar System

Nissan's Rear Sonar system (as equipped in the 2004 Quest) detects obstacles up to 6ft from the vehicle's rear bumper, and operates at speeds at or below 3 mph. The system automatically activates when the ignition is on and the gear selector is set to reverse. A manual override switch allows drivers to turn the system off (an indicator light on the switch illuminates when the system is turned off). The system uses an audible tone to signal distance to objects; the rate of the tone increases as the distance to objects decreases. The tone becomes steady when the object is less than 10 inches away (25 cm). If the system detects a stationary or receding object further than 10 inches from the side of the vehicle, the tone will only sound for 3 seconds.

Toyota Park Assist

The Toyota Park Assist system (as reviewed for the 2004 Sienna) uses sonar technology to provide front corner and rear sensor coverage out to approximately 6ft (rear), and 2 ft (forward corners); limited rear corner coverage is also provided. Unlike other dual coverage systems, the Toyota Park Assist system does not provide front forward sensors (just front corners). Some models/configurations are also only equipped with rear sensor coverage (no front corner coverage). The system operates at or below 6mph, and works when the ignition is on and the vehicle is set to any position other than Park. A switch, illustrated in Figure 16, is used to turn the system on and off (the manual does not make it clear whether the system automatically activates or if the driver must first manually turn on the system). Distance to objects are provided through an indicator and auditory signal (buzzer) which is coded based on distance to the object. The owner's manual does not provide detail on the how the visual indicator functions. Coverage areas are presented in table form for the various zones (rear sensors, rear corner sensors, and front corner sensors). For the rear sensors, an intermittent buzzer means that the detected obstacle is approximately 3-6 ft away; a fast intermittent buzzer indicates that the object is approximately 2-3 ft away; and a continuous buzzer means that the object is 1.8 ft. or less away.

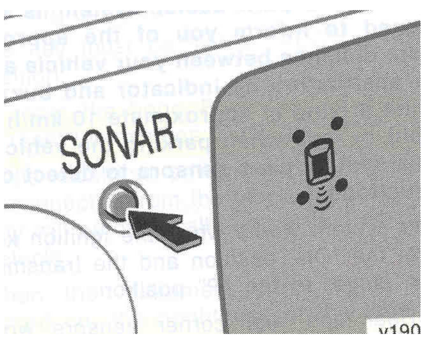
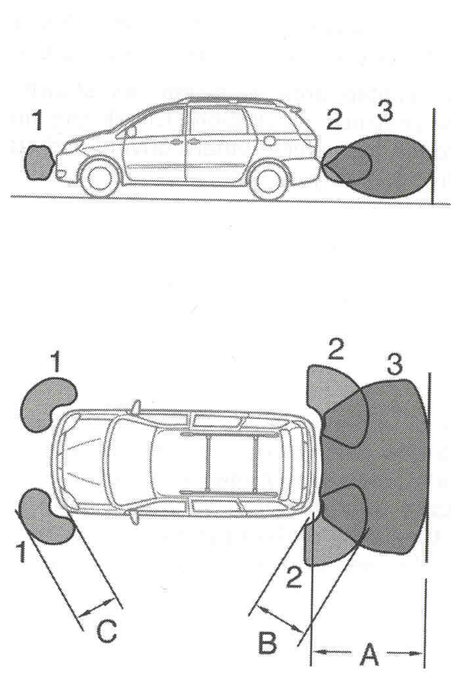
Controls	Coverage Areas
	

Figure 16. Toyota Park Assist Interface Elements

Night Vision Systems

There are currently only two light vehicle manufactures (Cadillac and Lexus), and two vehicle models offering night vision (both as an optional feature) – the Cadillac Deville and the Lexus LX470. As shown in Table 4, two other manufacturers may introduce their version of night vision in future product rollouts. Both the Cadillac and Lexus systems rely on a projected Head-Up Display image.

Table 4. List of Night Vision System Equipped Vehicles By Make, Model and Year

Vehicle Make	Vehicle Model	Model Year	Option/Standard	Marketed As
Cadillac	Deville (DHS & DTS)	2000	Optional	Cadillac Night Vision
Hummer	H2 SUT (Concept)			
Lexus	LX 470	2004	Optional	Lexus Night View
Volvo	Cross Country XC90			

<u>Cadillac Night Vision</u>

Cadillac's Night Vision system is intended as an aid to allow drivers to see beyond the range of their headlamps at night (see Figure 17). The system, the first of its kind introduced into the light vehicle consumer market, is offered as an option on the Cadillac Deville DHS and DTS models. Two controls (located to the left and below of the steering wheel) allow drivers to adjust the brightness and location of the displayed image which is projected onto a Head-Up Display. The image brightness control also doubles as an on/off switch. The displayed image appears to "float" just above the car's hood, and provides black-and-white images. The system relies on heat sensing with warmer objects such as moving cars, animals and pedestrians appearing whiter relative to the darker background of cooler objects (signs, parked vehicles, etc.). The system must be manually engaged by the driver, requiring the image brightness switch to be set to any position other than Off. The system only works when the headlamps and ignition are both on and it is dark enough outside.

The owner's manual devotes over 3 pages to the system, and outlines procedures for adjusting system parameters as well as its proper use. For example, drivers are instructed not to stare at the image, but to occasionally glance at the display while driving; to keep the image dim and low in the driver's field of view (adjust the location of the display so that it is as low as possible while still remaining visible); and to not rely on the projected image as a replacement for the normal view of the roadway ahead. Drivers are also warned that the system cannot sense brake lights, turn signals, traffic lights or signs, as well as other cooler objects; and that images may not be clearly visible under severe weather conditions. In addition to the owner's manual, General Motors also provides a customer education video which provides an overview of the system, instructions for operating the night vision system, and usage information. Research conducted by GM found that driver knowledge of the night vision system was significantly improved with the use of a supplemental educational video (in addition to the owner's manual) compared to the information provided in the owner's manual alone (Geisler and Kiefer, 2004).

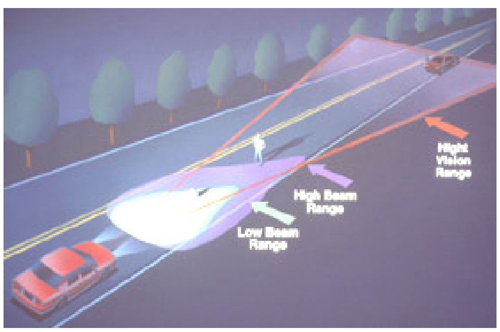
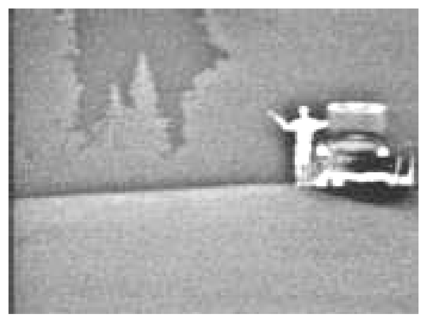
Controls	**Visual Display**
	
	

Figure 17. Cadillac Night Vision System Interface Characteristics

Lexus Night View

The Lexus Night View System (an option on the LX) uses near-infrared camera technology to enhance nighttime driving visibility by projecting images (of objects out to 500 feet ahead of the vehicle) on a Head-Up Display (HUD). The HUD is located on the lower portion of the windshield within the driver's field of view, and projects a black and white image across a 5x3 inch viewing area. A single integrated control is used to turn on the system and adjust the brightness level of the display (no control is provided to adjust the relative position of the displayed image). The system is activated when the main switch is turned on (with the headlamps on and in a dark setting). Indicator lamps on the control illuminate when the system is activated, and when the vehicle is moving. Relatively little operational information detailing how to use the system and interpret images is contained in the owner's manual. The owner's manual cautions drivers against setting the display too bright since the glare might interfere with their ability to see through the windshield. Drivers are also instructed to avoid use under various environments and conditions, including sever weather (rain, fog, snow), and curvy or hilly roadways. System limitations, including the in ability to detect road signs are outlined in the manual.

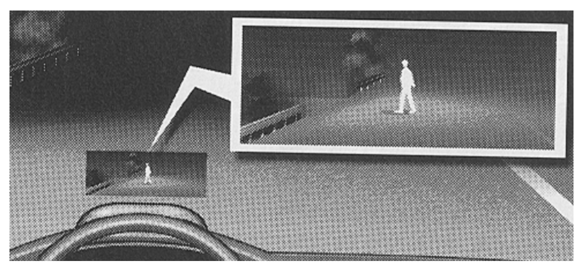
Controls	**Visual Display**
	

Table 5. Summary of Night Vision System Interface & Operating Characteristics

	Cadillac DeVille (2004)	Lexus LX 470 (2003)
System Name	Night Vision System	Lexus Night View System
Display Type	Head-Up Display (HUD); display has 16 shades of gray	Head Up Display shows a Monochrome image on the bottom of the windshield.
Control Location	Controls for turning on/off system and adjusting HUD image located below the steering wheel.	Controls for turning on the system on/off and adjusting image brightness located on the left under the steering wheel.
System Status Display & Location	HUD located on drivers side of IP, next to the windshield.	HUD located at the bottom portion of the windshield ahead of the driver.
Warning Modes	N/A	N/A
Warning Levels (staged, imminent)	N/A	N/A
Sensor Coverage (forward, rear, both)		
Operating Speed		
Type Sensor	Infra-Red	Near-Infrared floodlight
Sensor Detection Range		
Manual Override		
Number Pages in Manual	3	3
Warnings in Manual	Do not stare at HUD images (glance occasioanlly at display just as a mirror). Images may be unusable in severe weather conditions. Does not sense all objects.	Should be used as supplemental aid only, for use in flat area with few curves in the dark, do not stare at the near infrared floodlight (night view projector) for extended time or you eyes could be injured. If image in HUD is too bright, driver may not be able to clearly see the surroundings through the windshield.
System Defaults	Driver must turn on system. Only available when IP brightness knob is not set to off, sufficiently dark outside, headlamps on, ignition on.	HUD automatically is engaged when night system is turned on. Works if the ignition is on the system is on, it is dark outside, and the headlights are on. You can adjust the brightness.
Notes		The near infra red floodlight is located near the fog lights, the camera is located at the top of the windshield and the head up display is located at the bottom of the windshield. If IR lamp blows out, dummy light on dash illuminates, "night view"

Navigation & Route Guidance Systems

Navigation systems are becoming increasingly more widespread in the U.S., with over 90 2004 vehicle models offering some form of in-vehicle routing and navigation system (see Figure 18); an increase of over 25% compared to 2002 when 72 models offered on-board systems. Although many luxury class vehicles come standard with a navigation system, these systems are being offered in a wide range of vehicle classes including SUV's and minivans. Routing functions are also being integrated within larger driver information systems (radio, CD player, HVAC, etc.), and the use of voice recognition technology is becoming more common as a means to interact with and control system functions. Although the prevalence of navigation system currently outpaces all of the other surveyed technologies, consumer demand for ACC, night vision, and park aid systems is reportedly slightly higher (J.D. Power, 2000), suggesting that other types of safety and convenience systems will become increasingly more prevalent in the near future. Table 6 presents a limited list of speech-based navigation system equipped passenger vehicles in the U.S. by vehicle make, model, and year.

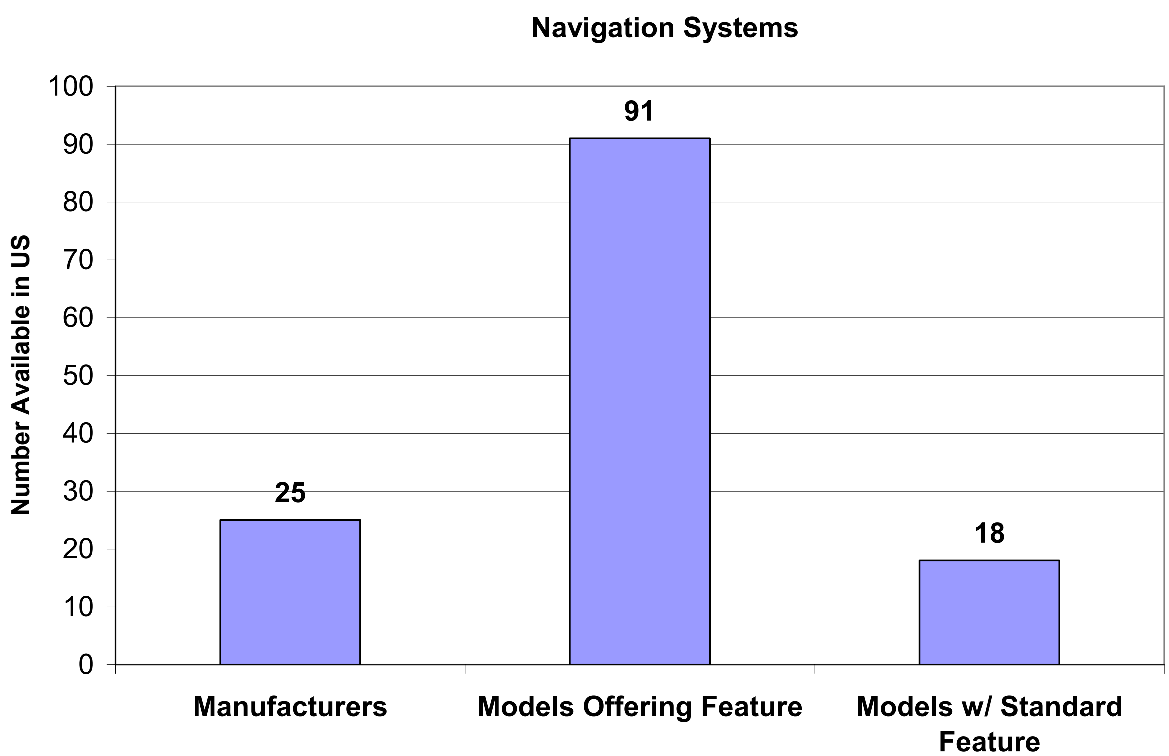


Figure 18. Navigation System Availability in the United States

Since the number of available navigation systems is quite large, this section merely highlights basic system features and designs presented and discussed in an earlier NHTSA report

(Llaneras and Singer, 2002). Systems with speech recognition capabilities, and those with new or unique designs are highlighted as well.

Table 6. Select List Of Speech-Based Navigation System Equipped Vehicles

Vehicle Make	Vehicle Model	Model Year	Option/Standard
Acura	RL	2004	Standard
Acura	TSX & MDX	2004	Optional
Austin Martin	Vanquish, DB9, DB7		Optional
BMW	7 Series	2000	Standard
BMW	X5 SUV	2000	Standard
Cadillac	Deville		Optional
Cadillac	Seville		Optional
Cadillac	SRX		Optional
Cadillac	ESV		Optional
Cadillac	EXT		Optional
Cadillac	Escalade		Optional
Cadillac	XLR		Standard
Honda	Accord (EX)	2002	Optional
Honda	Odyssey (EX)		Optional
Honda	Pilot (EX)	2003	Optional
Jaguar	X-Type	2000	Optional
Jaguar	S-Type	2000	Optional
Jaguar	XJ		Optional
Jaguar	XK		Optional
Lexus	LS, LX and GX		Optional
Lincoln	Aviator		Optional
Lincoln	Navigator		Optional
Lincoln	LS (V-6 Premium)		Optional
Lincoln	V8 Sport & Premium Sport		Optional
Mercedes-Benz	S-Class		Optional
Mercedes-Benz			Optional
Toyota	Land Cruiser	2003	Optional
Toyota	Avalon (XLS)	2003	Optional
Toyota	Camry (XE, XLE)	2003	Optional
Toyota	Solara SLE	2003	Optional
Toyota	Matrix XRS	2003	Optional
Toyota	Prius	2003	Optional
Toyota	4 Runner (limited)		Optional
Toyota	Highlander (limited)		Optional
Toyota	Sienna (XLE)		Optional

Navigation System Displays & Location

All of the available factory installed systems include some form of visual display which drivers use to program destinations, view maps, receive systems status information, access visual-based routing and guidance information, and perform other navigation related tasks. Most navigation systems rely on three primary guidance display screens to communicate navigation information to drivers: (1) maps, (2) maneuver lists with sequenced turn directions, and (3) turn-by-turn guidance displays which generally “pop-up” in advance of a turn. The vast majority of systems tend to locate visual displays in the center stack area of the instrument panel where conventional radio and HVAC controls are typically found. Retractable displays (visible only when the system is in operation) are also becoming increasingly common; these configurations tend to locate the display closer to the driver’s line of sight, yet limit distraction when the system is not in operation. Most all systems allow the display (and the navigation system itself) to be easily viewed and operated by a front seat passenger. The Chrysler Pacifica is an exception, and is the only system currently available to embed the visual display within the instrument cluster itself. Figure 19 shows the 4.2 inch color visual display for the Pacifica which is integrated under the speedometer. This unique design is intended to allow the driver to easily glance to the display (as well as limit glare); it unfortunately also makes the system difficult for passengers to use since the view of the display is limited (as is access to the controls which are located to the right just under the cluster brow).

Figure 19. 2004 Chrysler Pacifica In-Dash Navigation System

System Operation & Satisfaction

Navigation systems incorporate a relatively large number of features and options for configuring displayed information and executing tasks. A variety of methods exist for programming a destination into a navigation system, and most systems tend to support at least 5 different methods, with street address, point of interest, and address book entry methods among the most prevalent. Some systems allow destinations to be programmed using a phone number, and even speech commands using voice recognition software. The vocabulary (or number of commands) recognized by the system varies by system. The 2004 Acura RL system can recognize 130 voice commands, while the BMW Voice recognition system is limited to 30 words. In many cases, the voice command system is activated by a button press and can be used to interact with systems other than navigation including, the radio, CD player, and telephone.

Many, but not all navigation systems restrict or lockout complex tasks (i.e., destination entry) when the vehicle is moving. All systems warn the driver against attempting to interact with the device while driving. Nevertheless, many systems do incorporate features that may minimize glance times to displays (and eyes-off-road time) and manage information flow such as limiting the number of available menu options or rows of items on a display, and use of auditory outputs for routing information and system feedback.

Navigation systems supplied by Denso and Alpine (suppliers of advanced technology) have been consistently ranked among the highest in customer satisfaction based in system performance and system design (J.D. Power, 2002 & 2003). Recent J.D. Power surveys, conducted over the past two years (with a combined sample of over 12,000 owners) have found the following:

- Top-ranked systems tend to provide large, high resolution displays; DVD-based map databases; and voice recognition technology.
- Few drivers (less than 3 percent) believe the system creates a dangerous driving situation.
- Some drivers agree entering a destination into the system while driving can be distracting. However, the majority of owners (particularly young drivers) with lock-outs preventing a destination to be entered while driving do not like the feature.
- Over 50% of new vehicle owners use the system at least once or twice a week. Drivers ages 16-23 use the system most.
- Systems are frequently used to find a residence/business or routes to unfamiliar locations; estimate travel time; locating points of interest (restaurants, hotels, ATM's, gasoline stations, etc.).

Table 7 highlights some of the top and bottom (above/below the industry average) ranked systems according to the 2003 J.D. Power customer satisfaction survey.

Table 7. Top/Bottom Owner Ranked Navigation Systems Based on J.D. Power 2003 Survey of 7,026 Owners

Top Ten (best listed first)		Bottom Ten (worst listed first)
1. Acura TSX (Alpine) 2. Honda Accord (Alpine) 3. Lexus GX-470 (Denso) 4. Infiniti FX (Xanavi) 5. Acura MDX (Denso) 6. Lexus GS Series (Denso) 7. Toyota Sienna (Denso) 8. Lexus RX Series (Denso) 9. Lexus SC 430 (Denso) 10. Lexus LX 470 (Denso)		1. Audi A6 (Bosch) 2. Land Rover Discovery (Harman) 3. Olds Aurora (Delphi) 4. BMW 7-Series (VDO/Siemens) 5. Audi A4 (Bosch) 6. Mercedes SL- Class (Bosch) 7. Cadillac Escalade (Delphi) 8. Mercedes S- Class (Bosch) 9. Porsche Cayenne (Harman) 10. Toyota Avalon (Denso)

SURVEY DEVELOPMENT & ADMINISTRATION

This section details the survey development process, recruitment methods, administration, and results of the survey. Although this task explored a variety of approaches for collecting user experience data (including focus groups), the primary activity focused on the development (and later administration and analysis) of a telephone-based survey instrument intended to gather data on driver acceptance and behavioral adaptation.

Survey Instrument

The survey was intended to gather driver real-world system experiences useful in assessing driver behavioral adaptation (changes in behavior over time), as well as driver acceptance (ease-of-use, effectiveness, desirability, etc.) associated with four in-vehicle devices (Adaptive Cruise Control, Night Vision, Park Aid, and Navigation). Each of the system surveys followed a parallel structure, with questions anchored to several important dimensions, including: system usage; perceived system effectiveness and acceptance; knowledge of system functions, capabilities and limitations; safety and behavioral impacts; and interface characteristics. Questions within each of these general categories were tailored for each specific system. Table 8 details the number of questions (overall and within each category) for each of the four in-vehicle systems. Tables 9-12 list the specific questions developed and administered for each item class across systems. The majority of the items were forced-choice questions (yes/no, multiple choice, and ratings) with a few open-ended questions to capture unique insights and experiences related to the system. The overall survey instrument included additional items delivered as part of an up-front screener used to collect/verify information regarding vehicle make/model/year and to help screen and provide background information on eligible survey participants. The survey was designed to be administered over the phone in less than 30 minutes. Westat's Telephone Research Center staff managed the survey administration process; this included refining the instrument to ensure that the survey could be administered within 30 minutes, and developing an electronic database and coding scheme for the items.

Table 8 Number of Survey Items Across Key Dimensions (Information Categories) By In-Vehicle System

	Adaptive Cruise Control	Night Vision	Park Aid	Navigation
Background	4	3	3	3
System Usage	6	6	7	7
Effectiveness & Acceptance	11	11	10	9
System Knowledge & Learning	11	10	9	9
Safety & Behavioral Impact	15	14	11	13
Interface	6	2	6	8
Total Items	53	46	46	49

Table 9 Adaptive Cruise Control (ACC) System Question Structure: Key Dimensions and Associated Items

Background	200. Did you specifically ask for this option? 201. Please rate how the ACC system influenced your decision to buy this vehicle. 225. Do you have the option of using conventional cruise control without ACC? 218. Do you view ACC as a safety feature, or as a comfort and convenience feature?
System Usage	205. How often did you tend to use the system when you first bought the vehicle? 206. How has your use of the ACC changed over time since you first bought the vehicle? 207/208. Why has system usage increased/decreased? 209. How many times per week do you typically use the ACC system currently? 236. Under what conditions are you likely to turn off the ACC system?
Effectiveness & Acceptance	203. Describe your attitude toward buying your next vehicle with an ACC system. 204. Would you recommend this system to a friend? 215A. Rate your current impression of the usefulness of the system. 215D. Rate your current impression of the system's ability to work under a range of operating conditions. 217A. How effective is the ACC system in relieving you of the stress associated with driving? 217B. How effective is the ACC system in detecting and following vehicles in your lane ahead, including motorcycles? 217C. How effective is the ACC system in operating in a wide range of conditions? 217D. How effective is the ACC system in alerting you to the presence of slow moving or stopped vehicles? 217E. How effective is the ACC system in minimizing unnecessary alarms? 217F. How effective is the ACC system in minimizing the extent to which the system slows your vehicle by applying the brakes inappropriately? 237. Has the ACC system lived up to your expectations?
System Knowledge & Learning	202. Thinking about your owner's manual, have you read … 210. How long did it take you to feel comfortable using the ACC system? 211. How did you learn about the system functions, capabilities, and limitations? 212. Was the ACC system generally easy to learn how to use? 213. Were any features of the ACC system particularly difficult to learn how to use? 214. What features were particularly difficult to learn to use? 215C. Rate your current impression of the ease of use of the system. 223. If you encountered a stopped car in your lane ahead with the ACC system engaged, how do you think the system would react? 224. How would you rate your ability to learn when you need to take control and apply the brakes or steer? 227. Does the ACC system warn or alert you if you get too close to the vehicle ahead and need to intervene by applying the brakes? 228. Is the warning only active when the ACC is in use, or is the warning active even when the system is off?
Safety & Behavioral Impacts	215B. Rate your current impression of the safety impacts of the system. 216A. Has the ACC system changed your frequency of use of cruise control? 216B. Has your level of trust in the system changed over time? 216C. Has the ACC system changed your ability to predict and respond to road hazards? 216D. Has the ACC system changed your typical following distance? 216E. Has the ACC system changed your frequency of lane changes? 216F. Has the ACC system changed your ability likelihood of being involve in a crash? 219. Do you think the ACC system improves safety over conventional cruise control?

	220. Has the ACC system reacted in unusual or unexpected ways? 221. How often have you encountered situations where the ACC system brakes abruptly or hard causing the vehicle behind you to get uncomfortably close, or to brake hard? 222. Have you ever been "rear-ended" by another vehicle while using the ACC system? 226. To what extent have you been confused about which system is operating? (For system with both conventional cruise and ACC) 233. At what following distance do you typically have the ACC system set to? 234. When driving in the rain, how have you changed the vehicle's following distance? 235. When driving in heavy traffic, how have you changed the vehicle's following distance?
Interface	229. How intuitive and understandable are the ACC system's sounds? 230. How intuitive and understandable are the ACC system's displays? 231. To what extent have you been confused about what speed the ACC is set to? 232. To what extent have you been confused about what following distance the ACC is set to? 238. Why has the system not lived up to your expectations? 239. If you could change any aspect of the ACC system, what would you change?

Table 10 Night Vision System Question Structure: Key Dimensions and Associated Items

Background	300. Did you specifically ask for this option? 301. Please rate how the night vision system influenced your decision to buy this vehicle. 318. Do you think the system improves comfort and reduces stress during nighttime driving?
System Usage	305. How often did you tend to use the system when you first bought the vehicle? 306. How has your use of the system changed over time since you first bought the vehicle? 307/308. Why has system usage increased/decreased? 309. How many times per week do you typically use the system currently? 327. Under what situations have you turned off, or not used the night vision system?
Effectiveness & Acceptance	303. Describe your attitude toward buying your next vehicle with a night vision system. 304. Would you recommend this system to a friend? 315A. Rate your current impression of the usefulness of the system. 315D. Rate your current impression of the system's ability to work under a range of conditions. 317A. How effective is the system in displaying recognizable images? 317B. How effective is the system in helping you to detect and recognize pedestrians? 317C. How effective is the system in helping you to detect and recognize animals? 317D. How effective is the system in operating in a wide range of conditions? 317E. How effective is the system in enabling you to judge distances to objects? 317F. How effective is the system in minimizing the number of adjustments you need to make to the display? 329. Has the night vision system lived up to your expectations?
System Knowledge & Learning	302. Thinking about your owner's manual, have you read … 310. How long did it take you to feel comfortable using the system? 311. How did you learn about the system functions, capabilities, and limitations? 312. Was the system generally easy to learn how to use? 313. Were any features of the system particularly difficult to learn how to use? 314. What features were particularly difficult to learn to use? 315C. Rate your current impression of the ease of use of the system. 321. Has your ability to recognize objects in the display improved with experience? 322. What objects are difficult to recognize in the display? 323. What objects are easily recognized in the display?
Safety & Behavioral Impacts	315B. Rate your current impression of the safety impacts of the system. 316A. Has the system changed your willingness to drive at night? 316B. Has your level of trust in the system changed over time? 316C. Has the system changed your ability to predict and respond to road hazards? 316D. Has the system changed your ability to see obstacles or hazards at night? 316E. Has the system changed your speed while driving at night? 316F. Has the system changed your susceptibility to glare from oncoming vehicle headlights? 316G. Has the system changed your likelihood of being involved in a crash? 319. Have you experienced any situation where the night vision system helped you avoid hitting something that you otherwise might not have seen in time? 320. How distracting do you find the night vision display to be? 324. To what extent does the display interfere with your direct view out the windshield? 325. How often do headlights from oncoming vehicles interfere with your ability to see objects in the night vision display? 326. Has your frequency of glances to the night vision display changed since you first purchased or leased the vehicle? 328. Has the display caused you to use your rear and side view mirror less?
Interface	330. Why has the system not lived up to your expectations? 331. If you could change any aspect of the night vision system, what would you change?

Table 11 Park Aid System Question Structure: Key Dimensions and Associated Items

Background	400. Did you specifically ask for this option? 401. Please rate how the park aid system influenced your decision to buy this vehicle. 430. Does your vehicle include a camera view?
System Usage	405. How often did you tend to use the system when you first bought the vehicle? 406. How has your use of the system changed over time since you first bought the vehicle? 407/408. Why has system usage increased/decreased? 409. How many times per week do you typically use the system currently? 428. Under what situations have you turned off, or not used the park aid system? 431. Which would best describe your use of the camera display while backing…
Effectiveness & Acceptance	403. Describe your attitude toward buying your next vehicle with park aid system. 404. Would you recommend this system to a friend? 415A. Rate your current impression of the usefulness of the system. 415D. Rate your current impression of the system's ability to work under a range of conditions. 417A. How effective is the system in alerting you to the presence of unexpected obstacles? 417B. How effective is the system in helping you to avoid hitting obstacles? 417C. How effective is the system in providing sufficient advance notice to allow you to react? 417D. How effective is the system in minimizing unnecessary warnings or information? 417E. How effective is the system in reliably detecting and warning you of objects that are located behind you, but off to the side (not directly behind the vehicle)? 432. Has the park aid system lived up to your expectations?
System Knowledge & Learning	402. Thinking about your owner's manual, have you read … 410. How long did it take you to feel comfortable using the system? 411. How did you learn about the system functions, capabilities, and limitations? 412. Was the system generally easy to learn how to use? 413. Were any features of the system particularly difficult to learn how to use? 414. What features were particularly difficult to learn to use? 415C. Rate your current impression of the ease of use of the system. 420. Does the system operate under any speed when backing? 421. Does the system adjust the warning time based on your backing speed and distance to the obstacle, or is the warning based solely on distance to the obstacle?
Safety & Behavioral Impacts	415B. Rate your current impression of the safety impacts of the system. 416A. Has the system changed your ability to park the vehicle? 416B. Has he system changed you confidence in parking? 416C. Has the system changed your reliance on mirrors and direct glances to the rear while backing? 416D. Has your level of trust in the system changed over time? 416E. Has the system changed your likelihood of being involved in a backing related crash? 418. Have you experienced any situation where the park aid system prevented you from hitting something you had not seen? 419. How often has the system failed to detect and alert you to the presence of an object when it should have? 422. When driving another vehicle without the park aid system, have you experienced situations where you mistakenly thought the vehicle had a park aid system? 426. If the park aid issued an unexpected alert while backing, would you…. 429. Do you tend to look to the rear, or use the mirrors later when backing or parking with the park aid system?
Interface	423. How intuitive and understandable are the ACC system's sounds? 424. How intuitive and understandable are the ACC system's displays? 425. Are the visual displays in a comfortable location where they are easy to see while backing? 427. Do you rely more on the warning lights or the warning sounds? 432. Why has the system not lived up to your expectations? 434. If you could change any aspect of the park aid system, what would you change?

Table 12 Navigation System Question Structure: Key Dimensions and Associated Items

Background	500. Did you specifically ask for this option? 501. Please rate how the night vision system influenced your decision to buy this vehicle. 532. Are you able to make selections and interact with the system through voice commands?
System Usage	505. How often did you tend to use the system when you first bought the vehicle? 506. How has your use of the system changed over time since you first bought the vehicle? 507/508. Why has system usage increased/decreased? 509. How many times per week do you typically use the system currently? 526A-H. Rate extent to which the various input methods are used to program a destination. 528. Do you travel more on neighborhood streets to avoid congestion?
Effectiveness & Acceptance	503. Describe your attitude toward buying your next vehicle with a navigation system. 504. Would you recommend this system to a friend? 515A. Rate your current impression of the usefulness of the system. 515D. Rate your current impression of the system's ability to work under a range of conditions. 517A. How effective is the system in providing sufficiently advanced notice to allow you to make correct turns? 517B. How effective is the system in positioning the visual display so that it can be easily seen and reduce glare? 517C. How effective is the system in restricting access to complex interactions that may distract you while driving? 517D. How effective is the system in limiting the amount of information provided while driving so it does not overwhelm you? 540. Has the navigation system lived up to your expectations?
System Knowledge & Learning	502. Thinking about your owner's manual, have you read … 510. How long did it take you to feel comfortable using the system? 511. How did you learn about the system functions, capabilities, and limitations? 512. Was the system generally easy to learn how to use? 513. Were any features of the system particularly difficult to learn how to use? 514. What features were particularly difficult to learn to use? 515C. Rate your current impression of the ease of use of the system. 521. Is the system capable of providing voice instructions and blanking-out the visual display? 522. Is the system able to repeat a verbal instruction when you want to hear it again?
Safety & Behavioral Impacts	515B. Rate your current impression of the safety impacts of the system. 516A. Has the system changed your willingness to drive in unfamiliar areas? 516B. Has your level of trust in the system changed over time? 516C. Has the system changed you ability to predict and respond to road hazards? 516D. Has the system changed your incidence of erratic or last minute maneuvers because you were unprepared to make a turn? 516E. Has the system changed your likelihood of being involved in a backing related crash? 516F. Has the system changed how often you scan your environment, or look at your mirrors? 518. Is using the system safer than using a paper map or written set of directions? 519. Have you ever unintentionally run a stop sign or traffic signal because you were looking at the visual display? 520. Have you ever had a crash or close call while programming the system when driving? 527. Do you look away from the road more frequently and for longer periods of time when driving with the navigation system? 535. Have you changed your normal mode of input (voice recognition versus manual) since using the system? 537. Which do you feel is safer to use, voice input, manual input…
Interface	524. How easy are the voice instructions to follow? 525. How easy are the visual displays to follow? 523. Do you rely more on voice instruction, or the visual display? 529. Which method used most for guidance while driving? 534. How much of the time does the system reliably recognize your voice inputs?

	538. How often do you have difficulty remembering particular voice commands? 540. Why has the system not lived up to your expectations? 541. If you could change any aspect of the navigation system, what would you change?

Recruitment Methods

A major objective of this research was to evaluate and assess the relative effectiveness of different methods for identifying and recruiting system owners for participation in the telephone survey. Six unique recruitment methods were used to solicit participation in the survey, these included:

1) Mail-outs to lists of registered vehicle owners
2) Newspaper recruitment ads
3) Internet recruitment ads
4) Magazine recruitment ads
5) Direct (Outbound) calls to registered vehicle owners
6) Dealership contacts

Each of these recruitment methods is discussed in detail below. Radio recruitment ads were also investigated, but were not used in this specific effort. A series of unique toll-free telephone numbers were established in order to track the success of different recruitment methods (each recruitment method was assigned a unique toll-free number).

<u>Mail Outs to Lists of Vehicle Owners (RL Polk)</u>

This represents one of the most successful and reliable recruitment methods used. It relies on accessing vehicle owner contact information (name, telephone number, and mailing address) through Department of Motor Vehicle registration records. In our case, we used an independent consumer marketing firm (R.L. Polk) to supply lists of vehicle ownership data for targeted vehicle makes and models rather than accessing them directly through DMV records (which would have been much more time consuming). There are, however, some restrictions in accessing DMV records information using R.L. Polk; vehicle ownership information is not accessible in 17 states, many located in the western United States. Refer to Figure 20 for details on the availability of ownership data through R.L. Polk. Since the goal of this task was to assess the feasibility of the method itself (ownership contact lists), this limitation was not viewed as problematic; future efforts requiring nationally representative samples could access the information directly through state Departments of Motor Vehicles if needed.

An iterative process was used to identify potential system owners; this involved identifying a pool of available vehicle owners, then drawing a sample from the available records. The process started by first generating a list of targeted vehicle makes and models for recruitment (vehicle models were based on the results of the inventory conducted as part of Task 1). This list, which included 29 vehicle models sampled across 7 states (Colorado, Florida, Illinois, Michigan, New York, Texas, and Virginia) was submitted to RL Polk. Results of the search conducted by RL Polk (shown in Appendix A) found over 140,000 available vehicle owners. An initial sample of 8,340 owners was drawn from the available pool; the sample balanced geographic regions, in-vehicle systems, and manufacturer to the extent possible (Appendix D also provides a breakdown of the acquired owner list by vehicle make, system, and make by system). It is important to note, however, that the resulting list of available owners only represents candidate system owners; unless the vehicle was equipped with the system as a standard feature, we could not guarantee that the individuals actually purchased the option based solely on DMV records.

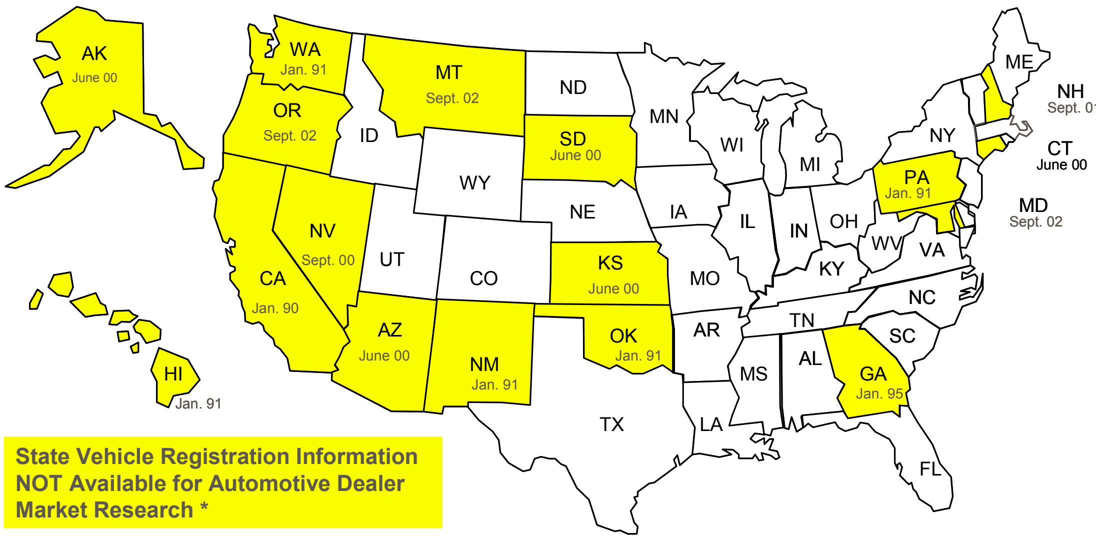


Figure 20 Availability of Vehicle Ownership Information Through R.L. Polk.

In all, a sample of 10,251 vehicle owners was drawn from the available list; an initial sample of 8,340, and a subsequent sample of 1,911 owners. A recruitment letter was developed and mailed to the sample of 8,340 vehicle owners (Appendix F presents the letter). A number of techniques were incorporated into the mail-outs in order to increase the likelihood that individuals would open and read the letters. For example, the NHTSA logo was included in the letterhead as well as in the mailing envelopes (accompanied by Westat's logo). Envelopes also included a stamp (rather than an imprinted postmark) and were directly imprinted with the owner's name and address as opposed to using a mailing label. The letter itself was broken into a series of sections organized by topical headings or questions - each addressing an important and relevant issue (e.g., What are we asking you to do? Why should I participate? Who is sponsoring the research? etc.). This structure was intended to help prospective respondents quickly access important information and provide answers to common questions and concerns. The letter also defined the types of systems of interest, and provided a means for individuals to participate by calling a toll-free number. Those calling the toll-free number were directed to leave basic information (including name, phone number, vehicle type and system, and preferred time to take the survey). This strategy allowed individuals to act immediately upon opening the letter, even if they could not take the survey at that time. It also made the survey administration process more efficient by allowing Telephone Research Center staff to better manage and organize call-outs.

Letters were mailed in three waves in order to distribute the workload for the Telephone Research Center (TRC). Each wave consisted of approximately 3,000 letters (the first wave was mailed on April 15th; the second wave was mailed April 22nd; and the remaining letters were mailed April 28th). Two levels of incentives were also used during the mail-outs. The first series of 8,340 vehicle owners were provided a $25 incentive for participation in the survey. A second letter (mailed to an additional sample of 1,911 vehicle owners on June 2, 2004) included and increased incentive of $50. This enabled us to determine how an increased incentive influences response rates. Thus, a total of 10,251 recruitment letters were mailed to prospective in-vehicle system owners using this method.

Newspaper Advertisement

A recruitment advertisement was placed in the Washington Post – a major newspaper in the Washington DC area with a circulation of over 1,000,000 readers. The ad appeared in the sports section of the Washington Post on May 12th, 2004.

Internet Ads and Auto Club Web Sites

Two basic types of Internet recruitment methods were used. The first involved posting notices (recruitment ads) on a variety of individual auto club web sites (each tailored to a particular vehicle brand such as Cadillac, Volvo, Lexus, etc.), while the second approach relied on posting recruitment notices on a generic, but popular car enthusiast web site. In general, the former types of outlets required no advertisement fees, while the latter relied on sponsors and charged fees for advertisements. Recruitment notices were placed on several auto club web sites, including Cadillac Owners Club (www.caddyinfo.com), Volvo Club of America (www.vcoa.org), Land Rover Club (www.series123.com/usa), Lexus Owners Club (www.lexusownersclub.com), among others. Some of these web sites were very active; the recruitment ad on the Cadillac site (caddyinfo.com), for example, was viewed over 180 times. Nevertheless, we received few call-ins using this recruitment method.

Several generic Internet web sites (pay to advertise sites) were explored and considered, including Autoweek.com, WardsAuto.com, Edmunds.com, CarandDriver.com, MotorTrend.com, AutomobileMag.com, and TheCarConnection.com. Some represented on-line versions of popular magazines, others featured automobile buying guides, reviews, and automobile industry news and articles. Selection factors included demographics of the audience (age and income), nature of the site, market penetration (number of hits and scope of the audience), and pricing. The Car Connection was selected due to these factors: 75% of users were between the ages of 25-54 years old, approximately 20% of the audience had incomes over $75,000, the site featured automotive news, buyers guides, review and articles, and has won awards. The advertisement ran for approximately two weeks using two banners that rotated throughout the site with over 600,000 impressions of the advertisement page.

Magazine

A recruitment advertisement was placed on a popular weekly automotive magazine, AutoWeek (with over 350,000 paid subscribers, and a median household income of over $100,000). The quarter page, color advertisement was placed in the classifieds section of the magazine in the May 24, 2004 issue. A unique toll-free number was assigned in order to track the success of the advertisement. As with the other recruitment methods, callers were asked to leave basic information, including a preferred time for an operator to call for them to take the survey.

Direct (Outbound) Calls to Registered Vehicle Owners

This method was actually coordinated with the mail-out effort and took the form of follow-up telephone calls to vehicle owners. The calls focused exclusively on owners whose vehicles came equipped with systems as a standard feature (Adaptive Cruise Control and/or night vision systems). Calls were also only made to individuals who had not responded to the letter. Thus, individuals contacted using this method had been previously sent information regarding this study.

Dealership Contacts

Contacts with local area automobile dealerships were made in an effort to recruit prospective owners and buyers of technology equipped vehicles. In-person contacts were made with the general sales managers of fourteen area dealerships. Since it was common for a dealership to offer vehicles from multiple manufacturers, our sample included offerings from Audi, BMW, Buick, Chrysler, Ford, Honda, Infiniti, Jaguar, Land Rover, Lexus, Lincoln-Mercury, Mercedes, Nissan, Porsche, Toyota. None of the contacted dealerships were willing to provide lists of vehicle owners (primarily due to privacy concerns). However, several dealerships agreed to distribute and/or display study recruitment notices.

Telephone Research Center Survey Management and Administration

Westat's Telephone Research Center (TRC) managed the survey administration and data collection process. The TRC operates a nationwide network of interviewing locations to take advantage of time zone differences in scheduling calls. Ten experienced telephone interviewers were used; each received tailored instruction on administering the Early Adopters survey during a 9-hour training session. The survey itself was administered using a hardcopy questionnaire, rather than a computer-assisted form (this was done in order to reduce costs). Computers were used, however, to dial outbound telephone numbers and track the survey administration process. TRC staff monitored incoming calls (in response to the recruitment advertisements), and tracked survey responses daily. Once a call record was established (i.e., a prospective survey respondent calls the toll-free number and leaves contact information), interviewers returned the call at the scheduled time and continued doing so until contact was made with the individual. Detailed records documenting the process were maintained. Completed questionnaires were reviewed (by the interviewer and a TRC manager) in order to ensure responses were legible and clear. Survey responses were subsequently entered into a computer database and checked again for accuracy and data entry errors.

SURVEY RESULTS

Results associated with two aspects of the survey effort are documented in this general section. The first addresses the relative effectiveness of the various survey recruitment methods (recruitment results), while the second documents the responses to the survey items (survey results).

EFFECTIVENESS OF RECRUITMENT METHODS

The survey data collection effort was initiated on April 15, 2004 with mail-outs to over 8,300 vehicle owners, and extended nearly 10 weeks ending June 22, 2004. During this time-frame, the telephone research center processed 620 unique call-ins resulting in 846 completed interviews (325 park aid interviews, 249 navigation system interviews, 213 Adaptive Cruise Control interviews, and 59 night vision system interviews). Many individuals completed more than a single interview (provided data on up to two systems). Figure 21 plots the number of call-ins and completed cases across the ten week survey period; it also identifies the start date for each of the various recruitment efforts which were staggered across time.

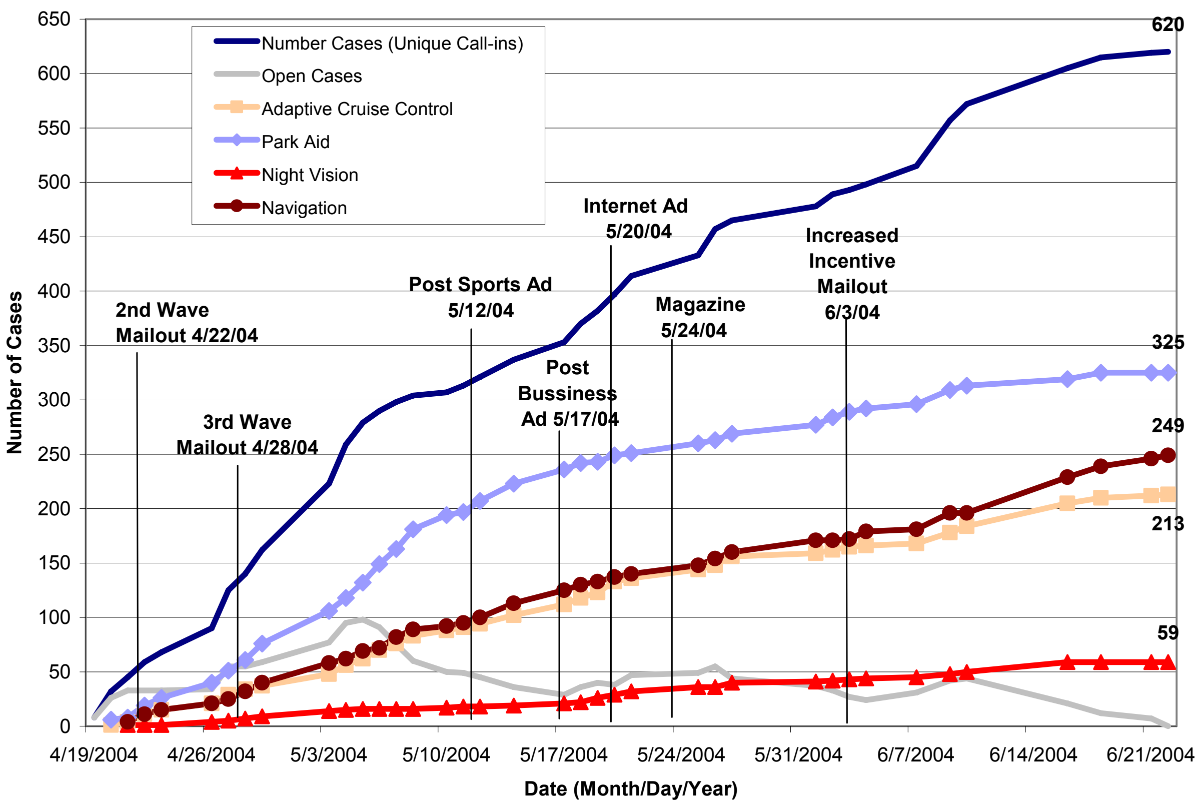


Figure 21. Survey Response Tracking Across Time and By System. Figure Illustrates the Number of Call-Ins and Completed Interviews During the Survey Period with Benchmarks for Each of the Recruitments Efforts.

Subsequent examination of the data found that some completed surveys were in fact not valid because the reported vehicle did not offer the targeted feature and therefore could not have been equipped with the system (respondents were either confused or not truthful about what systems were equipped in their vehicles). Of the 846 completed surveys, 155 (or approximately 18%) were invalid on this basis alone. Although all of the recruitment forms suffered from this problem to varying degrees, the majority of these invalid cases originated from the Internet and Magazine recruitment (refer to Figure 22). Invalid cases significantly impacted the effective number of usable surveys for night vision and adaptive cruise control systems. As shown in Figure 23, approximately 75% of the completed night vision systems surveys (44 of 59), and 30% of completed ACC surveys (63 of 213) were cases in which the vehicle indicated by the survey respondent did not offer a factory installed system. It is also possible that the rate of invalid cases is actually higher than reported for park aid and navigation systems. Tables 13 to 17 provide additional detail regarding the number of valid/invalid cases across recruitment methods and by type of in-vehicle system. The resulting database contained 691 valid completed surveys (150 Adaptive Cruise Control, 15 night vision, 298 park aid, and 228 navigation), roughly 82% of the completed surveys. This finding highlights the importance of recruitment and screening procedures and suggests that future survey efforts should conduct more aggressive screening and/or limit the use of Internet and magazine recruitment.

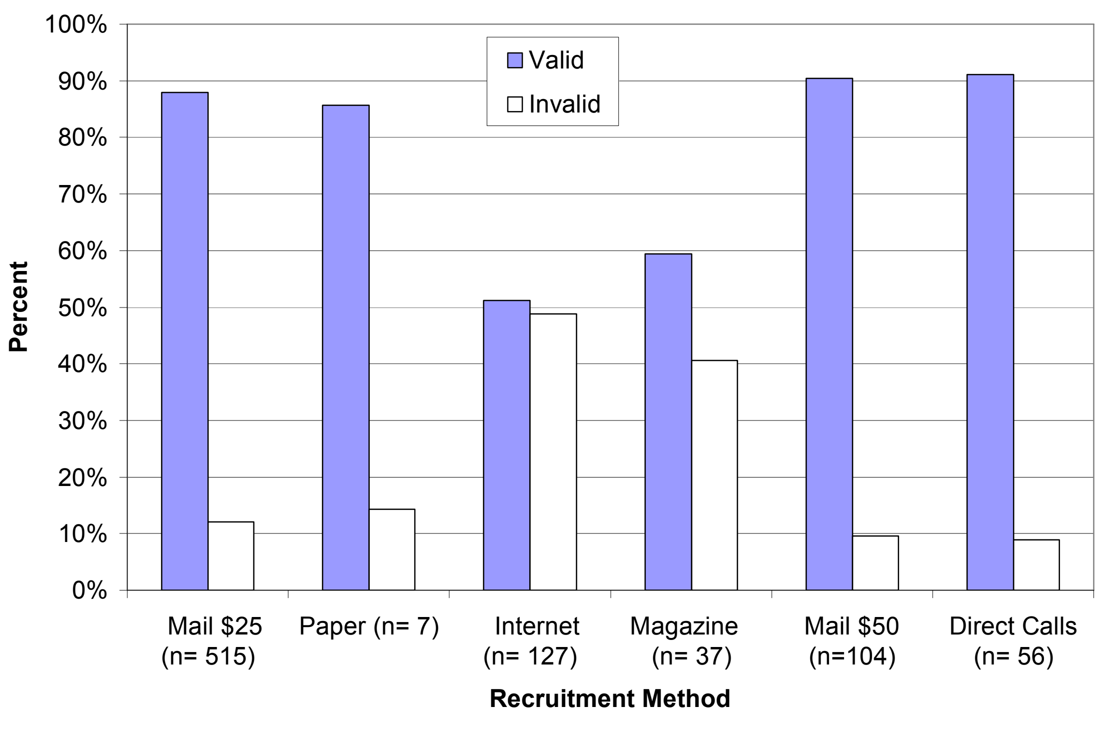


Figure 22 Overall Percent of Valid and Invalid Cases By Recruitment Method

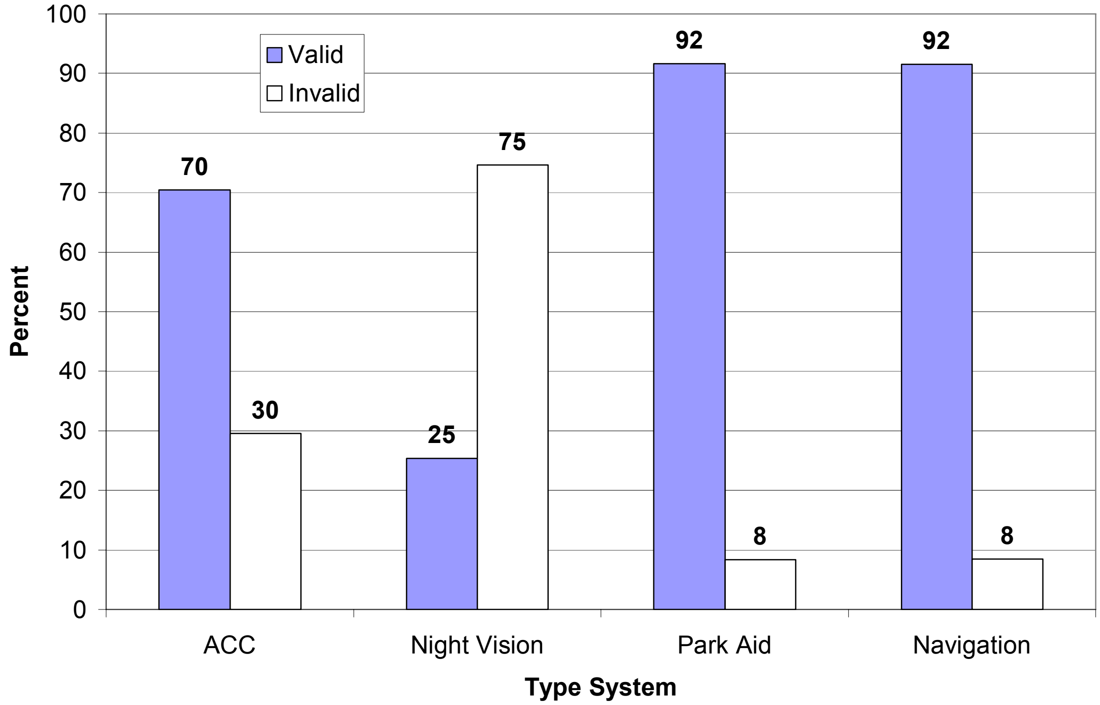


Figure 23 Percent of Valid and Invalid Completed Surveys by Type of In-Vehicle System

Table 13 Overall Percent of Valid and Invalid Cases by Recruitment Method

		Mail 25	Paper	Internet	Magazine	Mail 50	Direct Calls	Total
Invalid	Frequency of Respondents	62	1	62	15	10	5	**155**
	Percent of Total Respondents	7.33%	0.12%	7.33%	1.77%	1.18%	0.59%	**18.32%**
	Percent of Invalid Respondents	40.00%	0.65%	40.00%	9.68%	6.45%	3.23%	
	Percent of Invalid Respondents by Recruitment Method	12.04%	14.29%	48.82%	40.54%	9.62%	8.93%	
Valid	Frequency of Respondents	453	6	65	22	94	51	**691**
	Percent of Total Respondents	53.55%	0.71%	7.68%	2.60%	11.11%	6.03%	**81.68%**
	Percent of Valid Respondents	65.56%	0.87%	9.41%	3.18%	13.60%	7.38%	
	Percent of Valid Respondents by Recruitment Method	87.96%	85.71%	51.18%	59.46%	90.38%	91.07%	
Total	Frequency of Respondents by Recruitment Method	515	7	127	37	104	56	**846**
	Percent of Respondents by Recruitment Method	60.87%	0.83%	15.01%	4.37%	12.29%	6.62%	**100.00%**

Table 14 Percent of Valid and Invalid Adaptive Cruise Control Cases By Recruitment Method

		Mail 25	Paper	Internet	Magazine	Mail 50	Direct Calls	Total
Invalid	Frequency of ACC Respondents	30	0	26	2	5	0	**63**
	Percent of Total ACC Respondents	14.08%	0.00%	12.21%	0.94%	2.35%	0.00%	**29.58%**
	Percent of Invalid ACC Respondents	47.62%	0.00%	41.27%	3.17%	7.94%	0.00%	
	Percent of Invalid ACC Respondents by Recruitment Method	25.64%	0.00%	65.00%	50.00%	21.74%	0.00%	
Valid	Frequency of ACC Respondents	87	2	14	2	18	27	**150**
	Percent of Total ACC Respondents	40.85%	0.94%	6.57%	0.94%	8.45%	12.68%	**70.42%**
	Percent of Valid ACC Respondents	58.00%	1.33%	9.33%	1.33%	12.00%	18.00%	
	Percent of Valid ACC Respondents by Recruitment Method	74.36%	100.00%	35.00%	50.00%	78.26%	100.00%	
Total	Frequency of ACC Respondents by Recruitment Method	117	2	40	4	23	27	**213**
	Percent of ACC Respondents by Recruitment Method	54.93%	0.94%	18.78%	1.88%	10.80%	12.68%	**100.00%**

Table 15 Percent of Valid and Invalid Night Vision System Cases By Recruitment Method

		Mail 25	Internet	Magazine	Mail 50	Direct Calls	Total
Invalid	Frequency of NV Respondents	15	18	3	3	5	**44**
	Percent of Total NV Respondents	25.42%	30.51%	5.08%	5.08%	8.47%	**74.58%**
	Percent of Invalid NV Respondents	34.09%	40.91%	6.82%	6.82%	11.36%	
	Percent of Invalid NV Respondents by Recruitment Method	57.69%	85.71%	100.00%	75.00%	100.00%	
Valid	Frequency of NV Respondents	11	3	0	1	0	**15**
	Percent of Total NV Respondents	18.64%	5.08%	0.00%	1.69%	0.00%	**25.42%**
	Percent of Valid NV Respondents	73.33%	20.00%	0.00%	6.67%	0.00%	
	Percent of Valid NV Respondents by Recruitment Method	42.31%	14.29%	0.00%	25.00%	0.00%	
Total	Frequency of NV Respondents by Recruitment Method	26	21	3	4	5	**59**
	Percent of NV Respondents by Recruitment Method	44.07%	35.59%	5.08%	6.78%	8.47%	**100.00%**

Table 16 Percent of Valid and Invalid Park Aid System Cases By Recruitment Method

		Mail 25	Paper	Internet	Magazine	Mail 50	Direct Calls	Total
Invalid		8	0	12	7	0	0	**27**
	Percent of Total PA Respondents	2.46%	0.00%	3.69%	2.15%	0.00%	0.00%	**8.31%**
	Percent of Invalid PA Respondents	29.63%	0.00%	44.44%	25.93%	0.00%	0.00%	
	Percent of Invalid PA Respondents by Recruitment Method	3.24%	0.00%	37.50%	46.67%	0.00%	0.00%	
Valid	Frequency of PA Respondents	239	2	20	8	13	16	**298**
	Percent of Total PA Respondents	73.54%	0.62%	6.15%	2.46%	4.00%	4.92%	**91.69%**
	Percent of Valid PA Respondents	80.20%	0.67%	6.71%	2.68%	4.36%	5.37%	
	Percent of Valid PA Respondents by Recruitment Method	96.76%	100.00%	62.50%	53.33%	100.00%	100.00%	
Total	Frequency of PA Respondents by Recruitment Method	247	2	32	15	13	16	**325**
	Percent of PA Respondents by Recruitment Method	76.00%	0.62%	9.85%	4.62%	4.00%	4.92%	**100.00%**

Table 17 Percent of Valid and Invalid Navigation System Cases By Recruitment Method

		Mail 25	Paper	Internet	Magazine	Mail 50	Direct Calls	Total
Invalid	Frequency of NAV Respondents	9	1	6	3	2	0	**21**
	Percent of Total NAV Respondents	3.61%	0.40%	2.41%	1.20%	0.80%	0.00%	**8.43%**
	Percent of Invalid NAV Respondents	42.86%	4.76%	28.57%	14.29%	9.52%	0.00%	
	Percent of Invalid NAV Respondents by Recruitment Method	7.20%	33.33%	17.65%	20.00%	3.13%	0.00%	
Valid	Frequency of NAV Respondents	116	2	28	12	62	8	**228**
	Percent of Total NAV Respondents	46.59%	0.80%	11.24%	4.82%	24.90%	3.21%	**91.57%**
	Percent of Valid NAV Respondents	50.88%	0.88%	12.28%	5.26%	27.19%	3.51%	
	Percent of Valid NAV Respondents by Recruitment Method	92.80%	66.67%	82.35%	80.00%	96.88%	100.00%	
Total	Frequency of NAV Respondents by Recruitment Method	125	3	34	15	64	8	**249**
	Percent of NAV Respondents by Recruitment Method	50.20%	1.20%	13.65%	6.02%	25.70%	3.21%	**100.00%**

In summary, a total of 620 individuals responded to the recruitment campaign. It was later determined that approximately 23% of these cases (140 of 620) did not actually own vehicles equipped with a system of interest and were therefore treated as invalid cases. The remaining 480 valid respondents completed a total of 691 interviews. The figure below overviews the process and illustrates how the valid cases track across completed interviews for each system of interest. Since some vehicles were equipped with multiple systems (or respondent had more than one vehicle with different systems), respondents were allowed to complete up to two interviews addressing different systems. Of the 480 respondents, 56% (269 individuals) completed an interview for a single system, while 44% (211 individuals) completed interviews for two in-vehicle systems. If individuals elected to complete two system interviews, the most common combinations were Adaptive Cruise Control and park aid, park aid and navigation, and Adaptive Cruise Control and navigation.

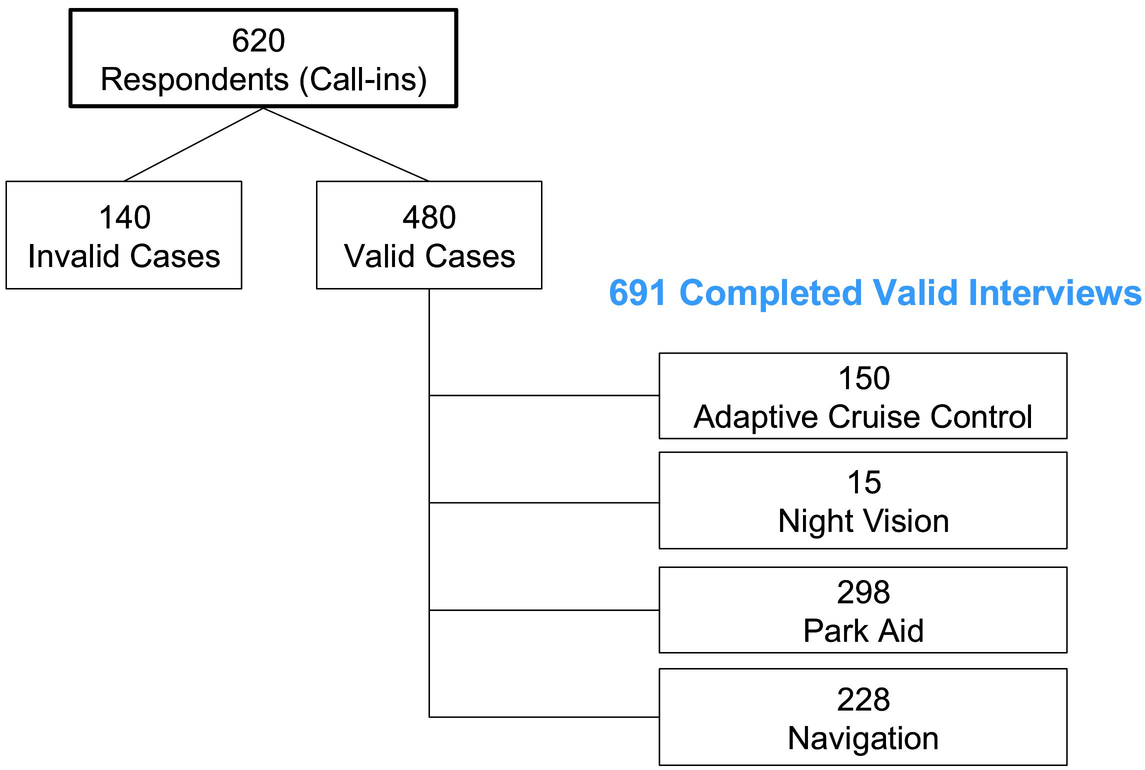


Figure 24 Number of Respondents, Valid and Invalid Cases, and Completed Interviews

Recruitment Method by Respondent Demographics

This section addresses whether certain recruitment methods are more likely to produce different types of respondents that could bias survey results along one or more important dimensions. As shown in Table 18, recruitment through newspapers, magazines and the Internet are likely to yield somewhat "younger" respondents than mail-outs or direct calls. Older drivers (over age 60) were more frequently recruited by mail-outs, while middle aged drivers (between ages 40-59) were successfully recruited through Internet and Magazine advertisements (see Figure 25). Although the overall sample was biased towards males (67% of respondents were males), magazine advertisements appealed almost exclusively to males (likely due to the readership of the magazine); owners recruited through magazines also tended to have the least amount of miles driven since purchasing the vehicle. Mail-outs to lists of vehicle owners accounted for a majority of the interviews conducted across each of the four systems.

Table 18 Key Demographic and Yield Measures Across Various Recruitment Methods

					Percent of Total System Respondents			
Recruitment Method	n	Mean Age (range)	Percent Males	Mean Miles Driven	ACC	Park Aid	Night Vision	Nav.
Mail ($25 Incentive	307	58 (24–84)	68%	15,120	54%	76%	44%	50%
Mail ($50 incentive)	70	58 (28–87)	71%	17,292	11%	4%	7%	26%
Newspaper	4	47 (35-66)	50%	15,500	1%	1%	0%	1%
Internet	47	48 (23–78)	57%	15,609	19%	10%	36%	14%
Magazine	15	49 (34-70)	93%	12,321	2%	4%	5%	6%
Direct Calls	31	55 (30–86)	54%	17,292	13%	5%	8%	3%
					100%	100%	100%	100%

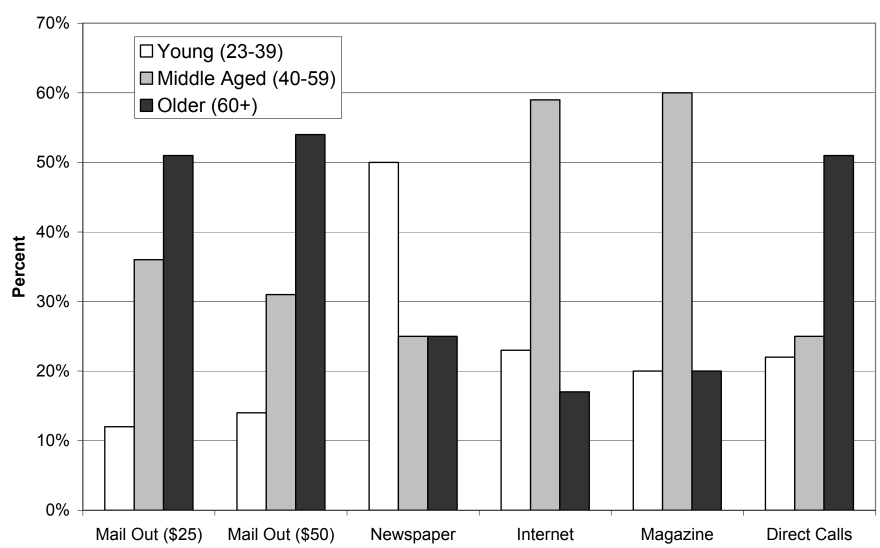


Figure 25 Distribution of Respondent Ages by Recruitment Method

Recruitment Method by Cost Per Respondent

This section assesses the relative effectiveness of the various recruitment methods using a straightforward calculation based on the cost associated with the recruitment method and the number of resulting respondents. This simple computation yields an overall cost per respondent, and provides a comparative measure across methods in terms of their ability to produce respondents. Results of the analysis are detailed in Table 19, and are based on the total number of unique respondents (n= 620). Costs related to mail-out, newspaper, Internet, and magazine are primarily based on direct expenses, while costs for the direct calls (follow-up calls) and dealership contact are primarily labor costs. This analysis shows a wide range of costs as measured in terms of cost per respondent, ranging from $34 to $159 per respondent. Recruitment via newspaper and magazine were among the most expensive in terms of cost per respondent (over $100 per respondent), while the Internet was the least expensive ($34 per respondent). Mail-out methods and direct calls were in the intermediate range, costing from $60 to $81 per respondent. The low cost of the Internet may be offset by the relatively large number of invalid cases associated with this method.

Table 19 Cost Per Respondent Across Recruitment Method

Recruitment Method	Cost	Number of Respondents	Cost Per Respondent
Mail Out*			
$25 Incentive (sample of 8,340 owners)	$23,315	352	**$66**
$50 Incentive (sample of 1,911 owners)	$7,349	91	**$81**
Newspaper	$1,112	7	**$159**
Internet Ad	$3,000	88	**$34**
Magazine Ad	$2,471	24	**$103**
Direct Calls**	$3,480	58	**$60**
Dealership Contacts	$720	0	--

* Includes cost for acquiring owner contact lists, printing envelopes and letterhead, postage, mailing services, and payment incentives. ** Ratio of 5hrs of labor per respondent (approximately 290 hours of interviewer labor).

On a per respondent basis, the added ($50) incentive mail-out cost $15 more than the base ($25) incentive - the difference was less than the $25 difference between incentives. Indeed, both mail outs yielded about the same number of respondents when calculated in terms of percentages. The $25 incentive yielded a 4.2% response rate (352 respondents out of a sample of 8,340 possible respondents), while the $50 incentive yielded a 4.7% response rate (91 respondents out of a sample of 1,911possible respondents). This suggests that the added incentive did not notably increase the response rate beyond the level of the base incentive. In this case, a $25 incentive worked to recruit participants just as well as a $50 incentive (note that it is possible that a substantially larger incentive, such as $100 payment, may result in a notable increase in the recruitment rate). However, a relatively large incentive may also be counter-productive; we suspect that many of the invalid cases were motivated by the monetary incentive alone. As anticipated by TRC staff, for this particular population, the real incentive to participate in this type of survey may not be monetary, but simply the opportunity to influence the design of systems and have their opinions heard by an authoritative organization (e.g., NHTSA). Our recruitment material was specifically designed to highlight the uniqueness of these drivers and appeal to their status and ability to offer insights based on their experience with the systems.

The relatively low response rate for mail-outs (e.g., 4.2 and 4.7%) reflects the fact that the pool of registered vehicle owners included individuals who purchased a vehicle model offering a particular technology, but not all may have purchased the system when offered as an option. Thus, in some cases, recruitment letters were mailed to individuals who's vehicle was not equipped with a system. The resulting response rates are therefore artificially low since this level of information could not be discerned from the available DMV records. If system owners could be exclusively identified and targeted (e.g., limit the sample or over-sample vehicles with standard systems), it is likely that the response rate would be much higher. Efforts were made to include a range of vehicle makes and not bias the sample to a limited few systems, and the resulting dataset did include a range of systems. As shown in Figure 26 response rates did vary somewhat across vehicle makes. However, in general, response rates were not necessarily based on the perceived luxury or overall cost of the vehicle.

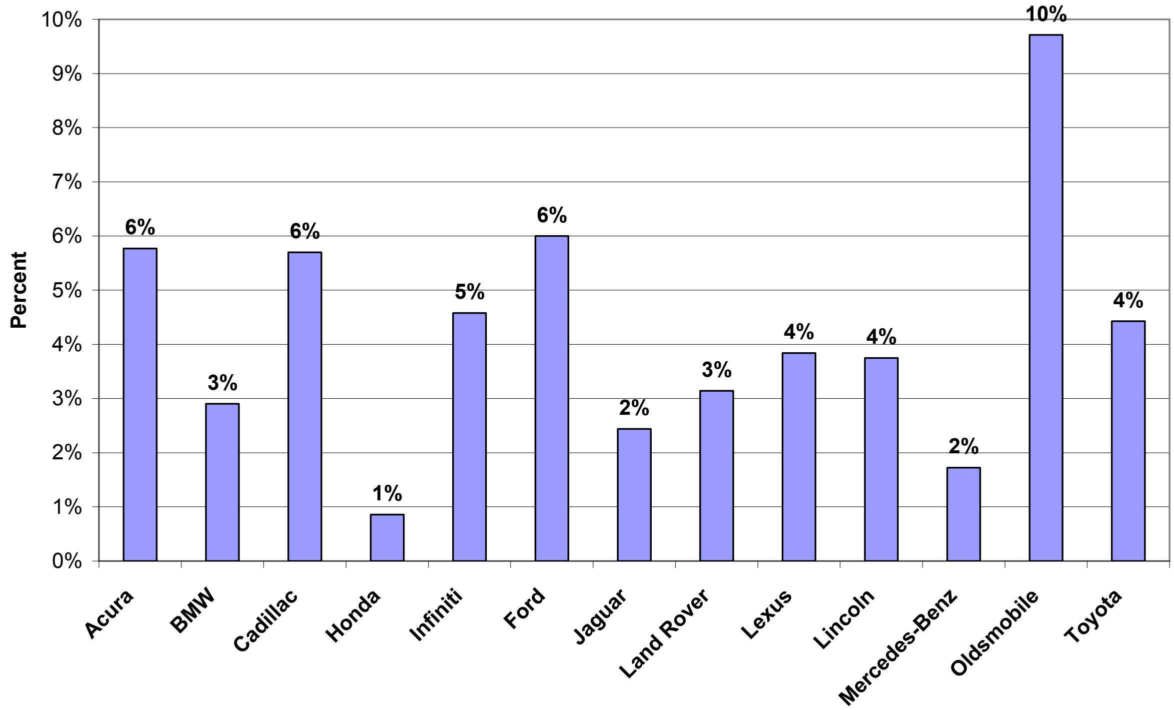


Figure 26 Response Rates for Mail-Outs by Vehicle Make

OWNER INTERVIEW RESULTS

This section documents the survey responses addressing issues on driver acceptance and behavioral adaptation associated with the each of the targeted systems. Only valid survey respondent are included in the analyses. The sections that follow break-out the survey responses by each system: Adaptive Cruise Control, night vision, park aid, and navigation.

Sample Demographics

The sample of 480 valid vehicle owners was heavily represented by males (67%) versus females (33%). The sample included a wide age distribution ranging from 23 to 87 years of age (mean age was 56 years). Approximately 15% were between the ages of 23-39 (younger); 38% between the ages of 40-59 (middle aged); and 47% age 60 and above (older). Owners averaged 39 years of driving experience, ranging from 4 to 70 years. The overwhelming majority of drivers in the sample (94%) purchased or leased the equipped vehicle themselves. Over 98% of the vehicles owned were 2002 or later models, and were driven an average of 15,606 miles since they were purchased or leased. A substantial percentage of the sample (25%) had driven the vehicle 7,000 miles or less; the top 25% of the sample had driven the vehicle over 20,000 miles since it was purchased. Ninety-five percent of the sample had driven the vehicle under 40,000 miles since it was first purchased. The vast majority of the sample (92%) were residents in states drawn from the RL Polk sample (Colorado, Florida, Illinois, Michigan, New York, Texas, and Virginia), although individuals from 16 other states were represented. The largest concentrations were residents from Florida (18%), Michigan (17%), and New York (15%). Approximately 18% of the sample owned a second equipped vehicle. Table 20 Percentage of Vehicle Makes in Sample of 480 Owners details the types of vehicle makes represented in the sample; not surprisingly BMW, Cadillac, Infiniti, Lexus, Mercedes, and Toyota accounted for a large percentage of the vehicles (these were over-sampled in the RL Polk dataset).

Table 20 Percentage of Vehicle Makes in Sample of 480 Owners

Vehicle Make	Percent of Sample		Vehicle Make	Percent of Sample
Acura	6.73		Jaguar	1.77
Audi	0.05		Land Rover	2.84
BMW	10.28		Lexus	12.05
Buick	0.07		Lincoln	5.14
Cadillac	17.02		Mercedes	8.15
Chrysler	0.01		Nissan	0.05
Ford	7.26		Oldsmobile	3.54
GMC	0.03		Porsche	0.03
Honda	1.41		Toyota	10.81
Hummer	0.01		Volvo	0.05
Infiniti	9.57			

Adaptive Cruise Control Systems

Information relating to driver experience and use associated with Adaptive Cruise Control (ACC) systems were collected for 150 vehicle owners. Survey respondents included owners from each of the eight available vehicle manufacturers offering ACC systems in the U.S. light vehicle passenger market. As shown in Table 21, the sample is over-represented by Toyota Sienna XLE Limited owners (the only minivan offering this feature), and by Infiniti and Lexus owners. Nearly 97% of the owners purchased or leased the vehicle themselves; slightly more than one quarter of the owners (28%) specifically asked for the Adaptive Cruise Control system. The system was a factor in most drivers' decision (55%) to buy the vehicle. The overwhelming majority of drivers sampled (85%) would recommend the Adaptive Cruise Control system to a friend; reasons included greater convenience and safety for long distance trips, increased sense of safety and confidence in maintaining safe headways, reduced fatigue, and making long distance trips more pleasurable by not having to hassle with resetting the cruise control. Those who would not recommend the system generally felt that it was too gimmicky, not practical in traffic, limited in terms of the settings in which it operates (e.g., does not work in the rain), sometimes functions in undesirable ways, and that it is a distraction from driving.

Table 21 Breakdown of Adaptive Cruise Control System Respondents by Vehicle Make and Model

Vehicle Make	Vehicle Model	Total Number In Sample	Percent of Sample
Audi	A8L (2)	2	1%
BMW	7 Series (16)	20	13%
	5 Series (4)		
Cadillac	XLR (9)	9	6%
Infiniti	Q45 (29)	33	22%
	FX (4)		
Jaguar	XKR (2)	2	1%
Lexus	LS 430 (27)	31	21%
	RX (4)		
Mercedes-Benz	SL (1)	5	3%
	S-Class (1)		
	CLK 320/500 (1)		
	E500 (2)		
Toyota	Sienna XLE Limited (48)	48	32%

Approximately 65% of the sample was males; this is comparable to the overall percentage of male drivers in the entire survey sample (67% males). Table 22 provides vital demographic information for the sample of ACC respondents, including age and experience driving the vehicle. Forty-seven percent of the drivers were above 60 years in age; 41% were between 40 and 59 years of age; and 12% were between the ages of 20 and 39.. Drivers from New York (20%), Florida (17%), Michigan (16%), Illinois (13%), Virginia (10%), Colorado (10%), and Texas (8%) comprised nearly 95% of the sample.

Table 22 Key Demographic and Experience Data for the Sample of ACC Vehicle Owners

n = 150	Mean	Standard Deviation	Min	Max	25th Percentile	50th Percentile	75th Percentile
Age	56.47	13.50	27	87	46	57	65
Years Driving Experience	39.36	15.05	10	70	28	40	49
Miles Driven in Vehicle	15,181	16,934	100	150,000	7,000	10,750	19,500
System Usage (per week)	2.98	6.29	0	15	1	1	3

System Usage

Drivers in the sample tended to use the system approximately 3 times per week on average. For most of the sample (59%), usage stayed about the same compared to when they first purchased the vehicle. Those reporting an increase in ACC usage (29%), generally attributed the increase to: a greater familiarity and understanding of the system's functions, increased trust in the system, and/or more frequent highway driving. One person reported expanding the usage of the ACC system to residential areas in order to increase fuel economy. Drivers whose usage decreased reported: a change in driving habits (less freeway driving, fewer long trips), problems with system performance (e.g., over-activates), and/or dislike for the system because they do not feel "in control" of the car. For some drivers, the decrease was simply due to inflated usage when the vehicle was first purchased and over time the novelty effect had worn off. Nevertheless, nearly half of the sample (48%) reported using the ACC system more frequently compared to conventional cruise control. As indicated in Figure 27, use of ACC under certain conditions and environments (e.g., residential streets and neighborhoods, heavy traffic, snow, freeway ramps) was restricted by most drivers, but many were willing to operate the system under degraded conditions (e.g., rain, fog, snow) despite advisories and warnings in many of the owners manuals (refer to Appendix G for sample content from various ACC systems owner's manuals).

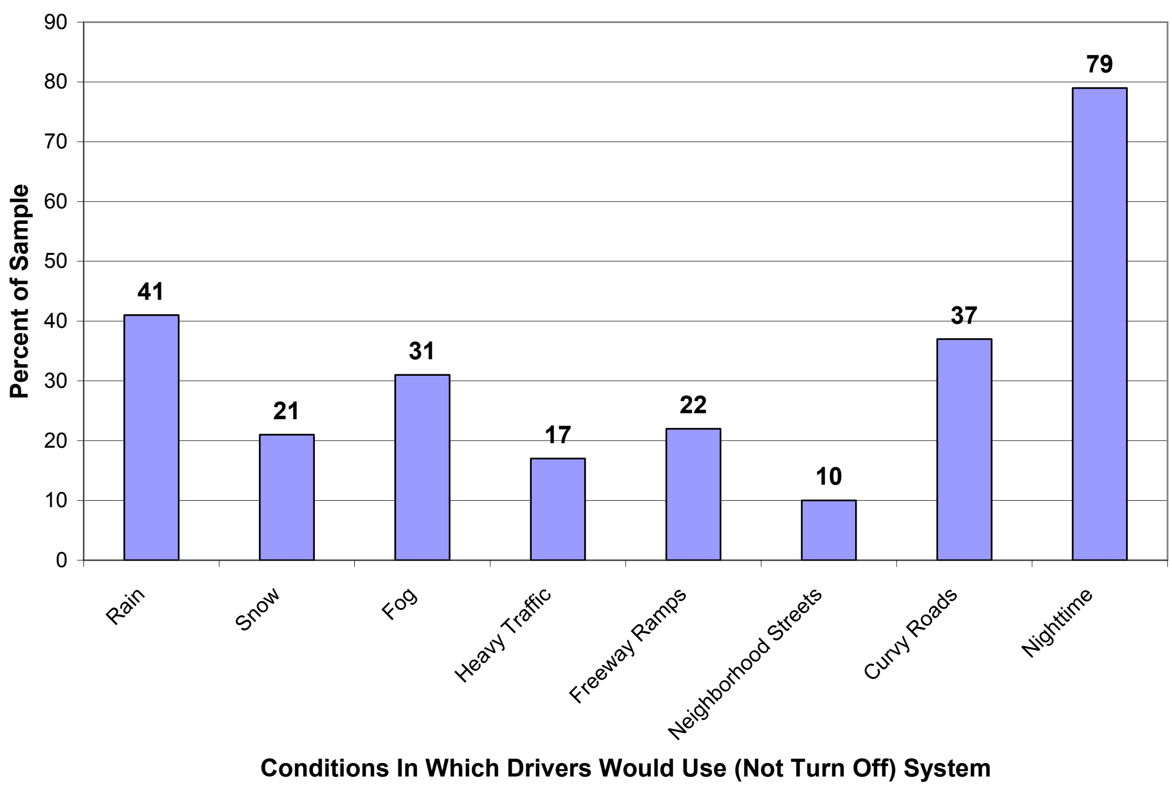


Figure 27 Percent of Owners Reporting Willingness to Use (Not Turn Off) the ACC System Under Various Environmental Conditions

In order to track how differences in system usage and experience influences the types of environments drivers are willing to use the ACC system, the sample of valid drivers was divided into different ACC experience levels. Three experience levels were defined based on both the self-reported number of times drivers currently use the system per week, and the number of miles driven since the vehicle was purchased. The experience levels were defined as: 1) a group of "low" experienced drivers (drivers using the ACC system less than 2 times per week and who had driven the vehicle less than 8,000 miles since the time of purchase); 2) a "high" experience group (drivers using the ACC system two or more times per week and who had driven the vehicle over 15,000 miles since the time of purchase); and 3) an "intermediate" level of experience (drivers who use the system two or more times per week, and who had driven the vehicle between 8,000 and 15,000 miles). The distinguishing factor between the experienced and intermediate group was the number of miles driven since the time of purchase. The classification scheme essentially identified the top and bottom ranges of the distribution (top and bottom-most 20% of the sample) and classified them as having low or high experience levels, respectively. The remaining 60% of the sample (roughly corresponding to the 21-79 percentile values)were classified as having intermediate experience with the ACC system.

Figure 28 clearly shows that experience with the ACC system influences driver willingness to operate the system (as indexed by self-reported use) under different environments (data in the Figure tracks that presented in Figure 27). Differences tend to be situation specific. In some instances, a driver's willingness to operate the system under degraded operating conditions increases as they gain experience with the system. For example, experienced drivers appear more willing to operate the ACC system on curvy roads, at night, and in heavy traffic compared to their less experienced counterparts. Experience can also serve to restrict system usage, such as under conditions of rain where inexperienced drivers are more willing to use the ACC system than drivers with intermediate or high levels of experience. In this case, drivers tend to avoid using the system in rain based on their previous experiences with the system. The difference between experience levels is less dramatic under certain conditions and environments such as snow, fog and on freeway ramps. The pattern of results suggests that initially, drivers appear somewhat cautious in their use of the ACC system limiting its use under degraded or challenging environments. However, with additional experience drivers become more accepting and willing to use the system under less than optimal conditions and environments.

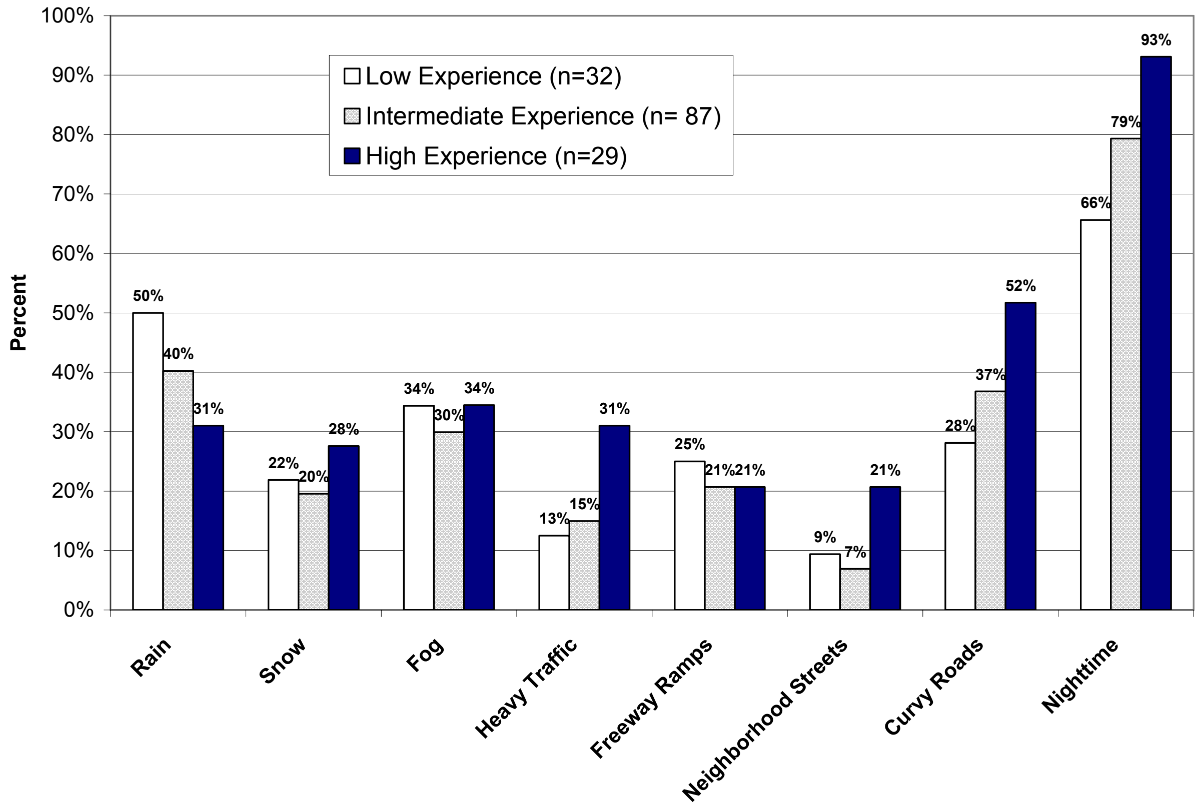


Figure 28 Driver Willingness to Use the ACC System Under Different Environmental Conditions as a Function of Experience With the ACC System

Effectiveness & Acceptance

The ACC system was perceived to be very useful and effective by most of the drivers sampled. Nearly 75% of valid ACC drivers found the system to be very useful (rated either a 4 or 5 on a 5 point scale). Only 3% of the drivers sampled, would not buy a future vehicle equipped with an ACC system. The vast majority of drivers would seek it out specifically (32%), or purchase ACC if it came standard or as part of a package (65%). Most felt that the ACC system relieves them of the stress often associated with driving and is effective in its ability to detect and follow vehicles. The system was also perceived to do a good job at minimizing the extent to which the system slows or brakes the vehicle inappropriately. As shown in Figure 29, approximately 45% of drivers felt the system was not very effective (rated a 3 or below on a 5 point scale) at operating under a wide range of conditions. Nevertheless, the vast majority of drivers (87%) indicated that the ACC has lived up to their expectations. The inability of the system to work under a wider range of environments (rain, heavy traffic) and false readings were some of the most common reasons cited by owners disappointed with the system.

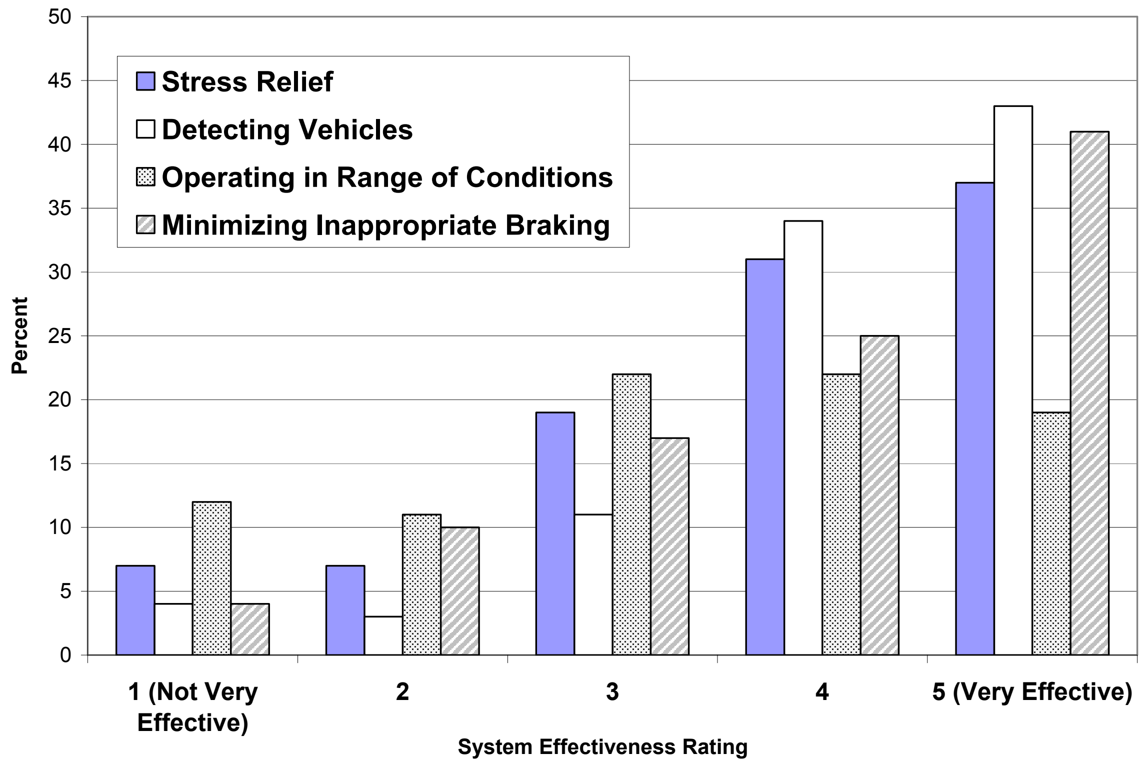


Figure 29 Perceived ACC System Effectiveness Ratings

System Knowledge and Learning

Over 90% of the drivers interviewed reported reading all or some part of the information relating to the ACC system in their owner's manual; 61% reported reading all about the ACC system, and 30% reported reading a little. Although these percentages appear somewhat high (and perhaps surprising), it is not inconsistent with previous work. Leonard (2001), for example, found that although only 10% of drivers in his sample read the entire owner's manual, 62% reported reading specific sections (special topics) within their owner's manual. Older drivers (age 60 and above) were most likely to read the entire ACC section in the owners manual, while younger driver (ages 20-39) were most likely to read a little or none of the manual (see Figure 30).

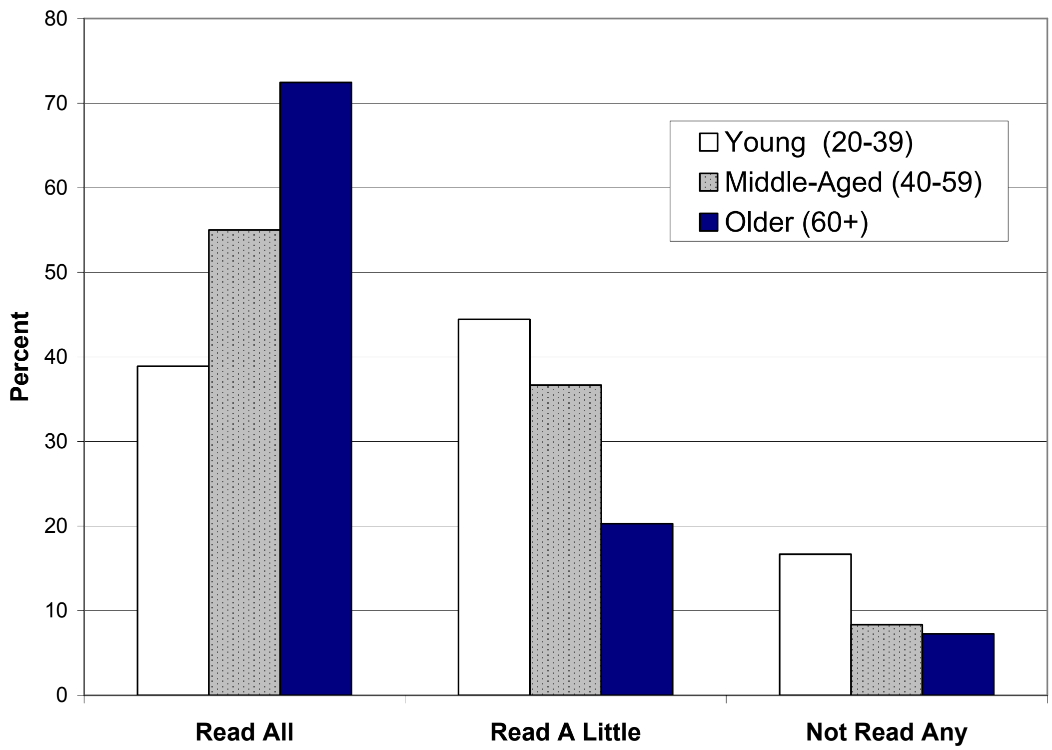


Figure 30 Percent of Drivers Reading the Owners Manual as a Function of Age Group

Although the owner's manual was a major source of information for many drivers, it was not the only source for learning about the functions, capabilities, and limitation of the ACC system. As shown in Figure 31, over half of the drivers (51%) received some limited instruction on the use of the ACC system by dealership sales staff, and 30% had access to videos or brochures which described the system. Nevertheless, on-road experience using the system was the most frequently cited means of learning about the system; 95% of drivers relied on trial and error through experience with the system.

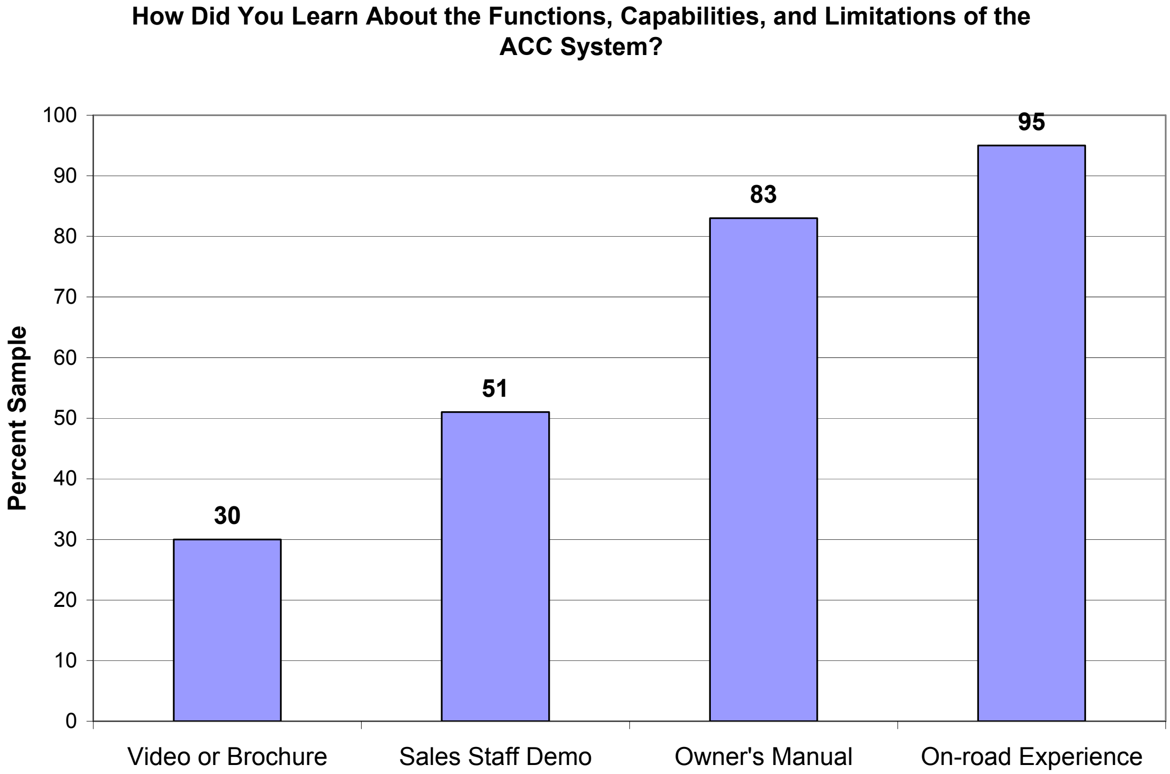


Figure 31 Information Sources Used by Vehicle Owners to Learn About System Capabilities, Limitations and Functions

Despite access to a wide array of information about the ACC system (owner's manual, access to brochures, videos, sales staff, as well as direct experience with the system) responses to knowledge-based questions about the system itself suggest that key information was not necessarily acquired or understood by a large number of drivers. Many held misconceptions (some potentially dangerous) about the functional capabilities of the ACC system. For example, when asked about how the system would react to a stopped vehicle ahead, only about 1% of drivers (2 out of 150, both middle aged drivers) were able to correctly answer the question (e.g., the system would not be able to detect the stopped car). Most owners erroneously believed that the ACC system would react to a stopped in-path vehicle in much the same manner as a forward vehicle the system was tracking (refer to Figure 32). That is, the system would detect the stopped vehicle and begin to slow, but the driver would eventually need to intervene in order to be able to avoid striking the vehicle. The fact that the system would ignore stopped or slow moving vehicle is available in the owner's manuals for all of the ACC systems reviewed, yet drivers were not aware of this important operational characteristic of the system (refer to Appendix G). For example, the 2004 Toyota Sienna owner's manual states that, "Under certain conditions where the vehicle in front slows drastically, or is stopped, the dynamic laser cruise control will neither warn you nor decelerate," (page 196). Similarly, the 2003 BMW 7-Series owner's manual states, "It [the active cruise control] will not apply the brakes or decelerate your vehicle when there is a slow-moving vehicle, stopped vehicle or stationary object ahead of you" (page 77). Moreover, this inaccuracy regarding system performance was pervasive across all experience levels with the ACC system and did not appear to change over time with ACC system usage.

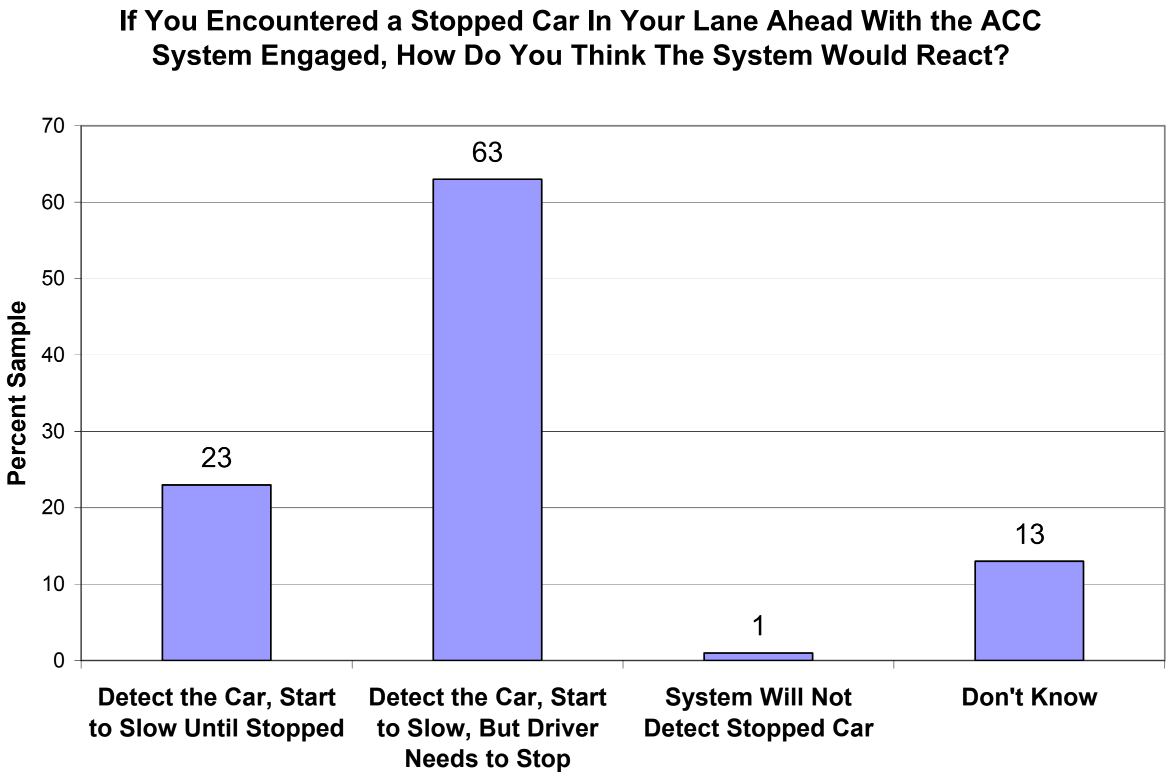


Figure 32 Driver Response to Key Safety Issue Related the ACC System's Ability to Detect In-Path Stop Vehicles

All of the ACC systems in the sample included an approach warning feature which alerts the driver under situations when system braking is insufficient to handle the closing distance to the lead vehicle and manual intervention by the driver is required. When asked about the existence of this feature, 29% of drivers did not know that their ACC system provided this type of approach warning or alerting function. Some ACC systems (those on the Jaguar and Mercedes) provide this approach warning function even when the ACC system is disengaged (e.g., turned off). Of those drivers in our sample with this expanded functionality, 57% (4 of 7) were not aware that the warning was available even when the ACC system was disengaged. Of greater concern are drivers who think that the warning feature operates all the time, but in fact does not. Over 6% of drivers in our sample were under the mistaken impression that the approach warning feature is active in their vehicles even when the ACC system is disengaged; these individuals are assuming a greater level of protection than the system actually provides. Again, this misinterpretation of the system's capability was not moderated by experience with the system.

Most drivers (90%) rated their ACC system to be very or somewhat easy to learn, with many drivers (61%) feeling comfortable with the system after the first 2-3 days of use. Ratings of learning difficulty were similar across age groups, suggesting that older drivers did not find the system more or less difficult to use than younger or middle-aged drivers (refer to Figure 33). Nevertheless, some drivers (approximately 12%) found certain system features and interactions to be difficult to learn; including, setting the system speed and headway, adjusting headways, turning the system on and off, deciding when to use the system, selecting an appropriate headway, and switching between ACC and conventional cruise control. Note that most comments were from Infiniti, Lexus, and Toyota owners, however, given the relatively small sample it may not be suggestive of particular problems with these system designs.

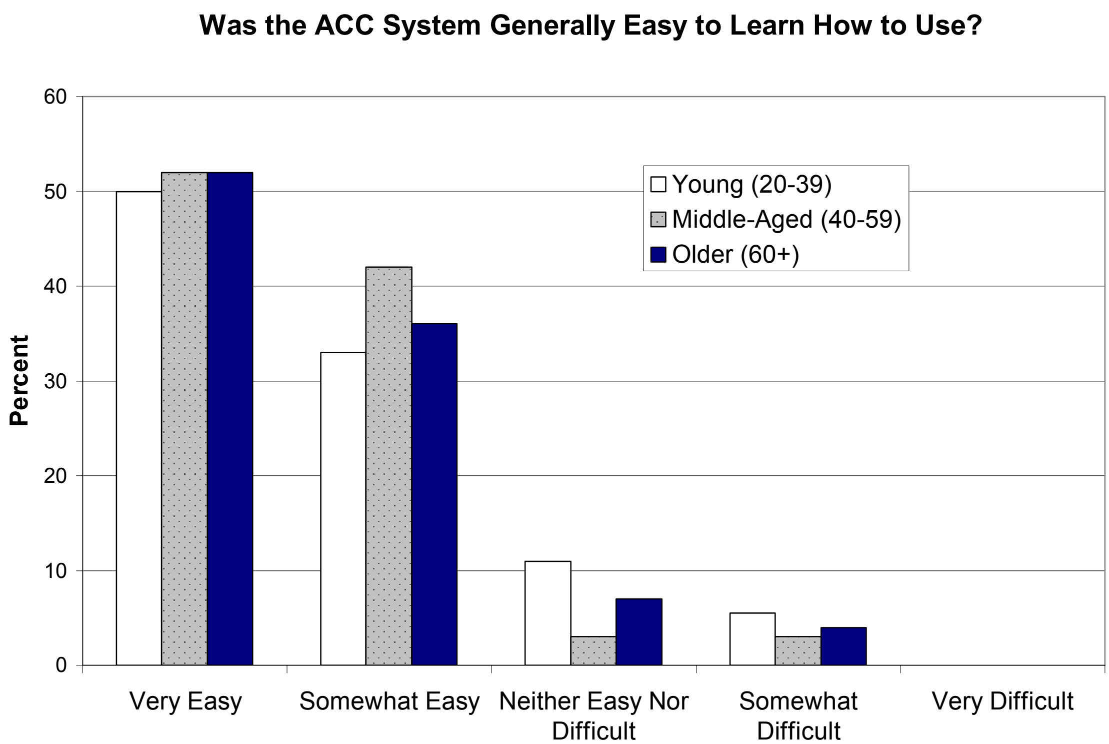


Figure 33 Driver Ratings of ACC System Learning Difficulty as a Function of Age

Safety & Behavioral Impacts

Although many ACC system owners (41%) perceive the system as solely a comfort and convenience device (consistent with how the systems are marketed), most owners recognize the important safety benefits of the system. A considerable percentage of owners (34%) regard the ACC system as primarily a safety feature, and the overwhelming majority of ACC system owners (84%) feel the system improves safety over conventional cruise control. Forty-three percent of drivers believe that the system reduces their likelihood of being involved in a crash while using the system, and 38% of drivers feel the system increases their ability to predict and respond to roadway hazards and their awareness of the environment. Driver trust in the system's ability to respond to other vehicles appears to increase over time, as does system use.

Data also suggest that some drivers modify their behavior as a result of interactions with the ACC system; among these is their use of cruise control, typical following distances, and frequency of lane changes. As shown in Figure 34, almost half of the drivers sampled (48%) use their ACC more frequently compared to their use of conventional cruise control. The typical following distance to lead vehicles has also increased for 39% of the drivers sampled; although some drivers (4%) report adopting shorter headways as a result of using ACC.

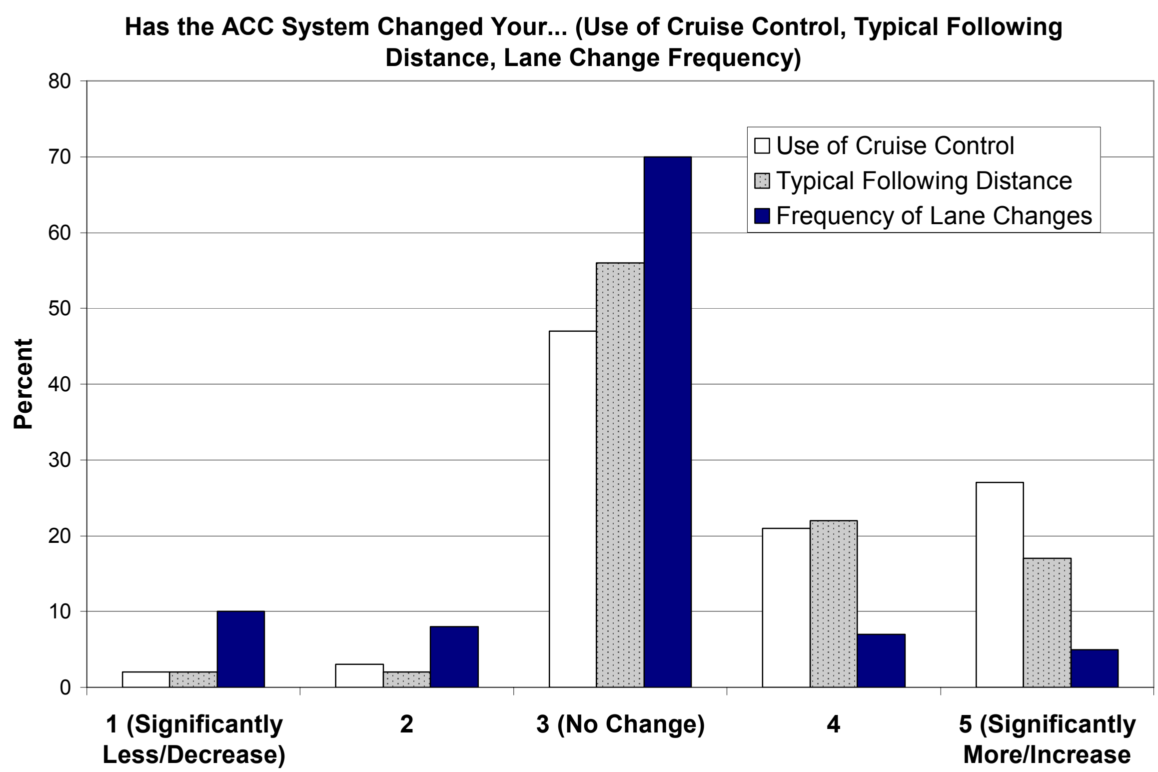


Figure 34 Behavioral Impacts Associated With ACC Use: Use of Cruise Control, Following Distances, and Lane Changes

ACC usage tends to have no appreciable impact on the frequency of lane changes for the majority of drivers (70%); when modifications do occur, they appear nearly evenly distributed in terms of increasing frequency of lane changes for some (12%), and decreasing the frequency for others (18%).

Data indicate that most drivers typically set the ACC's following distance to the medium (34%), or longest headway setting (27%). About 1 in 5 drivers (19%) use the shortest setting allowing them to get as close to the lead vehicle as possible. One important issue is the extent to which drivers adapt their use of the ACC system to the prevailing roadway and environmental conditions. In specific, adjustments to following headway under conditions of rain and heavy traffic. As shown in Figure 35, most drivers increase their headway settings under conditions of rain (43%) and in heavy traffic (22%). Surprisingly, a considerable percentage of drivers do not change their headway settings under either of these conditions. Not surprisingly, many drivers adopt shorter headways under heavy traffic conditions (presumably to minimize the incidence of cut-ins); some drivers indicated the desire to have the ability to select shorter headways than were currently provided by their system.

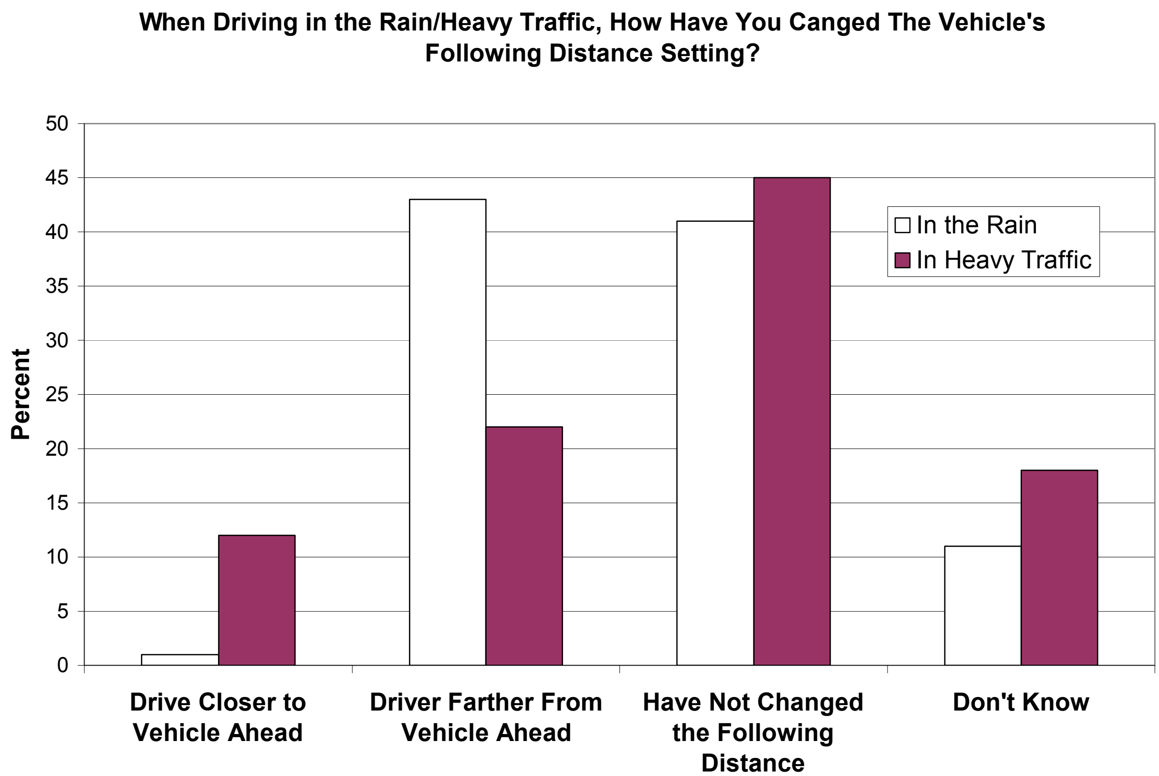


Figure 35 Percent of Drivers Who Adjust ACC Headway Settings Under Conditions of Rain and Heavy Traffic

Although it is possible drivers are not making headway adjustments because they simply do not know how to make these adjustments, this is unlikely given that 80% of drivers reported making adjustments to the system's following distance settings, and nearly 90% of the drivers reported reading all or part of the owner's manual relating to the operation of the ACC system. (Note that 18% of drivers report not making any changes to the headway setting since the vehicle was purchased).

Drivers were also asked about the extent to which their ACC system was perceived to react in ways (and under situations) that may be unexpected (Note that driver perceptions of unusual or unexpected ACC system behavior is likely influenced by their level of experience with and understanding of the system). One particular concern is that the ACC system may brake suddenly (e.g., trigger braking in response to a guard rail or overhead sign) or harder than expected thereby increasing the risk for rear-end crashes if the following vehicle driver is not alert or is following too closely. Although this type of situation may occur in the normal course of driving, its frequency of occurrence could increase under ACC driving. All of the ACC systems examined automatically trigger the vehicle's brake lights when the system decelerates or engages braking (presumably to minimize the incidence of rear-end collisions). Data from our sample of drivers suggest that although the incidence of this type of situation is rare (where ACC system braking causing the following vehicle to get uncomfortably close or brake hard), some drivers have experienced these events. As shown in Figure 36, 9% of drivers (16 out of 150) reported experiencing situations in which the ACC system braked hard or abruptly causing the following vehicle to brake hard or get uncomfortably close (this includes drivers who reported experiencing situations often or occasionally). None of the drivers in our sample, however, reported being "rear-ended" (being hit from behind) by another vehicle while using the ACC system. Nevertheless, additional data is needed to understand whether (and under what conditions) the use of ACC may increase the incidence of close calls and rear-end collisions. Our limited data indicate that some drivers may experience these types of "close calls" while using ACC but did not establish whether the frequency of this type of event is greater than drivers would normally experience.

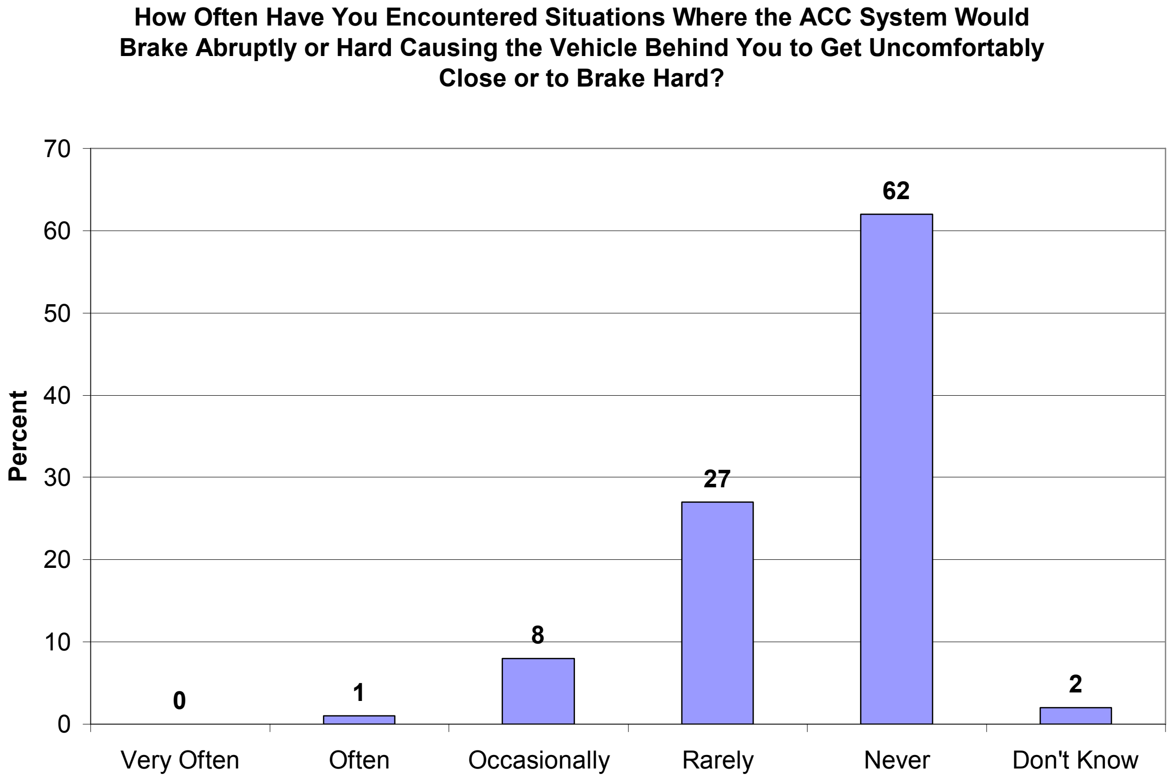


Figure 36 Reported Incidence of Hard/Unexpected ACC Braking Leading to Close Calls with Following Vehicles

Other types of unexpected ACC system behaviors reported by drivers are presented in Figure 37. The most commonly reported unexpected behavior was ACC slowing. Although speculative, this may reflect transient situations where the system activated in response to an object other than a lead vehicle (e.g., guard-rail, overhead sign, adjacent vehicle, etc.), and reacted by temporarily slowing the vehicle. Situations in which the system apparently failed to slow down or detect a vehicle were also fairly common, experienced by 24% of the drivers sampled. These types of events are particularly troublesome and may represent actual system failures or situations in which drivers erroneously expected the system to react by slowing. The latter explanation would include situations in which drivers incorrectly expected the ACC system to respond to a stopped or slow moving vehicle (a mistaken belief held by the overwhelming majority of system owners). Drivers also reported experiencing situations where the system unexpectedly sped-up (9% of drivers sampled), and dropped a lead vehicle the system was tracking (7% of drivers sampled). It is likely that some percentage of these situations (e.g., system sped-up unexpectedly) occurred as a result of the system being operated in non-optimal environments and poor driving conditions (e.g., rain, curvy roads, snow, etc.); many drivers, for example, indicated using the system in the rain, snow, freeway on-ramps, curvy roads, etc.

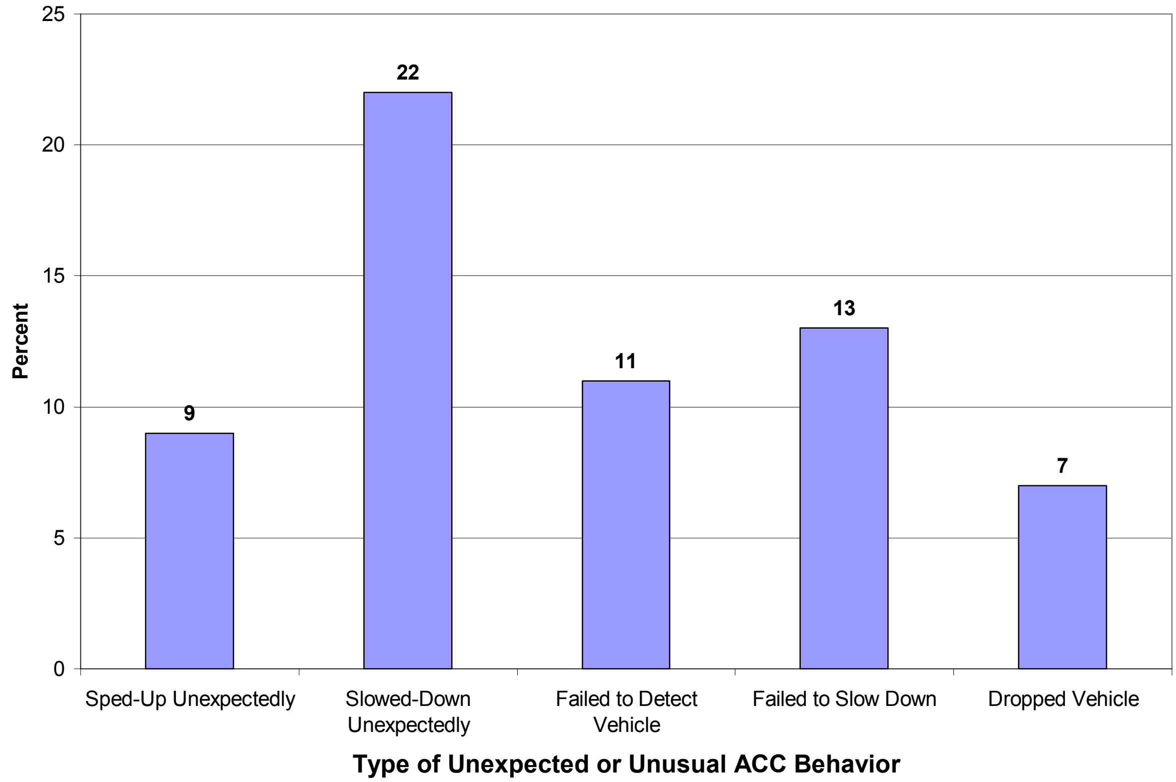


Figure 37 Unexpected ACC Behaviors Experienced by System Owners

Interface

ACC system controls and visual displays allow drivers to input, adjust, and view system settings (including set speed and distance settings), turn the system on and off, and determine when the system has detected a vehicle, among other functions. Audible cues also provide important functions including signaling drivers when to intervene (approach warning), and informing them of changes in system status. Nearly all owners found the ACC system displays and sounds to be intuitive; less than 4% of the sample (about 6 drivers) reported problems with these elements (found them to be not at all intuitive). Surprisingly, some ACC system owners reported that the system had no associated sounds (12% of the sample) or visual displays (3% of the sample). Drivers who reported having no audible or visual displays included owners of BMW, Cadillac, Infiniti, Lexus, and Toyota vehicles – all of which do possess ACC specific audible and visual displays. It is possible that these individuals were not aware of the presence of these displays, or had not yet experienced them. It is also possible that these drivers simply did not associate the sounds or displays with the ACC system. Yet another possibility is that these drivers did not in fact own a vehicle equipped with an ACC system and therefore were not knowledgeable about the presence of these displays (in this case, questions about the presence of these type of displays could serve as good screening items). Since, 10 of the 21 owners (47%) had vehicles (Toyota Sienna XLE Limited and Cadillac XLR) which came equipped with ACC as a standard feature, the last option seems unlikely to account for this finding. This suggests that some drivers were simply not aware of the existence of ACC system audible and visual displays.

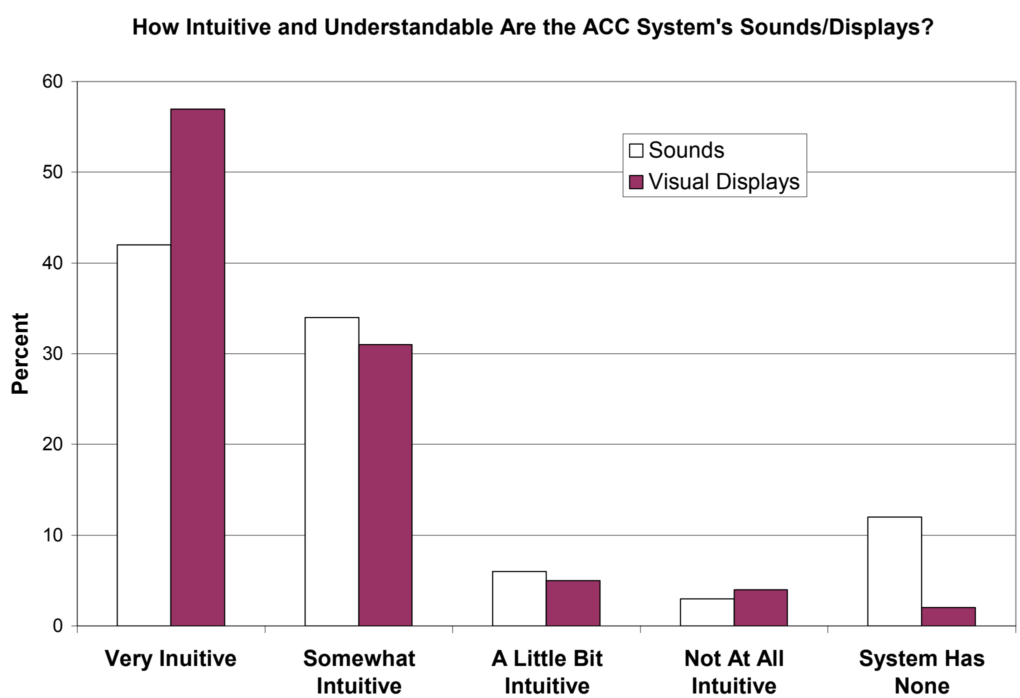


Figure 38 Owner Ratings of the Intuitiveness of ACC System's Sounds and Visual Displays

When asked a more specific question dealing with the ability to read the ACC system's displays and interpret the available information, more drivers appeared to have difficulty with the system displays (see Figure 39). Specifically, 13% of the owners sampled, indicated being somewhat or very confused about the set following distance. Fewer owners reported being confused (somewhat or very) in regard to the system's set speed (about 5% of the sample). Although the majority of the sample reported never being confused about the vehicle's set speed (83%) and following distance (69%), there does appear to be some room for improvement in designing displays to more effectively communicate speed and distance settings to drivers. Older drivers were somewhat less likely to be confused about the set headway; 25% of older drivers reported some level of confusion versus 37% and 39% of middle-aged and younger drivers, respectively. This may be due to the fact that older drivers were more likely to read the ACC manual compared to drivers in the other age groups.

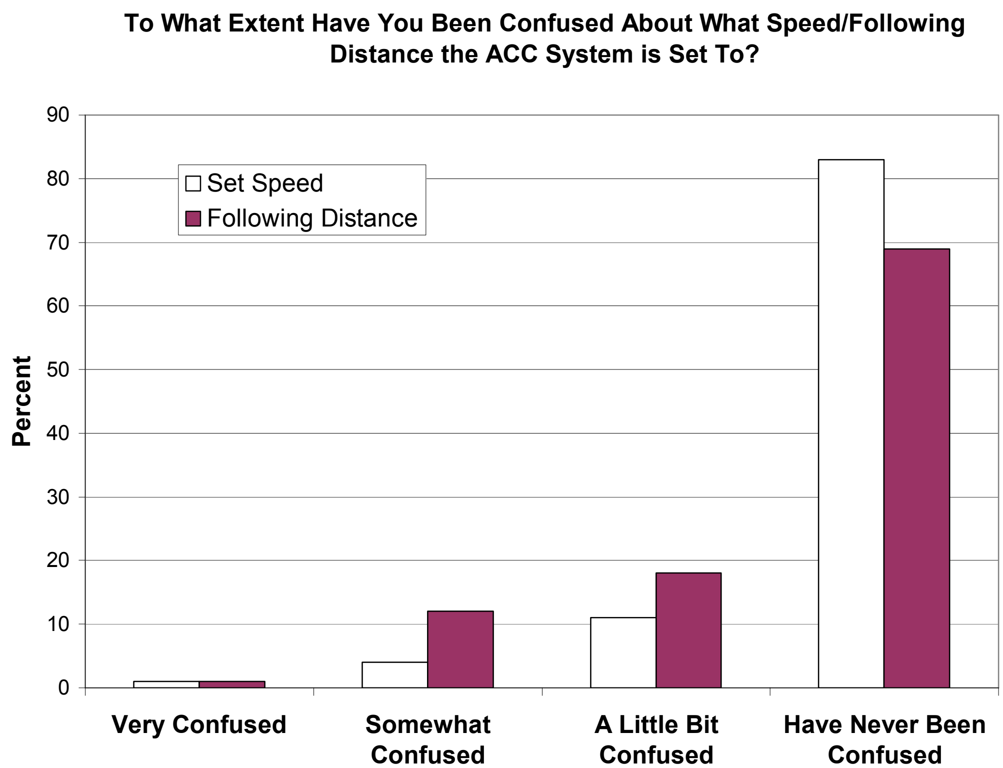


Figure 39 Percent of Drivers Who Report Being Confused About ACC Set Speed and Distance Settings

Approximately one-third of the owners sampled have ACC systems which are integrated with conventional cruise control, offering drivers the ability to use either ACC or conventional cruise control. This feature is available in Infiniti, Lexus, and Toyota systems. Although designers have taken steps to minimize confusion about which system is in use (conventional or adaptive cruise control) through unique displays and lockouts to avoid accidental or inadvertent changes from one system to another, the opportunity for driver error and confusion remains a real concern. In particular, drivers operating under the false assumption that the ACC system is engaged, when in fact the convention cruise is operating, run the risk of colliding with a lead vehicle (or coming uncomfortably close). As shown in Figure 40 although the vast majority of drivers sampled (78%) have never been confused about which system is operating (either conventional or adaptive cruise), approximately 22% of drivers report being confused to some degree (a little bit or somewhat). This suggests that drivers need to become better educated about their systems (i.e., come to understand how to discriminate between operating modes), and/or the displays need to be better designed so that differences in operating mode are more readily apparent. Drivers with an intermediate level of experience were more likely to be confused about the status of the system compared to inexperienced or experienced users; of those reporting some degree of confusion, 73% had intermediate levels of experience.

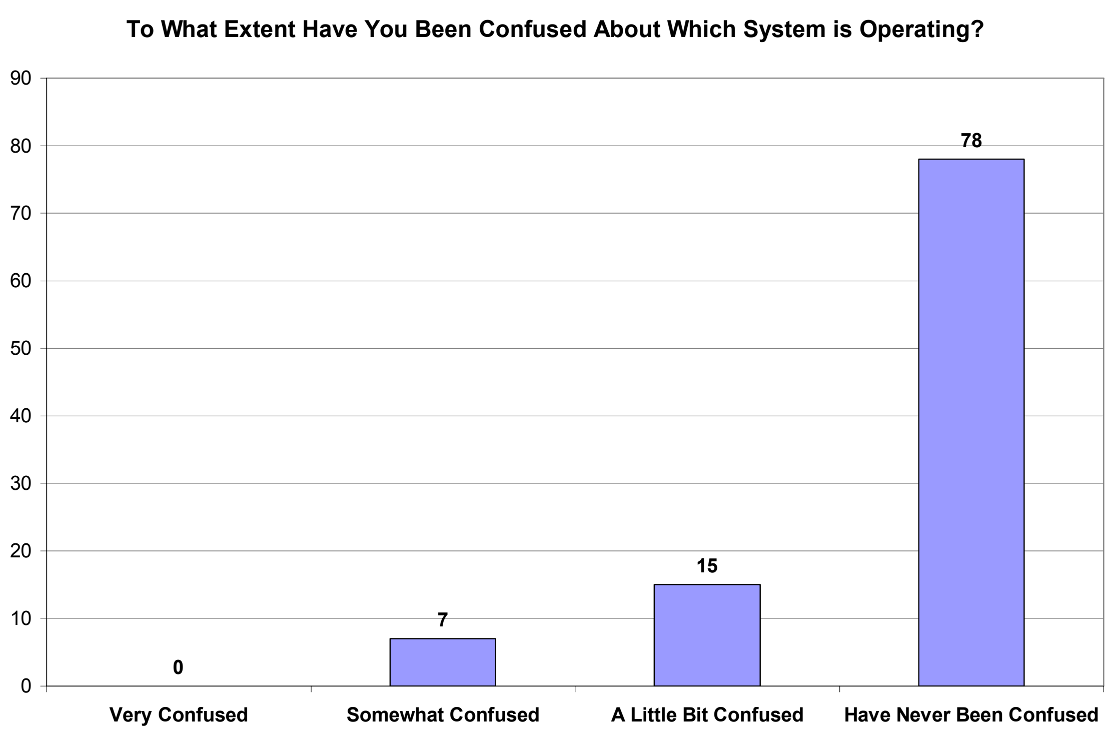


Figure 40 Percent of Drivers Reporting Being Confused About Which System (Conventional or Adaptive Cruise) is Operating

Individuals were provided with the opportunity to offer suggestions for improving aspects, features, and/or functions associated with the ACC system. While many individuals (48% of the sample) offered no suggested changes, most provided recommendations for possible system improvements. As shown in Figure 41, recommendations fell into three general categories related to extending the performance capabilities of the system (operating in rain, better acceleration, etc.), improving aspects of the interface and making the system easier to learn and use (bigger display, more instruction on system use, etc), and other miscellaneous comments. The two single biggest sets of comments dealt with extending the system's performance capabilities under rainy conditions so that it operates more reliably (12%), and general calls to make the system more user friendly (11%). Some drivers suggested increasing the number of headway settings with some desiring the capability to select shorter headways (allowing them to follow a lead vehicle at closer ranges). Others wanted a system capable of being used in heavy traffic.

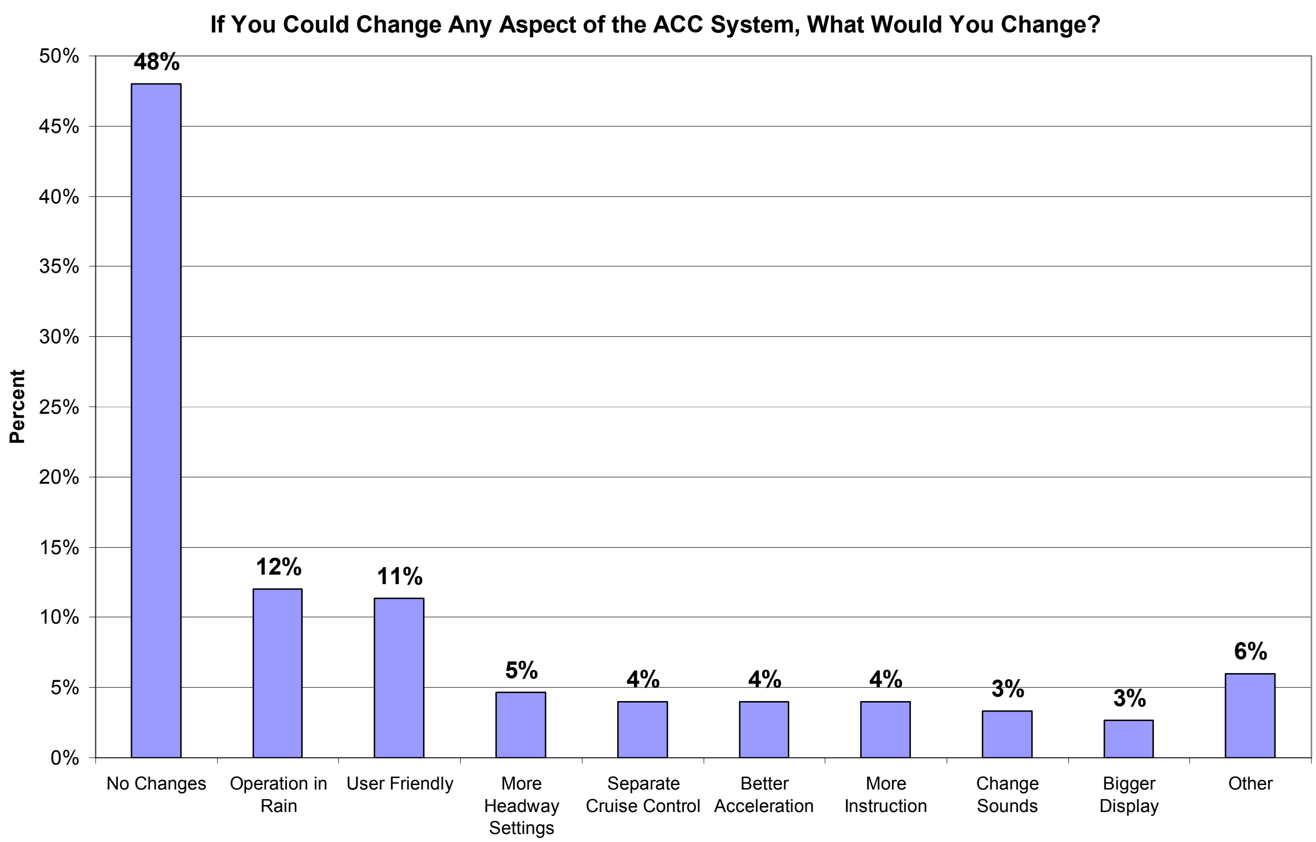


Figure 41 Recommended Changes to ACC System

ACC Design Influences

A number of different control and display designs were represented in the sample of ACC systems. This section examines and summarizes data bearing on the relationship between system design/interface aspects and driver performance and understanding of the systems. In many cases, the ability to make direct comparisons across system designs was limited due to restricted sample sizes. Also, observed or apparent differences across system designs may result from factors other than the particular interface characteristic examined. Thus, these data are only intended to provide some basic or exploratory insights into the potential influence of specific interface design characteristics; the analysis may, however, serve to guide future controlled experiments into these types of issues.

Survey results found that approximately 31% of ACC system owners report being confused to some extent about the set headway while using the system. Differences in the way headway information is displayed to drivers was examined in an attempt to identify whether specific display formats contribute to more confusion regarding the set headway. Two key interface dimensions were examined: 1) the orientation of the pictorial display representing headway or following distance, and 2) the number of available headway settings. Systems typically present headway information using pictorial displays with a representation of the lead vehicle with some form of spacing (distance bars) to represent the various levels of set following distance. Some systems orient the display vertically so that the lead vehicle is spatially represented in a manner consistent with the image out the windshield (vertical alignment). Others orient the display horizontally with the lead vehicle aligned in the horizontal axis (horizontal alignment). Given that the horizontal alignment approach may require drivers to mentally rotate the image, one could hypothesize that this design may lead to more confusion about the set headway spacing than the vertical alignment approach. As shown in Figure 42, no obvious differences in display orientation were found in terms of their likelihood to lead to driver confusion (in fact slightly more confusion was associated with the vertical alignment approach).

More detailed examination of the particular system designs for owners reporting being somewhat or very confused about the distance displays (set headway) did not reveal any obvious patterns in system design. An equal number of BMW and Toyota owners reported problems interpreting distance settings even though these systems orient the distance display in different axes (the BMW is aligned in perspective, while the Toyota's is horizontally aligned), and offer a different number of discrete following distances (the BMW offers four following distance settings and the Toyota offers three). It is important to note, however, that systems within a particular orientation, also differed on other factors, including the specific graphics used to depict vehicles, spacing, and the number of distance settings.

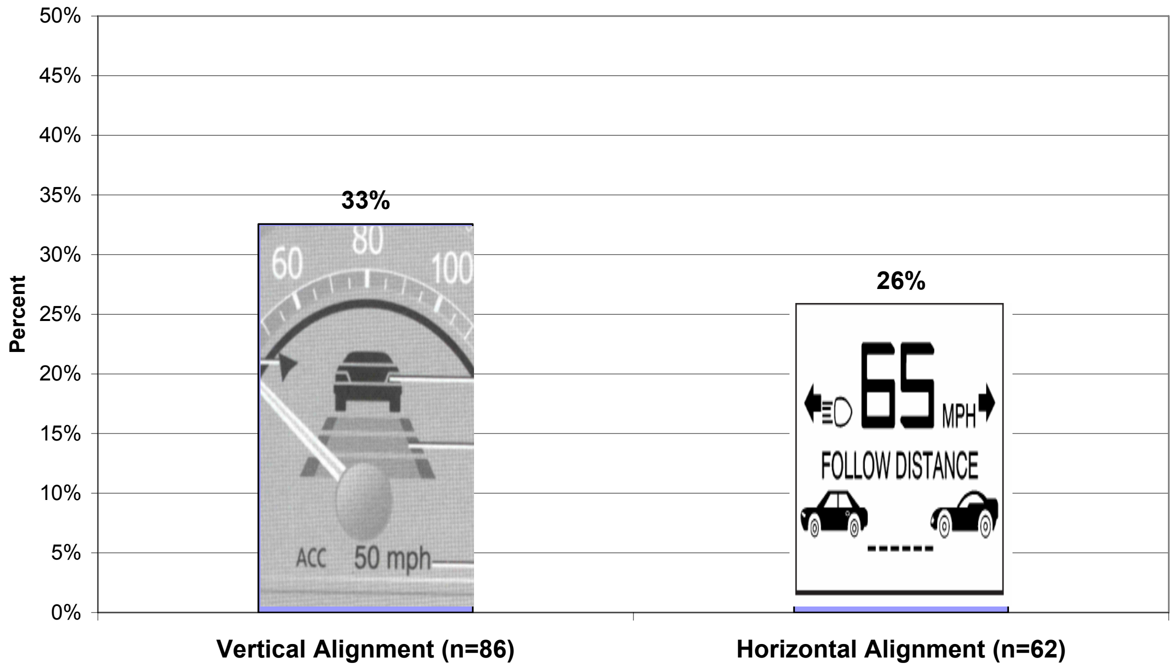


Figure 42 Percent of ACC Drivers Reporting Confusion (Very, Somewhat, or A Little) Over ACC Set Headway (Following Distance) as a Function of Display Orientation

ACC systems in our sample included a range of discrete distance settings including three (long, middle, short), four and six presets, as well as one system that offered continuous adjustments (no defined presents). Systems were grouped and analyzed in terms of the number of available headway/distance settings offered to drivers in order to see whether confusion about the set headway increases with increasing headway options. As shown in Figure 43, the results are mixed and difficult to interpret. Although there is some evidence to suggest that increasing the available number of headway settings from 3 to 4 increases the potential for confusion, this trend does not hold when the number of headway settings is increased to 6 discrete settings. The small sample size makes it difficult to obtain reliable data when extended beyond 4 discrete settings. Thus, the available data are inconclusive, but worthy of further study.

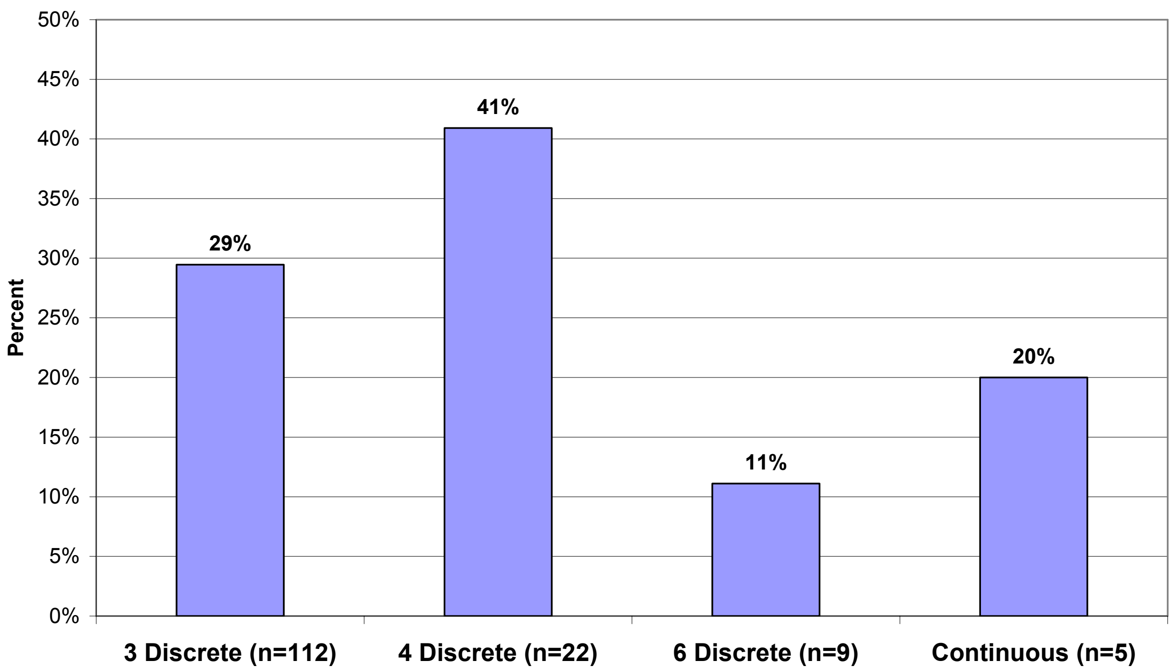


Figure 43 Percent of ACC Drivers Reporting Confusion (Very, Somewhat, or A Little) Over ACC Set Headway (Following Distance) as a Function of the Number of Available Settings

Three vehicle models in our sample (Infiniti, Lexus, and Toyota) integrate ACC with conventional cruise control, affording the opportunity for the problem of mode confusion (where drivers are unsure of whether the cruise control is operating in adaptive or conventional mode) to arise. As previously discussed, ACC mode confusion occurred to some degree for approximately 20% of drivers in our sample. Figure 44 shows the percentage of drivers within each type of vehicle reporting some degree of mode confusion. There appears to be a difference across system makes between the Toyota ACC system and the other two systems (Lexus and Infiniti) suggesting that Toyota's design may possibly lead to fewer mode confusions. Differences in display designs across systems were examined.

Although no definitive design differences among the systems were found that can explain the apparent observed differences in mode confusion across systems, drivers may benefit from the use of a dedicated mode display indicator which is distinct and conspicuous. All three ACC models allow drivers to determine the ACC system state by information provided in a visual display. Typically, the display includes a lead vehicle icon and distance bars (or other symbols to denote following distance) when operating under ACC mode. These display elements are not presented when operating in conventional cruise control mode; the absence of information indicates operation in conventional mode. Toyota's system also provides a dedicated indicator light on the instrument panel labeled, “NORM.” to denote that the cruise control is operating in conventional mode. The Lexus system also provides a visual mode indicator (labeled “NORM” or “RADAR”), within the ACC display area. The Infiniti FX ACC system does not appear to have a dedicated mode indicator – the absence of the ACC display elements (e.g., vehicle ahead indicator, distance indicator) serves as the primary means of distinguishing between operating modes.

Apparent differences in mode confusion among the systems could also result from differences in system usage rates, in particular the relative use of ACC and conventional cruise (this specific aspect was not explored). However, ACC system usage rates did vary across models for drivers who indicated some degree of mode confusion. Toyota system owners used the system an average of 3 times per week, while Infiniti and Lexus owners tended to exercise the system much less on average, 1.33 and 0.75 times per week, respectively. Thus, it appears that mode confusion may be less likely to occur with increasing system use and experience. Nevertheless, displays could be better designed to make operating mode more evident to even inexperienced or infrequent system users by incorporating a separate and distinct mode indicator.

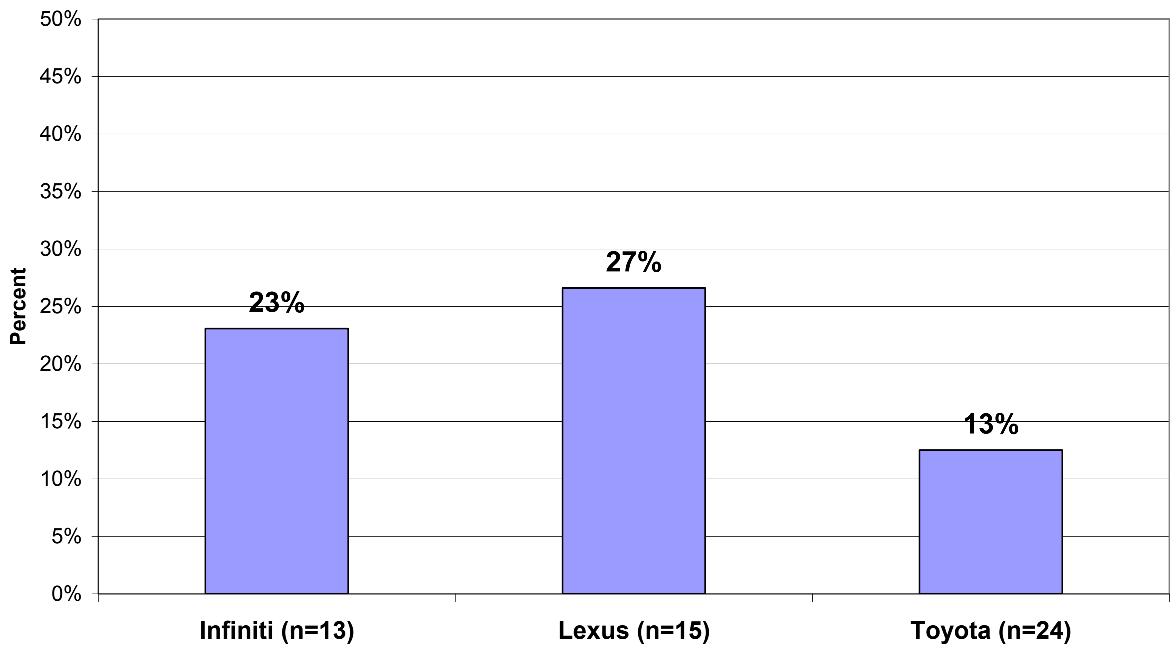


Figure 44 Percentage of ACC System Owners With Integrated Systems Who Report Being Confused (Very, Somewhat, or A Little) About Which System is Operating, Conventional or Adaptive Cruise.

ACC System Summary

Interviews were conducted with 150 ACC system owners; the sample included vehicles from each of the eight major vehicle manufactures offering ACC in the United States. The sample was heavily represented by males (comprised 65% of the drivers) and older drivers (mean age was 56 years), but offered a range of experience levels with the ACC system. Drivers tended to use the system more frequently compared to conventional cruise control, averaging 3 uses per week. The ACC system was perceived to be very useful and effective with a majority of drivers (85%) indicating they would recommend the system to a friend. Most drivers (84%) felt the system improves safety over conventional cruise control, and many (43%) indicated that the system reduces their likelihood of being involved in a crash. Nearly all drivers (90%) rated their system as easy to learn with the majority of drivers feeling comfortable operating the system after the first 2-3 days of use.

While nearly all drivers read all or some part of the owners manual relating to the ACC system, many held misconceptions about the functional capabilities of the system. For example, most owners mistakenly believed the ACC system would react to a stopped in-path vehicle, and many were not aware that the system provided an approach warning feature that alerts the driver when manual intervention is required in situations where the system's braking authority is exceeded. Situations in which the ACC system reacted in unexpected or unusual ways were reported by some drivers; instances where the system caused the vehicle to slow-down unexpectedly were experienced by 22% of drivers. Drivers also reported experiencing situations where the ACC system braked hard or abruptly causing the following vehicle to brake hard or get uncomfortably close. No drivers reported being rear-ended while using the ACC system.

The ACC system was also found to influence headways adopted by drivers; some adopted greater following distances when using ACC, while others adopted shorter headways. Evidence also suggests that while some drivers adapt their headway settings based on prevailing environmental conditions, a substantial percentage of drivers (over 40%) do not adjust headways in response to rain or heavy traffic. Experience with the ACC system influences driver willingness to operate the system under a range of different environments. Drivers, for example, tend to increase their use of the system in heavy traffic, on curvy roads, and a nighttime as they gain experience with the system.

While most drivers found the system displays and sounds to be intuitive, some suggested using larger displays and more defined sounds; a substantial percentage of drivers (12%) were not aware that the system provided audio alerts or sounds (e.g., indicate the need for driver intervention or braking). Data also suggest that displays need to be more effectively designed to communicate specific information items including distance and speed settings, and operational modes to drivers.

Park Aid Systems

This section presents results from interviews conducted with 298 park aid system owners. The sample included systems from 15 different vehicle makes; systems from Cadillac (23%), Ford (12%), Toyota (12%), Infiniti (10%), and Lexus (10%) were among the most highly represented (see Table 23). Approximately one-quarter of the sample included systems equipped with rearward camera views.

Table 23 Breakdown of Park Aid System Respondents by Vehicle Make and Model

Vehicle Make	Vehicle Model	Total Number In Sample	Percent of Sample
Acura	MDX (9)	9	3%
Audi	A8L (1)	1	--
BMW	7 Series (19); 5 Series (3)	22	7%
Buick	Rendezvous (1)	1	--
Cadillac	Deville/DHS/DTS (59); Escalade (3); XLR (8)	70	23%
Ford	Aviator (1); Escape (2); Expedition (5); Windstar (29)	37	12%
Infiniti	Q45 (26); FX (4)	30	10%
Jaguar	XKR (5)	5	1%
Land Rover	Range Rover/Discovery (6)	6	2%
Lexus	LS 430 (20); RX (9)	29	10%
Lincoln	Aviator (5); Navigator (13); Town Car (1)	19	6%
Mercedes-Benz	SL (1); S-Class (2); CLK 320/500 (1); E500 (1)	5	1%
Mercury	Mountaineer (2)	2	--
Oldsmobile	Silhouette (17)	17	6%
Toyota	Sienna XLE Limited (38)	36	12%

The availability of a park aid system factored in the decision to purchase the vehicle for a majority of cases (60%), and approximately 28% of the owners specifically asked for this option in their vehicles. Drivers overwhelmingly like their park aid systems with 94% of the sample indicating they would recommend the system to a friend.

Approximately 65% of the sample was male with predominantly older drivers (mean age 57 years); 13% of the overall sample were younger (ages 20-39), 37% middle-aged (40-59), and 50% Older (60+). General driving experience ranged from 7 to 61 years (mean of 40 years), with experience with the specific vehicle ranging from 100 miles to 100,000 miles (mean of 14,352 miles). The majority of cases (94 %) were drawn from RL Polk sampled states; Michigan (19%), Florida (16%), Virginia (14%), New York (14%), Illinois (12%), Texas (11%), and Colorado (8%). Other states represented in the sample included, California, Indiana, Kansas, Maryland, Minnesota, New Jersey, Nevada, Ohio, and Washington State. Table 24 summarizes key sample demographic data.

Table 24 Key Demographic and Experience Data for the Sample of Park Aid System Owners

n = 298	Mean	Standard Deviation	Min	Max	25th Percentile	50th Percentile	75th Percentile
Age	57.49	14.02	25	84	46	59	69
Years Driving Experience	40.33	14.36	7	61	28	41	50
Miles Driven in Vehicle	14,352	11,306	100	100,000	7,050	11,000	18,000
System Usage (per week)	16.41	16.28	0	90	6	12	21

System Usage

Unlike some in-vehicle systems which are specifically activated by drivers (e.g., Adaptive Cruise Control, Navigation System), most park aid system automatically activate when the vehicle is placed into reverse. In this case, therefore, usage refers to both the intentional act of turning the system on as well as relying on the information provided by the system. Drivers in the sample tended to use the system an average of 16 times per week, with estimated weekly usage ranging from 0 to 50 (the inter-quartile range was 6 to 21 times per week). Nearly three-quarters of the sample (74%) used the system frequently (very often or often) when they first purchased the vehicle. Use patterns did not vary considerably across age groups (see Figure 45). Usage remained about the same for the vast majority of drivers (66%), and increased for about one-third of the sample (33%) primarily due to greater trust and reliance in the system and realization of the benefits the system offers, including increased safety, and easier parking. Very few drivers reported a decrease in system use (some forgot the system was available, others preferred using the mirrors).

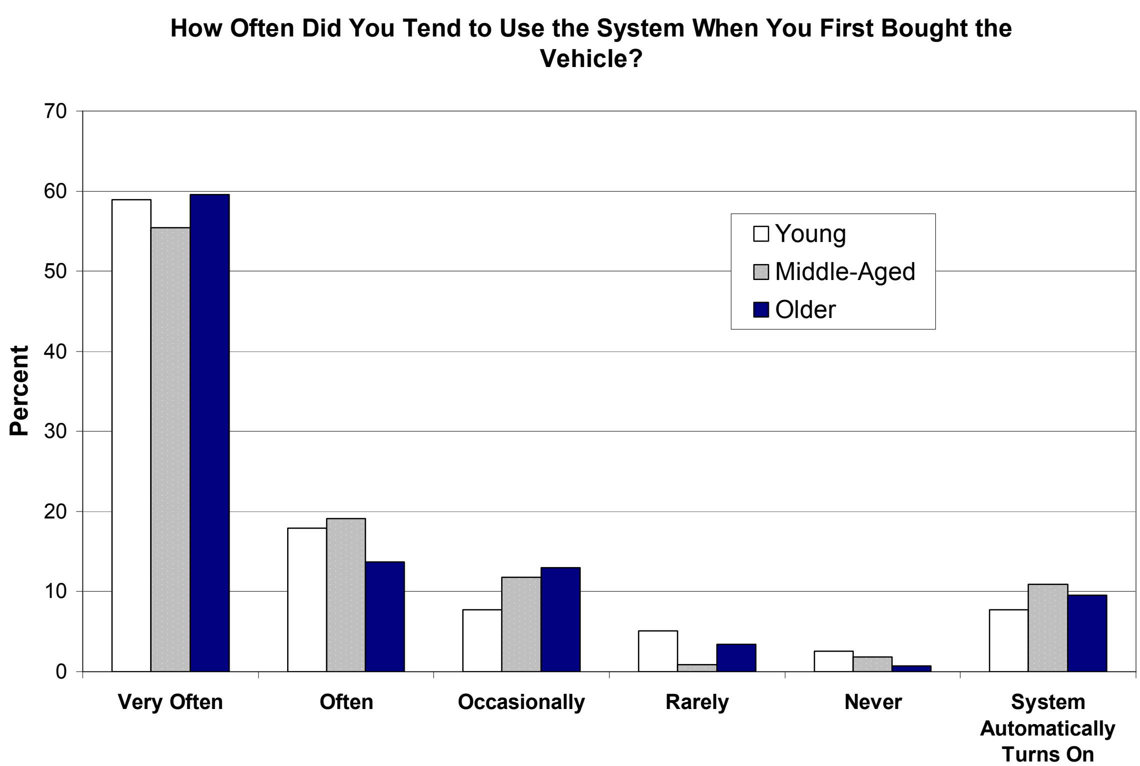


Figure 45 Reported Usage Rates by Driver Age Groups

Few drivers reported disabling or turning-off the park aid system, suggesting that the majority of drivers have used the system without experiencing undue problems across a range of operating conditions. As shown in Figure 46, drivers who do turn off the system have done so in response to poor weather, heavy pedestrian traffic, parking lots and garages, among other situations. None of these particular situations appears to be more likely to prompt drivers to turn-off the system than another. Nearly one-third of drivers (29%) report being unable to turn-off the park aid system – meaning the system does not provide an option for disabling the unit (this may suggest that more drivers would disable the system under specific conditions if they could). In some of these instances, the system did include a manual override or disable switch, but owners were apparently not aware of this feature.

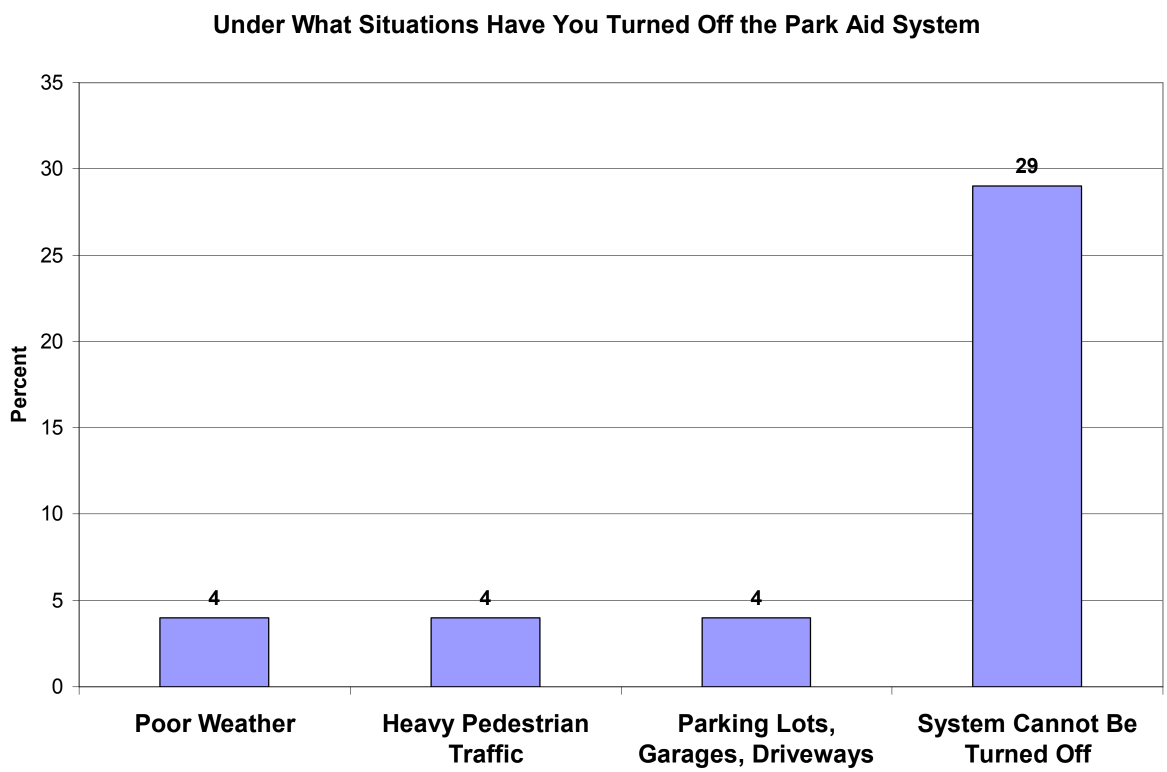


Figure 46 Percentage of Park Aid System Owners Who Report Disabling the System Under Different Environmental Conditions

Effectiveness & Acceptance

Nearly half of the park aid system owners (49%) indicated they would seek out this type of technology when buying their next vehicle, and the overwhelming majority of drivers (94%) would recommend a park aid system to a friend. Increased safety (preventing backing-related accidents, minimizing damage to vehicle, reduces blind spots, etc.), confidence, and performance when backing and parking (e.g., improves ability to maneuver in tight spaces, aids in judging distances while backing and parking, compensates for problems with depth perception) were among the most prevalent reasons for recommending the system. Some older drivers commented that the system reduces their need to turn around and look backwards; a perceived benefit for individuals suffering from limited range of motion and head/neck problems. Six percent of the drivers sampled (18 out of 298) would not recommend the system to a friend; some felt the alarms were annoying, and that the system did not provide sufficient value relative to the cost. Nevertheless, the majority of drivers (76%) rated the park aid system as very effective. Figure 47, provides a breakdown of how drivers rated various performance aspects of the system including its ability to alert drivers to the presence of obstacles, providing timely alerts, minimizing unnecessary or annoying warnings, and detecting obstacles located to the rear sides of the vehicle (off-angle objects). Clearly, a majority of drivers felt the system was effective across all of these dimensions (assigning ratings of 4 or 5). The system's ability to minimize false, nuisance and annoying alarms (and to a lesser extent its ability to detect off-angle objects) was not rated as highly by many users.

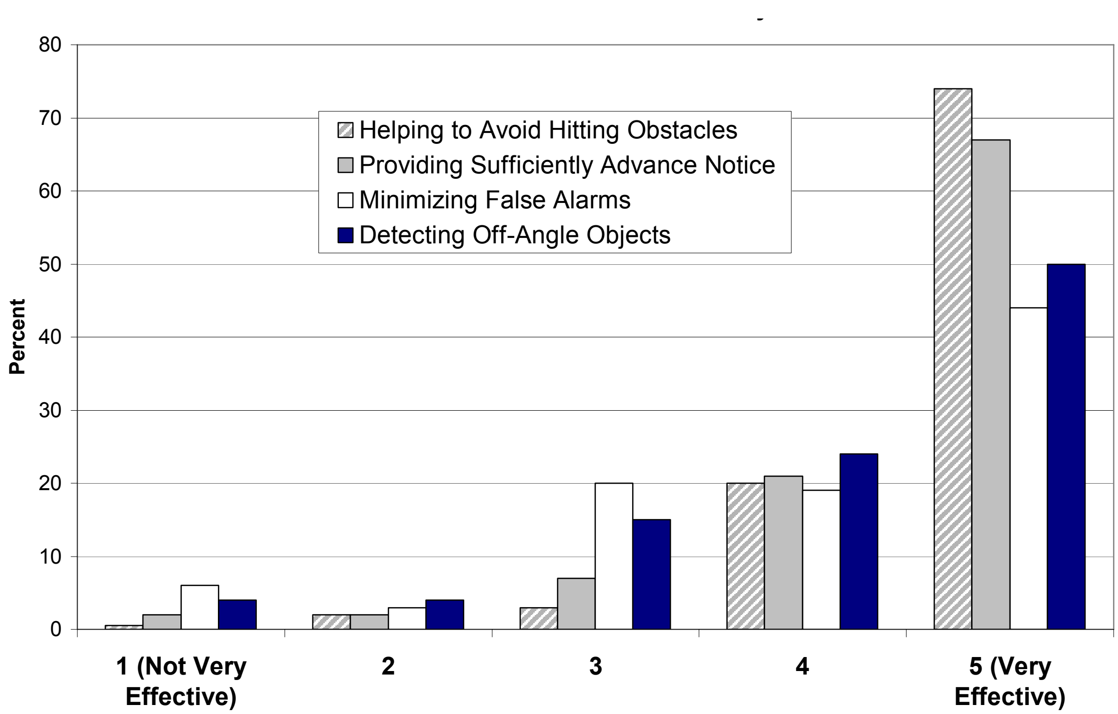


Figure 47 Owner Ratings of the Park Aid System's Effectiveness

System Knowledge and Learning

Approximately 80% of owners reported reading some or all of the information relating to the park aid system in their owners manual. As illustrated in Figure 48, young drivers were somewhat less likely than their counterparts to read all about the system in manual, while older drivers were somewhat less likely to bypass reading any part of the manual.

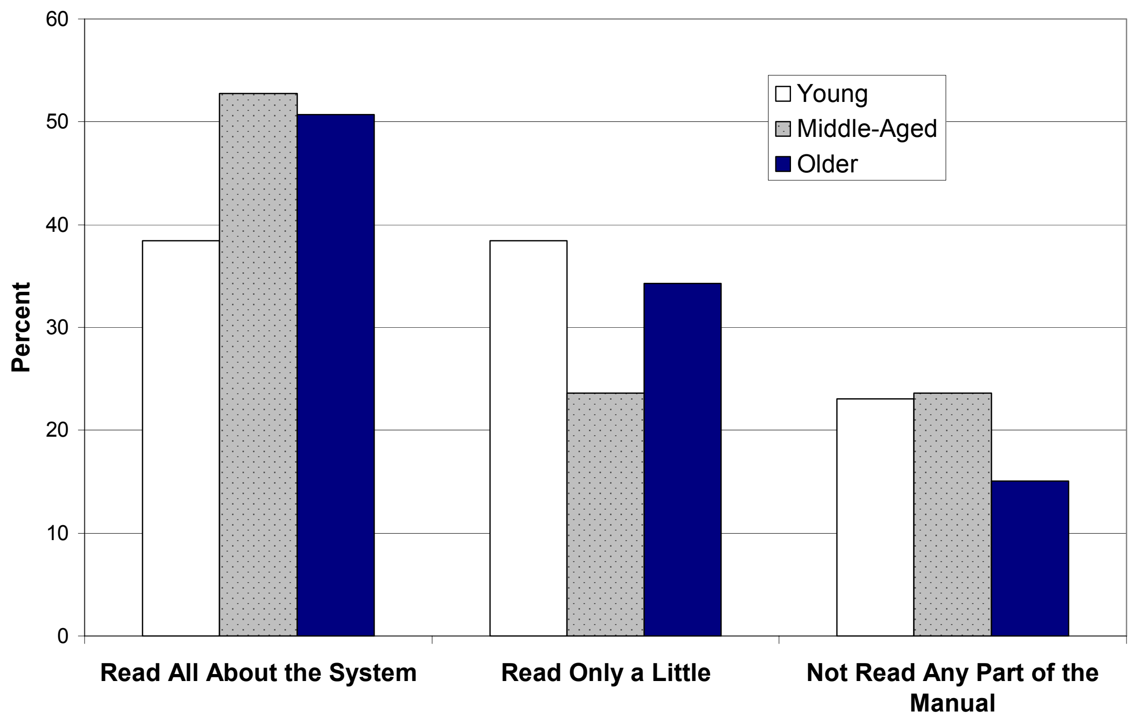


Figure 48 Percent of Drivers Reading the Owners Manual as a Function of Age Group

The majority of drivers (86%) relied on direct on-road experience with the system to learn about the functional capabilities and limitations of their park aid system (see Figure 49). Many drivers also used information available in their owner's manual and from sales staff demonstrations to learn about the system. Nearly all drivers (96%) felt the system was somewhat or very easy to learn, and most (60%) were comfortable using the system within the first 2-3 days of using it. A small percentage of drivers (6%) indicated that some aspects of the system were particularly difficult to learn; these included, understanding how the scale units of the visual display relate to actual external distance, interpreting the meaning of the audible beeps (how the tones relate to actual distance), discriminating real from false alarms, and coming to understand the reliability and accuracy of the system.

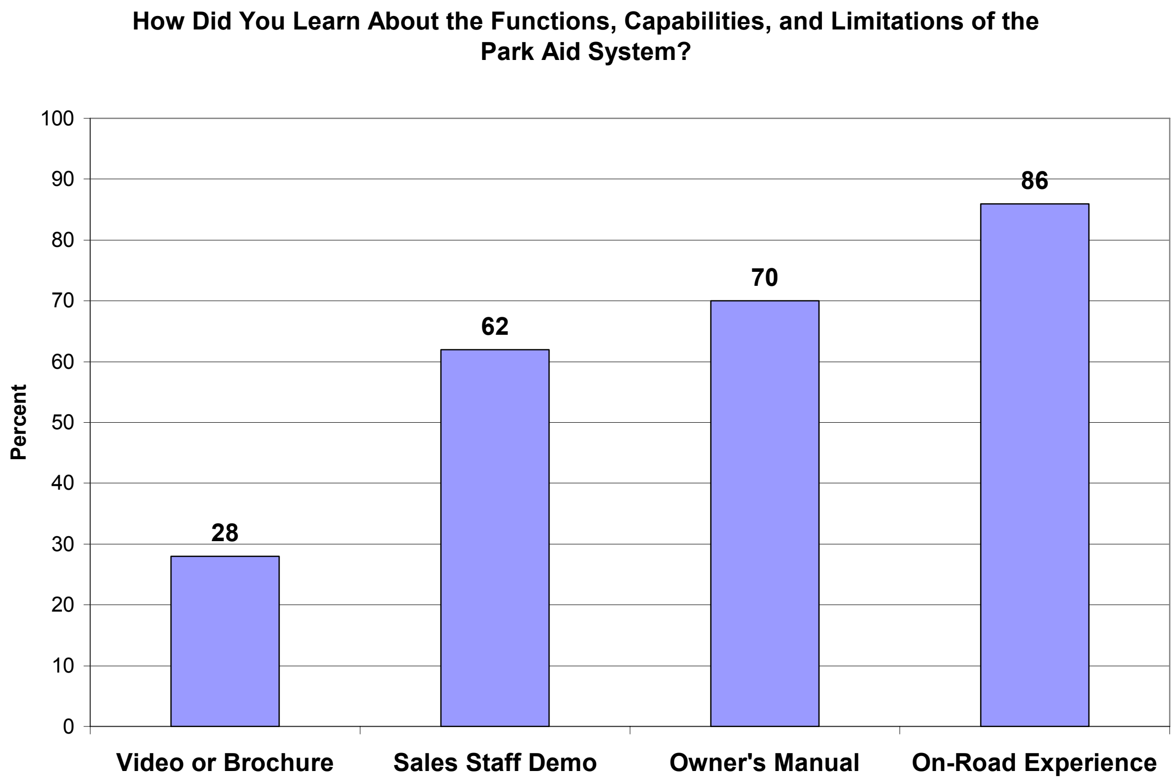


Figure 49 Information Sources Used By Vehicle Owners to Learn About Park Aid System Capabilities, Limitations and Functions

Inexperienced users, those with less exposure to the park aid system, were more likely to incorrectly assume that the system adjusts the timing of the warning based on both speed and distance to the obstacle, rather than using a fixed warning timing based on distance alone. As shown in Figure 50, nearly twice as many "low experience" users (22%) were operating under this false assumption compared to their more experienced counterparts (11%). Also of some concern is the finding that a substantial percentage of system owners (27%) were unsure of the underlying basis for how the system triggered the warning (distance or a combination of speed and distance), and experience with the system did not appear to significantly improve driver understanding on this specific issue. The vast majority of drivers were also unaware of the system's functional speed limitations; 67% believed that the park aid system operates under any speed when backing (most systems only operated at speeds under 6 mph). Experience with the system also did not appear to improve understanding of the system's functional speed range.

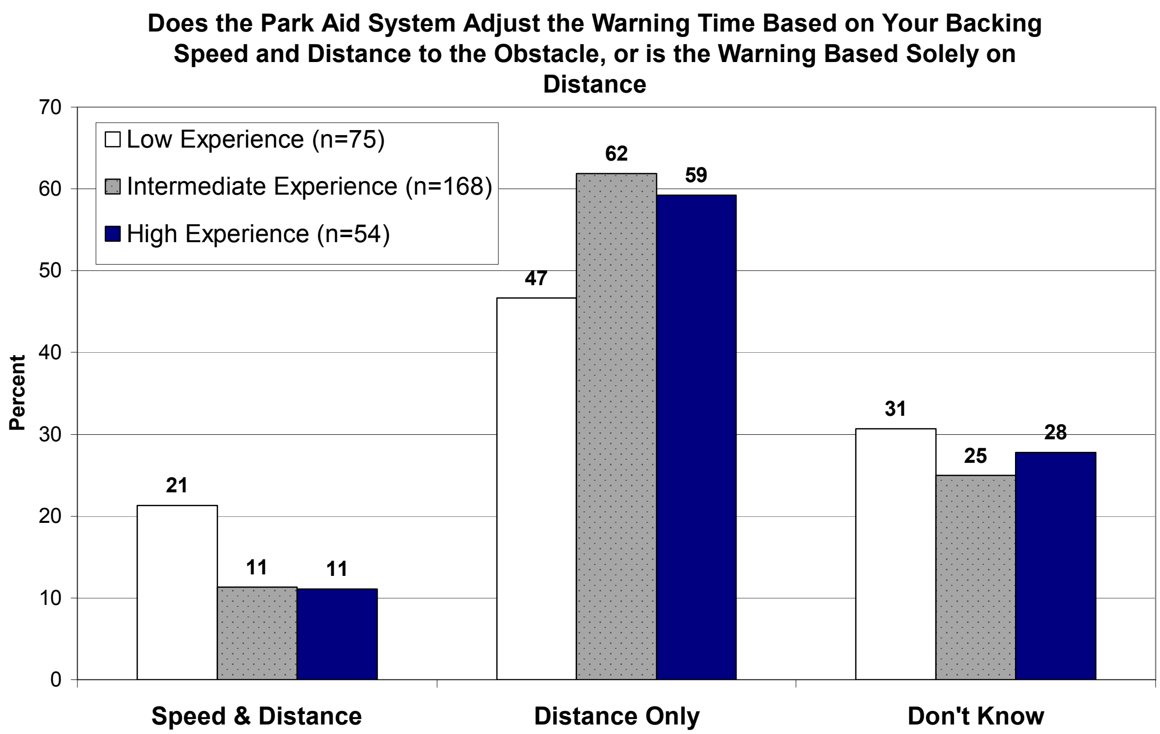


Figure 50 Percentage of Park Aid System Owners Who Assumed the Warning is Based on Speed and Distance, Versus Just Distance to the Obstacle as a Function of Experience Level

Safety & Behavioral Impacts

Sixty-six percent of park aid system owners have experienced a situation where the park aid system prevented them form hitting something they had not seen. When asked to rate the general safety impacts of the park aid system on a scale of 1 to 5 (where 1 means the system decreases safety and 5 means the system increases safety), 95% of owners rated the system as increasing safety (assigning as a value of 4 or 5). When specifically asked about the likelihood of being involved in a backing-related crash while using the system, 80% of drivers reported a decreased likelihood; still a disproportionately large number, but fewer than the general safety question. More importantly, as shown in Figure 51, 11% of system users felt the system might actually increase their likelihood of being involved in a backing-related crash. Interestingly, driver age and experience was related to the perceived increase in crash risk. Middle-aged and older drivers appeared more likely to feel the system would increase crash risk compared to younger drivers (none of the younger drivers perceived an increased risk of a crash compared to 12 and 13 percent of the middle-aged and older drivers, respectively). As shown in Figure 52, inexperienced system users ("low" experience) and those with an intermediate level of experience appeared more likely to report an elevated crash risk when using the system compared to experienced users. For example, 18% of inexperienced users reported an increased risk of crashing while using the system (rating of either 4 or 5), compared to 4% of experienced drivers. Behavioral influences associated with the use of the park aid outlined below may help to provide insights into these findings.

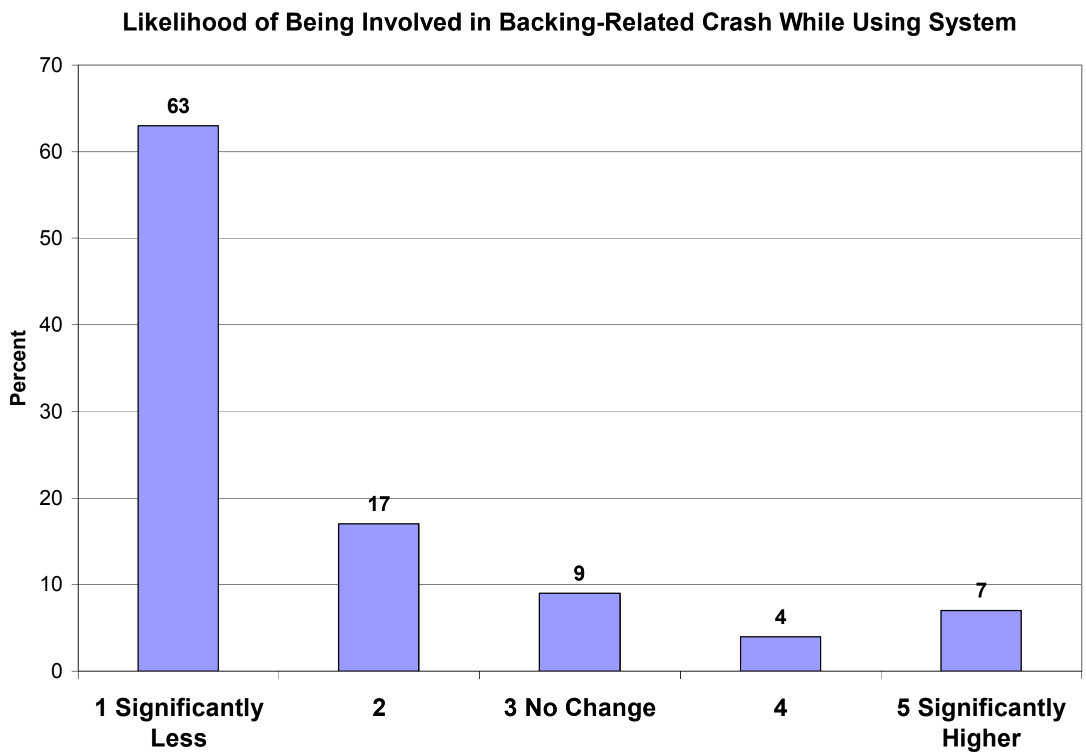


Figure 51 Ratings of Crash Likelihood While Using the Park Aid System

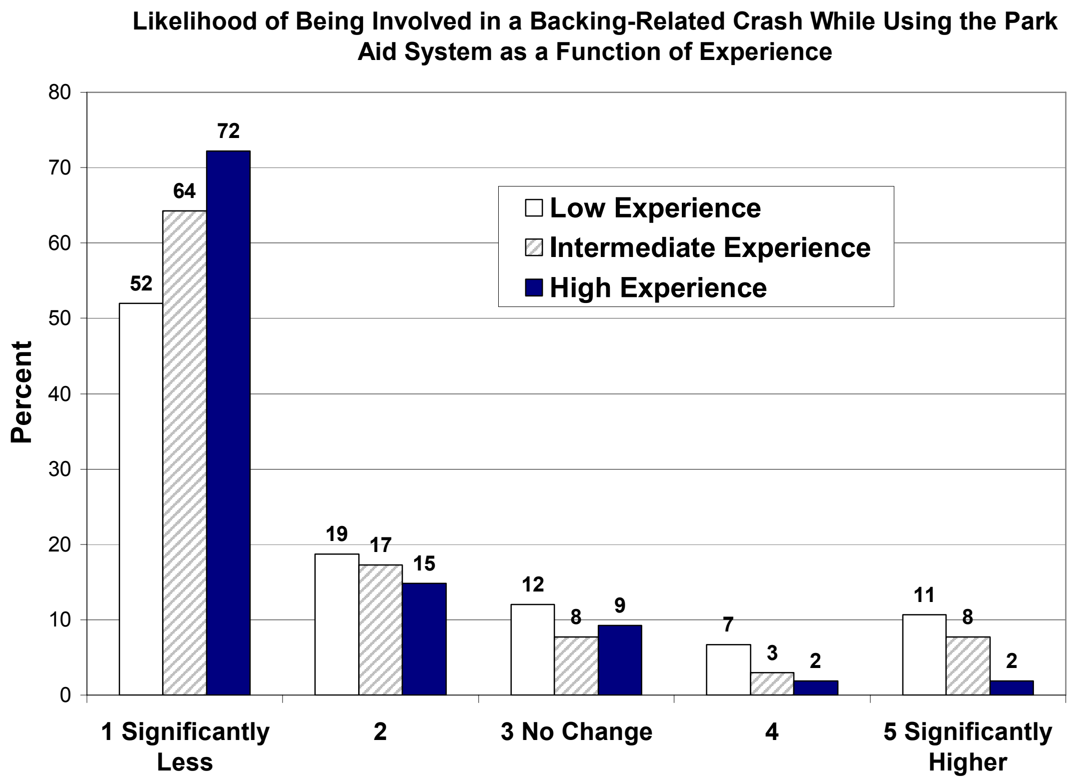


Figure 52 Perceived Crash Risk by User Experience Level

Park aid systems were generally perceived to increase a drivers' ability to park and back their vehicle, as well as increase confidence levels when executing parking and backing maneuvers (refer to Figure 53). For most drivers (54%), these types of systems serve as supplements or enhancements to their vision when parking and backing with no change to their reliance on direct glances/mirror use. As shown in Figure 53, some drivers (20%, or 60 out of 298) reported a decrease in their reliance on mirrors and direct glances while backing, apparently treating the park aid system as a substitute for conventional search methods. An even larger percentage of drivers (25%, or 75 out of 298) reported an increased reliance on the vehicle's mirrors and direct glances as a result of using the park aid (a somewhat surprising result).

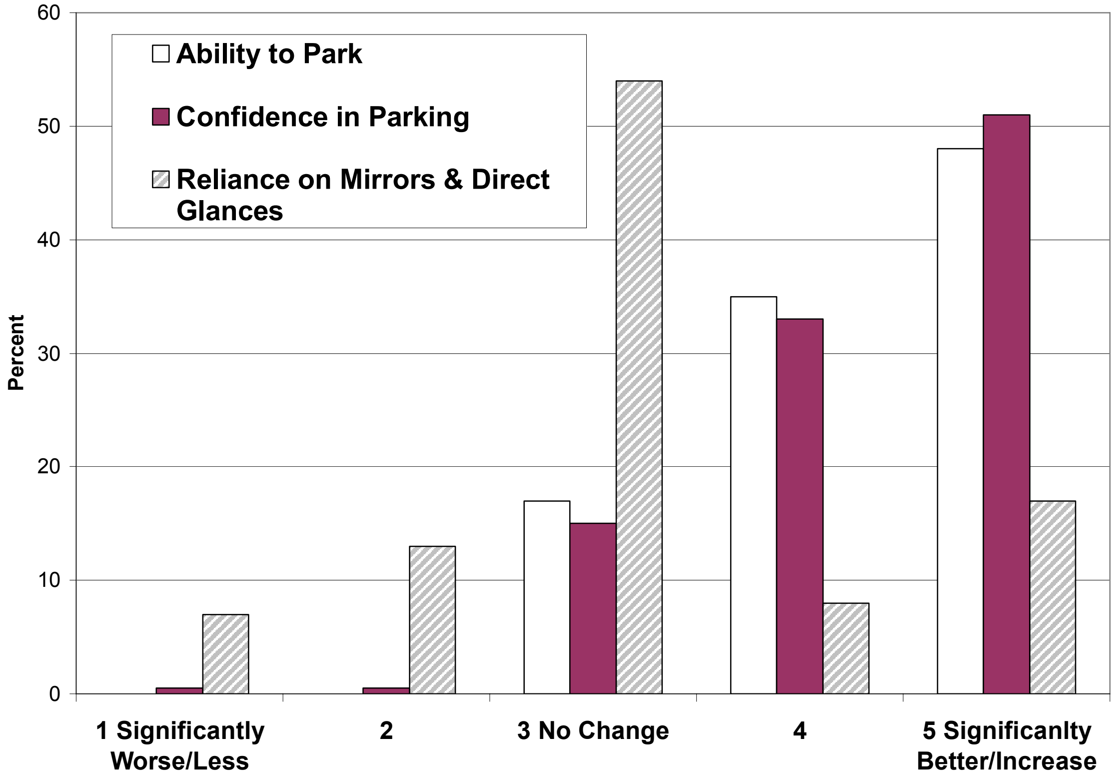


Figure 53 Perceived Impacts of Park Aid System On Driver's Ability to Park, Confidence Levels, and Reliance on Mirrors and Direct Glances

While most drivers did not appear to use the park aid system as a replacement for typical search practices, the system did appear to influence how many drivers searched when parking and backing. Specifically, 36% of the drivers interviewed indicate that they postpone or delay looking to the rear or using the mirrors when backing with the park aid. That is, the system appeared to change the time course for these search events, delaying the onset of these activities for some drivers. Interestingly, as shown in Figure 54, the propensity for this behavior appears to decrease with increasing park aid experience. Specifically, drivers who are relatively inexperienced with the park aid are more likely to delay making direct looks or glances to the mirrors compared to more experienced drivers. This suggests that some drivers may over-rely on the system initially and use the park aid as a cue to initiate glances rearward or to search the mirrors; drivers adopt a serial detection strategy in which they wait for the system to detect an object and then actively search. As experience with the system increases (and perhaps the novelty of the system dissipates, and/or drivers come to better understand the limitations of the system), drivers are more likely to revert back to established search patterns, adopting a parallel detection strategy (searching independently and in parallel with the system).

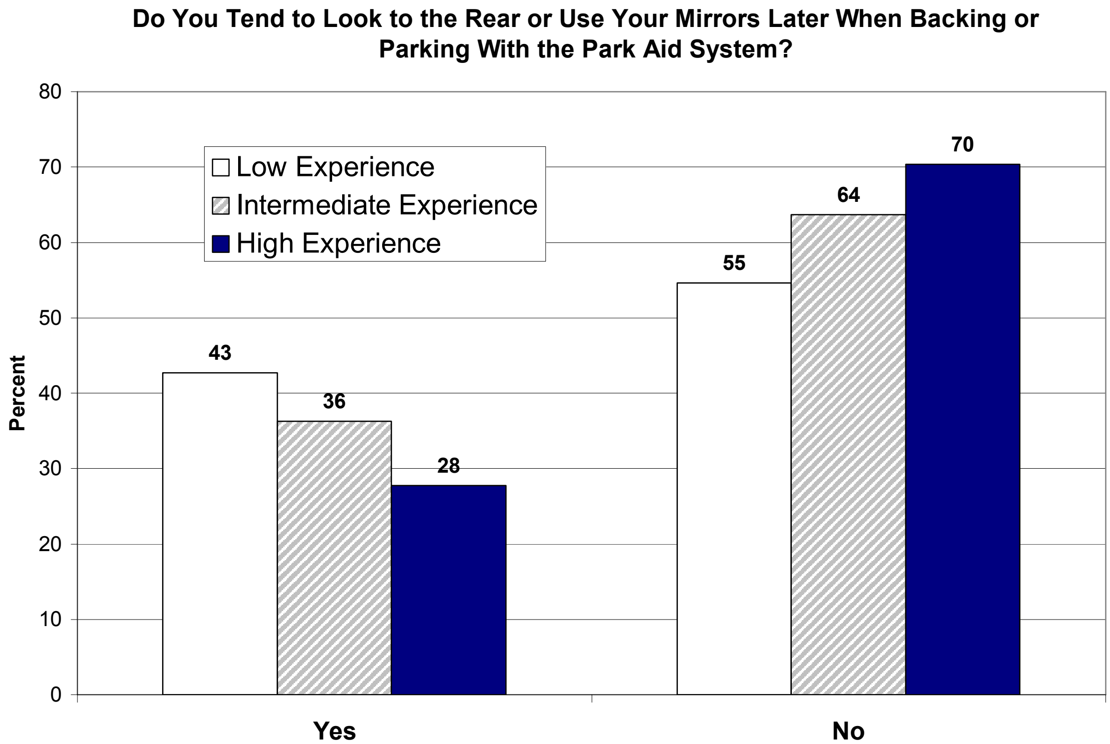


Figure 54 Percent of Drivers Who Report Delaying Making Direct Glances or Search the Mirrors While Using the Park Aid as a Function of Experience with the System

Shifts in attention (gaze) while backing were noted for drivers who had access to a rear-view camera system with an in-dash display. Presence of the in-vehicle display changed driver's focus while backing in approximately 32% of the cases. Over one-quarter of these drivers (28%) relied on the in-dash display more than the mirrors or direct glances, and 4% relied exclusively on the display while backing. As shown in Figure 55, although drivers of all ages tended to adopt these practices, young drivers in particular appeared more likely to rely on the in-dash camera view exclusively or more than on direct glances or the mirrors while backing..

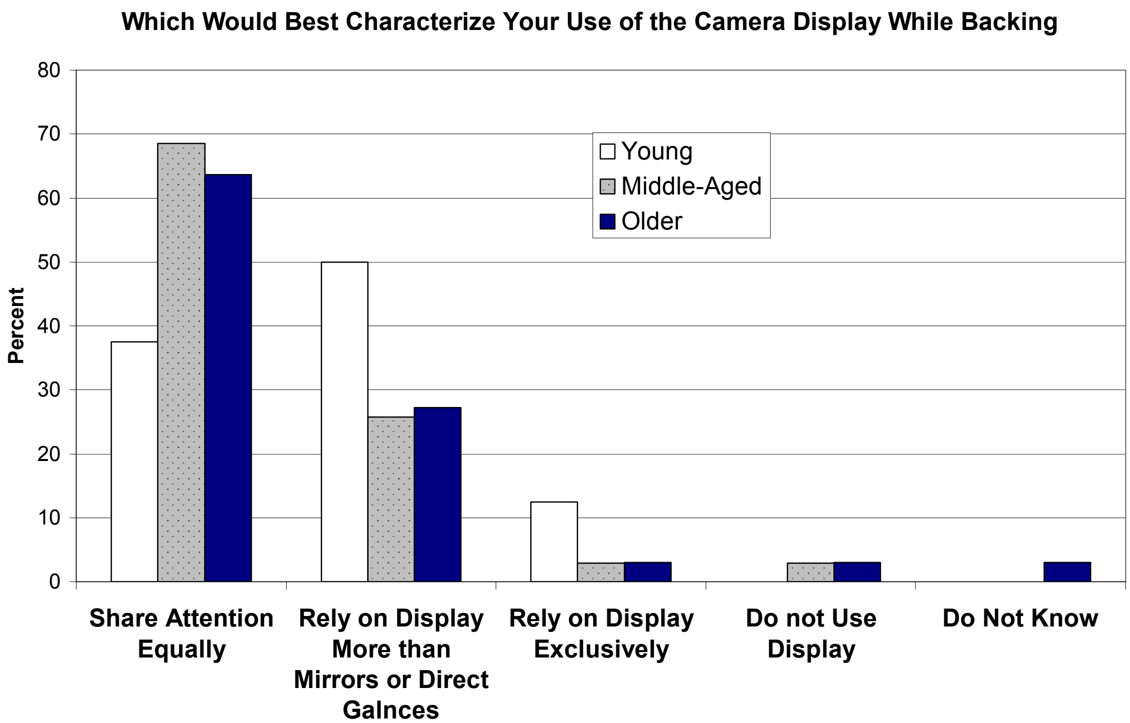


Figure 55 Self-Reported Use of In-Dash Display for Drivers with a Rear Camera System by Age Group (n= 77)

Some negative transfer issues have arisen in association with the use of these systems. Specifically, 17% of owners reported experiencing situations in which they mistakenly thought a vehicle they were driving was equipped with a park aid system.

Previous backing research (Llaneras et. al. 2005) has indicated that drivers may not necessarily respond to unexpected system alerts by immediately braking, but rather tend to seek to confirm the presence of an obstacle before braking to a stop. Interestingly, 81% of the drivers interviewed in our sample indicated that they would brake to an immediate stop if the park aid issued an unexpected alert while backing; work by Llaneras et. al. (2005) found that only 44% of drivers actually braked in response to an unexpected warning (even then, the level of braking in many cases was not sufficient to avoid colliding with the rear obstacle). While the majority of drivers (68%) in the referenced study were observed to exhibit precautionary behaviors in response to the warning (while searching for the obstacle), only 13% of drivers in this interview indicated they would slow down and confirm the obstacle before stopping. As shown in Figure 56, experience with the park aid system did not appear to have an appreciable effect on driver's response to the unexpected alert. Drivers with little exposure to the system were equally likely to indicate that they would brake immediately in response to the unexpected alert as drivers with more experience. This illustration serves to highlight the differences between self-reported behavior and actual behavior, among other issues.

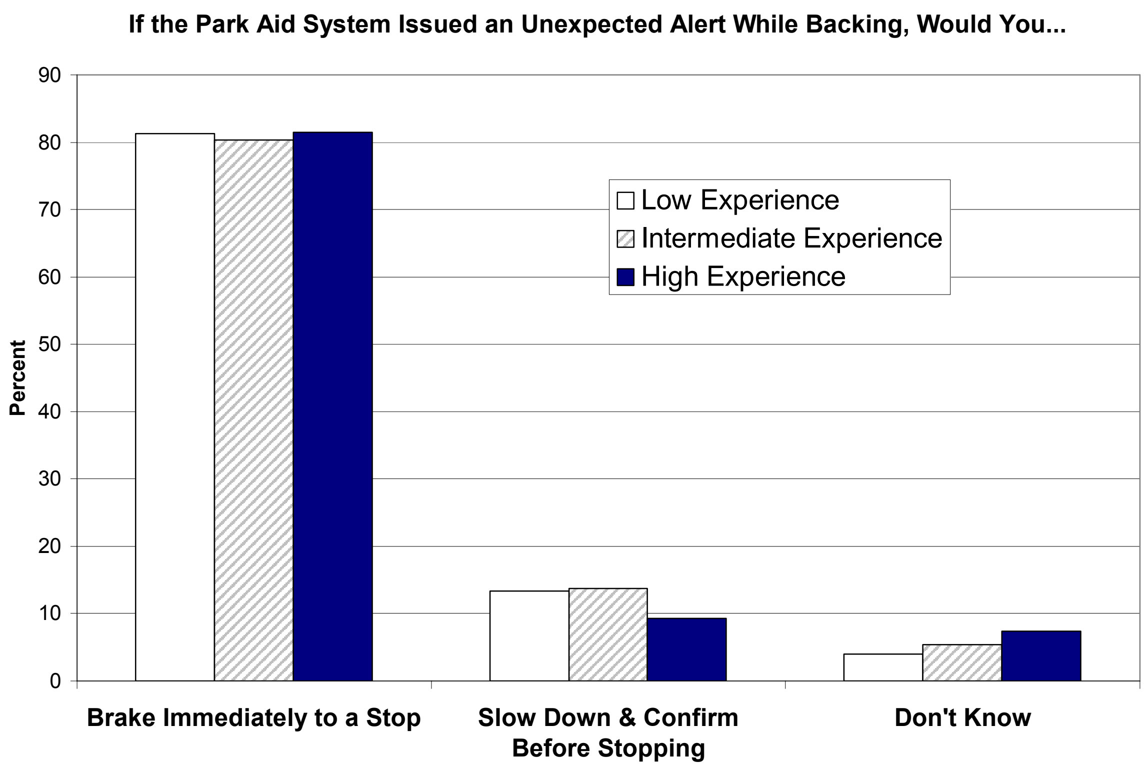


Figure 56 Self-Reported Response to an Unexpected Park Aid System Alert as a function of Experience with the System

Interface

Most park aid systems appear to have been designed with fairly intuitive and simple interfaces (see Figure 57). Only about 2% of the drivers interviewed found system outputs (sounds or visual displays) to be non-intuitive and difficult to understand. Some respondents indicated that audible displays should be louder, remain silent during transient events (e.g., vehicle drive bys), and automatically mute the radio, while visual displays should be visible in the mirrors, and include wider field of views (for camera systems).

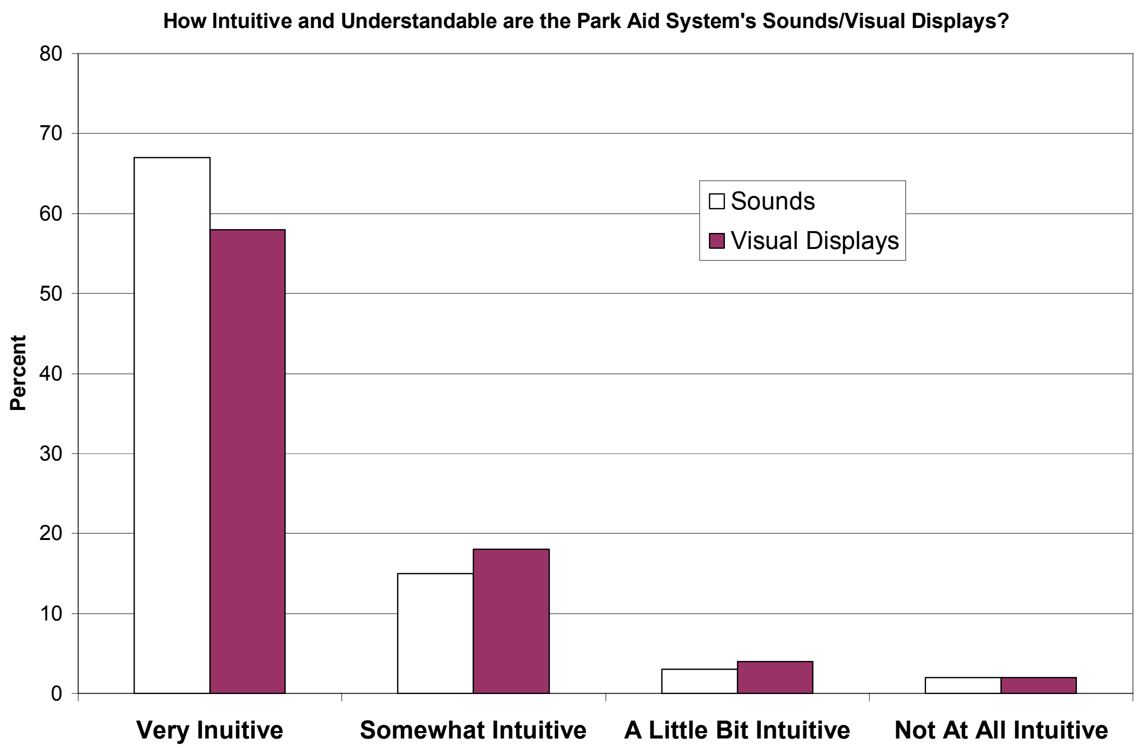


Figure 57 Rated Intuitiveness of park Aid System Audible and Visual Displays

The vast majority of drivers (90%) feel that system visual displays (when present) are located in a comfortable place where they can be easily seen when baking; 7% felt the visual displays were not appropriately located. No apparent product differences were evident across display locations for drivers who were not satisfied with the location of the visual display (some were located in the dash, others in the rear centrally located above the rear window). As shown in Figure 58, drivers are relying on audible system outputs more than visual displays for guidance when backing; this appears to be consistent with the design strategy of park aid systems where visual displays are used as secondary or supplemental displays.

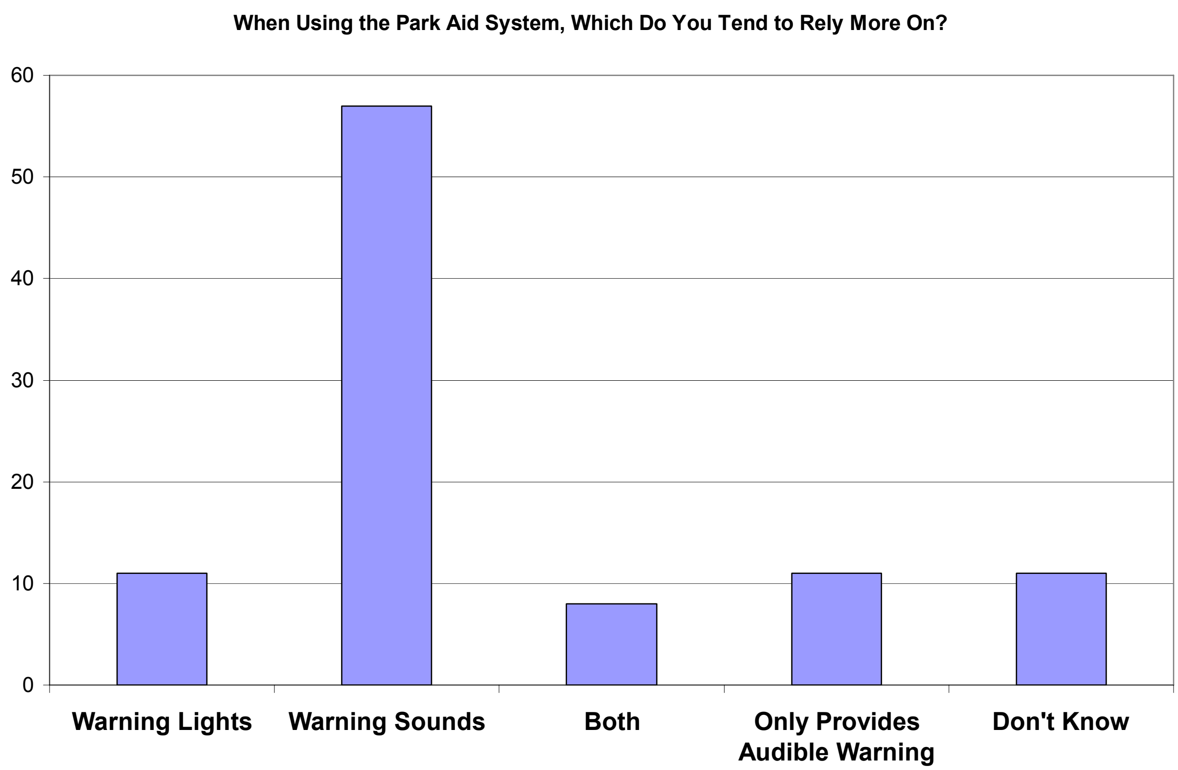


Figure 58 Driver Reliance on Park Aid System Visual Versus Audible Displays

Recommendations for improving the park aid system are summarized in Figure 59, and included calls for improving the interface and performance capabilities of the system. Many owners desired greater detection ranges and coverage to the rear sides of the vehicle, as well as the addition of sensors to the front bumper (front coverage). Drivers without camera systems desired the inclusion of a camera-based display so they could confirm the presence of an obstacle. While drivers with camera systems desired the inclusion of audible warnings to alert them to the presence of an obstacle without the need to constantly monitor the display. Some improvements to the interfaces included use of louder and more distinct warning sounds (including the capability to adjust the volume), inclusion of visual displays and better locations for visual displays, visual displays that automatically adjusted brightness levels, and provision for added detail regarding distance to objects (such as true distance to objects output in feet and inches). Owners with camera-based systems also desired clearer views with less distortion, wider fields of view, and use of protective devices to prevent icing and dirt accumulation on the camera units.

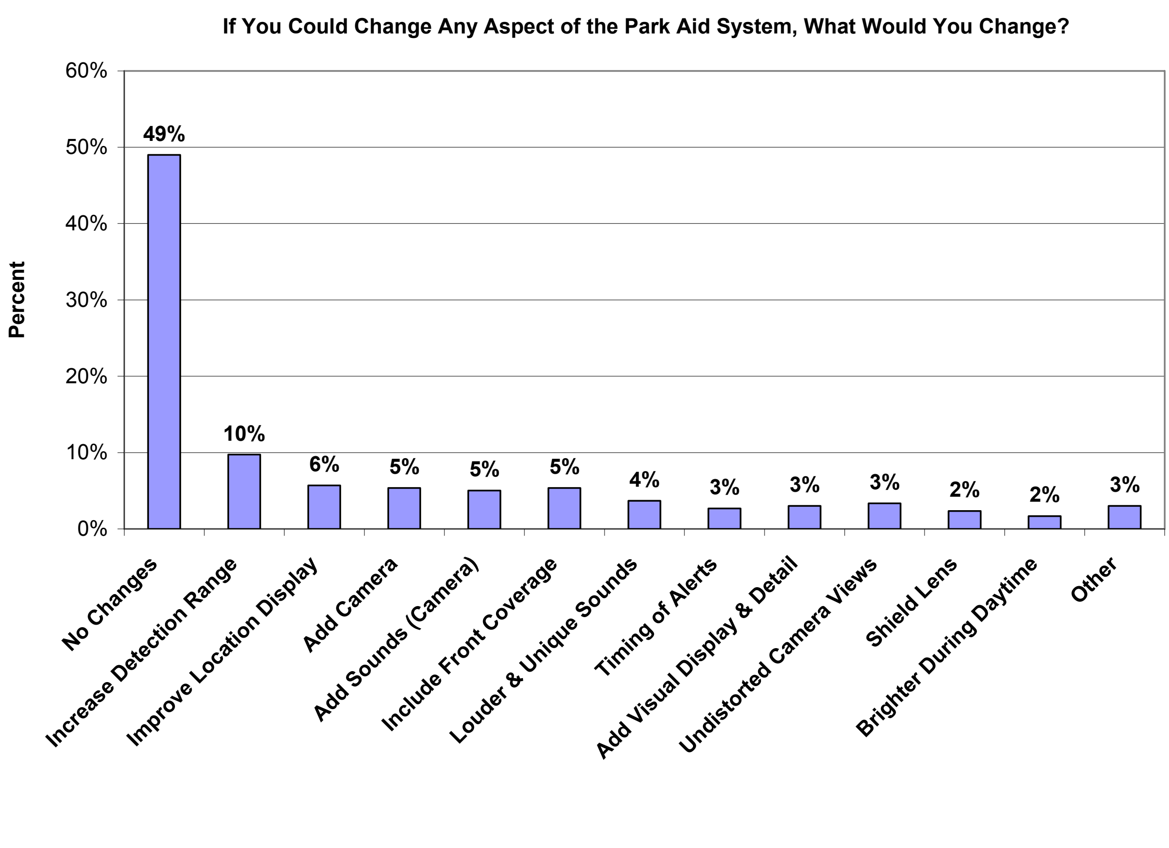


Figure 59 Recommended Changes to Park Aid Systems

Park Aid System Summary

Data on driver acceptance and use of park aid systems were collected through interviews with 298 system owners. A range of systems were sampled, including camera-based systems with in-dash displays. The sample of owners was heavily represented by males and older drivers, but included a range of driver ages (25 to 84 years) and system experience and usage levels. Most drivers in the sample (75%) had driven under 18,000 miles in their equipped vehicle using the system an average of 16 times per week. Nearly all the drivers would recommend the system to a friend and found the system to be easy to learn; most were comfortable with the system after the first 2-3 days of use. Usage patterns did not vary considerably across age groups and stayed about the same across time for most drivers. Few drivers report turning-off the system and tended to use the park aid under a variety of situations (e.g., poor weather, heavy pedestrian traffic, parking garages, etc.). Nevertheless, most drivers were not aware of the system's functional capabilities, including the operational range of the system and basis for issuing alerts (distance rather than speed and distance).

Although the park aid system was felt to increase safety by most drivers, some (11%) perceived that the system could actually increase the likelihood of being involved in a backing related crash. Changes in driver scan patterns, particularly with camera-based systems, and over-reliance on the park aid system appear to be key concerns. For example, 20% of users reported a decreased reliance on the vehicle's mirrors and on direct glances while backing with the system. Thirty-six percent of drivers also indicate that they postpone or delay looking to the rear or glancing in the mirrors when backing with the system engaged, suggesting that some drivers use the system to cue their search behavior. Driver experience appears to moderate this type of behavior; inexperienced drivers appear more likely to use the system as a replacement for direct search and mirror checks compared to more experienced drivers. Use of camera-based systems also appeared to result in behavioral changes with 28% of drivers reporting that they rely on the in-dash display more so than the mirrors or direct glances (4% reported that they rely on the in-car display exclusively while backing).

Most drivers rely on the audible warning sounds to guide their backing and parking behavior, despite the availability of both audible and visual displays; some of this may relate to the number and placement of visual displays. Recommendations for improvements generally centered around increases in system performance capability (greater detection range, side coverage, forward coverage) and improvements to the interface (more visual displays, better placement of displays, added detail regarding actual distance to objects, etc.). Interestingly, many camera-based users desired an active warning feature so they would not need to monitor the display, while those drivers with active warning systems desired a camera display to allow them to confirm the presence of obstacles.

Night Vision Systems

Night vision system owners were among the most difficult class of technology users to recruit with 15 drivers interviewed; this may reflect the relatively limited penetration of these devices into the market, among other factors. Although the sample included systems from both of the available vehicle manufacturers, Cadillac owners represented 87% of the sample (see Table 25). Results are therefore severely limited by the small sample size and range of systems, and may not be particularly robust or reliable. Nevertheless, basic insights and driver perceptions acquired from this sample can be useful in directing future investigation and identifying common or fundamental issues associated with these types of systems.

The sample was nearly equally divided between males (47%) and females (53%); most of the other technology groups were more biased toward male drivers. The night vision system was specifically sought after by 60% of the drivers sampled, and was a factor in the purchase of the vehicle in 47% of the cases. Nevertheless, a substantial percentage of drivers (40%) would not recommend the system to a friend. About 33% of vehicle owners who specifically sought out the night vision system (3 out of 9) would not recommend it to a friend. Many owners indicated that they believed the system served “no real purpose” having no real sense of the advantage provided by the system. Others felt the display was annoying and distracting, small and located too low on the windshield. Of those owners who would recommend the system (53% of those interviewed), many specifically indicated that they had problems seeing at night and that the system was effective in helping them see at night, and provided added comfort and security when driving at night.

Table 25 Breakdown of Night Vision System Respondents by Vehicle Make and Model

Vehicle Make	Vehicle Model	Total Number In Sample	Percent of Sample
Cadillac	Deville (13)	13	87%
Lexus	LX 470 (2)	2	13%

Relative to other technology groups sampled, night vision system owners were older (see Table 26); 47% were between the ages of 40 and 59 (middle-aged), and 53% were above 60 years of age (no younger drivers were included in the sample). Average driving experience was 42 years. Most of the sample had also driven the equipped vehicle for some time, averaging over 18,000 miles. The vast majority of system owners (80%) were recruited by mail-outs using vehicle ownership lists, and the remaining 20% from Internet advertisements. Several geographical areas were represented, including drivers from New York (29%), Virginia (21%), Texas, (21%), Michigan (14%), Florida (7%), and New Jersey (7%).

Table 26 Key Demographic and Experience Data for the Sample of Night Vision System Owners

n = 15	Mean	Standard Deviation	Min	Max	25th Percentile	50th Percentile	75th Percentile
Age	60.40	14.25	42	80	46	67	74
Years Driving Experience	42.00	16.25	20	60	26	41	57
Miles Driven in Vehicle	18,526	13,880	2,500	40,000	7,000	17,000	35,000
System Usage (per week)	2.13	2.35	0	7	0	2	4

System Usage

Drivers in the sample currently use the system an average of 2.25 times per week; however, drivers were extremely variable with usage ranging form 0 to 7 times per week. For example, 40% of the sample indicated that they often did not use the system in the course of a week. As shown in Figure 60, usage rates when the vehicle was first purchased also varied substantially. Usage over time increased for about 27% of the sample, decreased for about 7% of the drivers, and stayed about the same for 60% of the cases. Increases in system usage were primarily attributed to becoming more comfortable and familiar with the system, and increased night driving. Drivers whose usage dropped tended to feel disappointed with the system (e.g., was not effective, disruptive to their driving, not what they expected, etc.), as opposed to attributing the decrease to driving less at night.

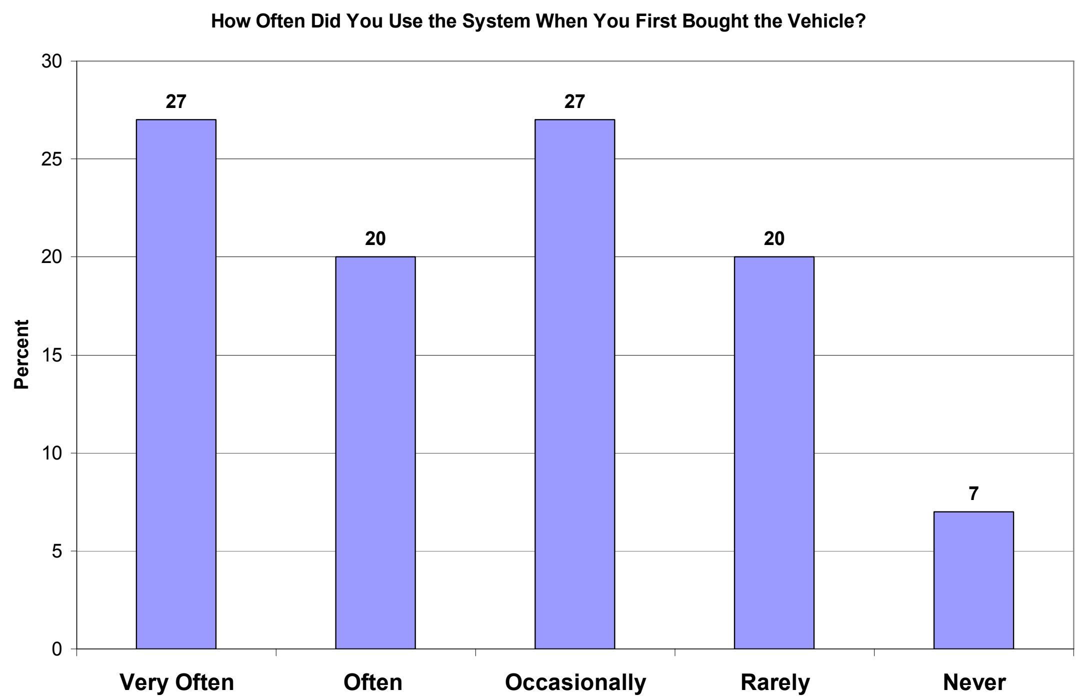


Figure 60 Self-Reported System Usage Rates When the Night Vision System was First Acquired

Drivers tended to use their night vision system under a range of driving environments, including freeways, hilly, and curvy roads. Relatively few drivers, however, reported a willingness to use the system on streets with lights, in heavy traffic, poor weather, and when driving on unfamiliar roads. With the possible exception of poor weather, lighted streets, and curvy roads, experience with the system (defined based on both the self-reported number of times drivers currently use the system per week, and the number of miles driven since the vehicle was purchased) did not appear to influence, to a great extent, driver willingness to use the system under most of the noted environments (refer to Figure 61 and Figure 62). Inexperienced drivers appeared somewhat more likely to use the system in poor weather and lighted environments (street lights).

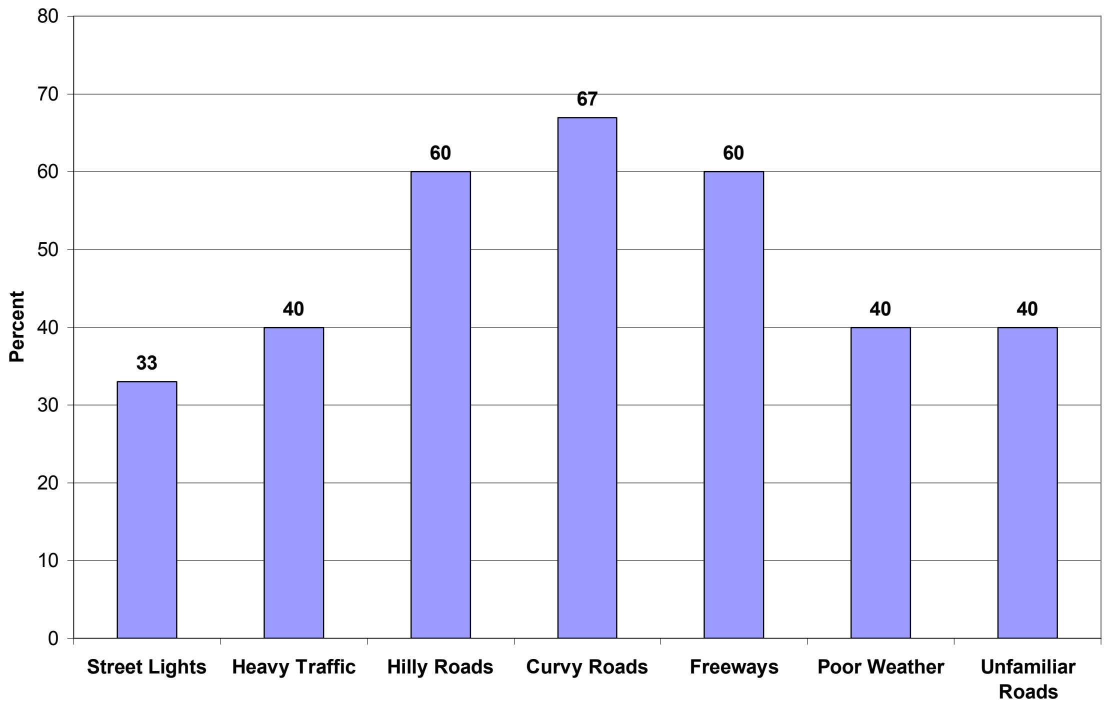


Figure 61 Willingness to Use (Not Turn Off) the Night Vision System

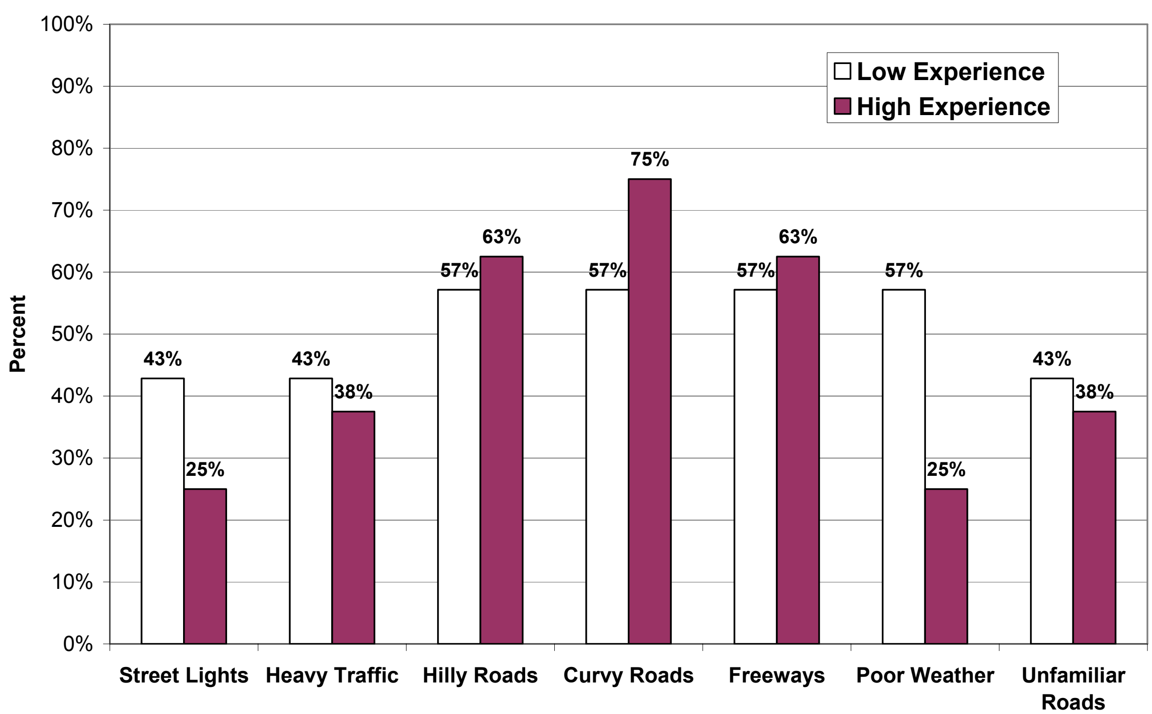


Figure 62 Willingness to Use System as a Function of Experience

Effectiveness & Acceptance

In all, 53% of night vision system owners sampled feel that the system improves comfort and reduces stress during nighttime driving; the same percentage of drivers would also like the system in their next vehicle if it came standard or as part of a package. Nevertheless, many also felt disappointed with the system; only 40% of those sampled believed that the system lived up to their expectations. Several felt the system was over-sold and only appears to function in unlit country roads. Others commented that the display is distracting and hard to use – the field of view is too small, requires continual glancing back and forth, is difficult to distinguish, recognize and locate objects. Ratings of the system's usefulness and ability of the system to work under a variety of conditions were divided, and appear to reflect differences in these views. As shown in Figure 63, 33% of drivers perceived the system to have limited usefulness (assigned a rating of 1 or 2), while 40% of users felt the system was very useful (assigned a rating of 4 or 5). Although most users (60%) appeared satisfied with the system's ability to operate under a range of conditions (assigned a rating of 4 or 5), some (about 20%) were not (assigned ratings of 1 or 2). Ratings of the system's usefulness were strongly correlated (r = .84) with system use (number of times the system is typically used per week)

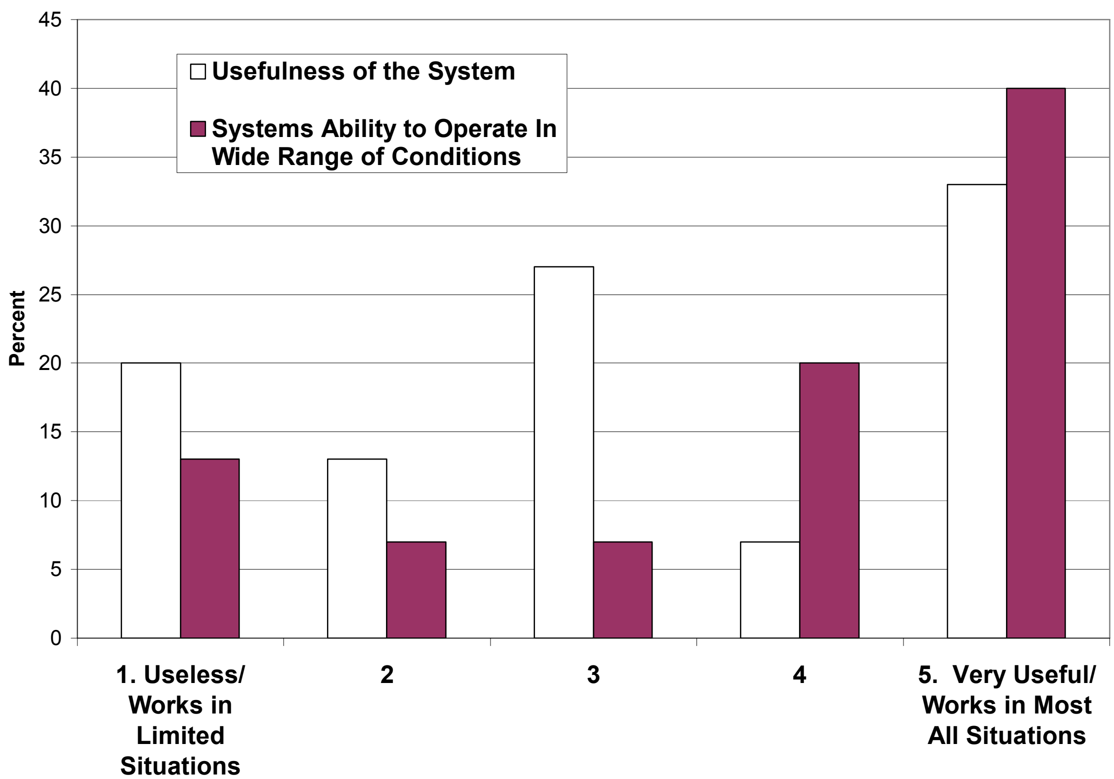


Figure 63 Driver Ratings of Perceived System Usefulness and Ability to Operate in a Wide Range of Conditions

A substantial percentage of users felt the system had specific limitations in terms of displaying recognizable objects and enabling them to judge distances to obstacles and objects. As illustrated in Figure 64, 27% of those sampled (4 out of 15 drivers) rated the system as "not very effective" in enabling them to judge distances to objects. About one in five users found the system to be limited in its ability to display recognizable images (assigned an effectiveness rating of 1 or 2). The system was perceived to be approximately equally effective in terms of allowing drivers to detect and recognize pedestrians and animals; average effectiveness rating for the two was 4.46 on the 5 point scale. The systems were also thought to be fairly well designed in terms of minimizing the number of adjustments required by drivers.

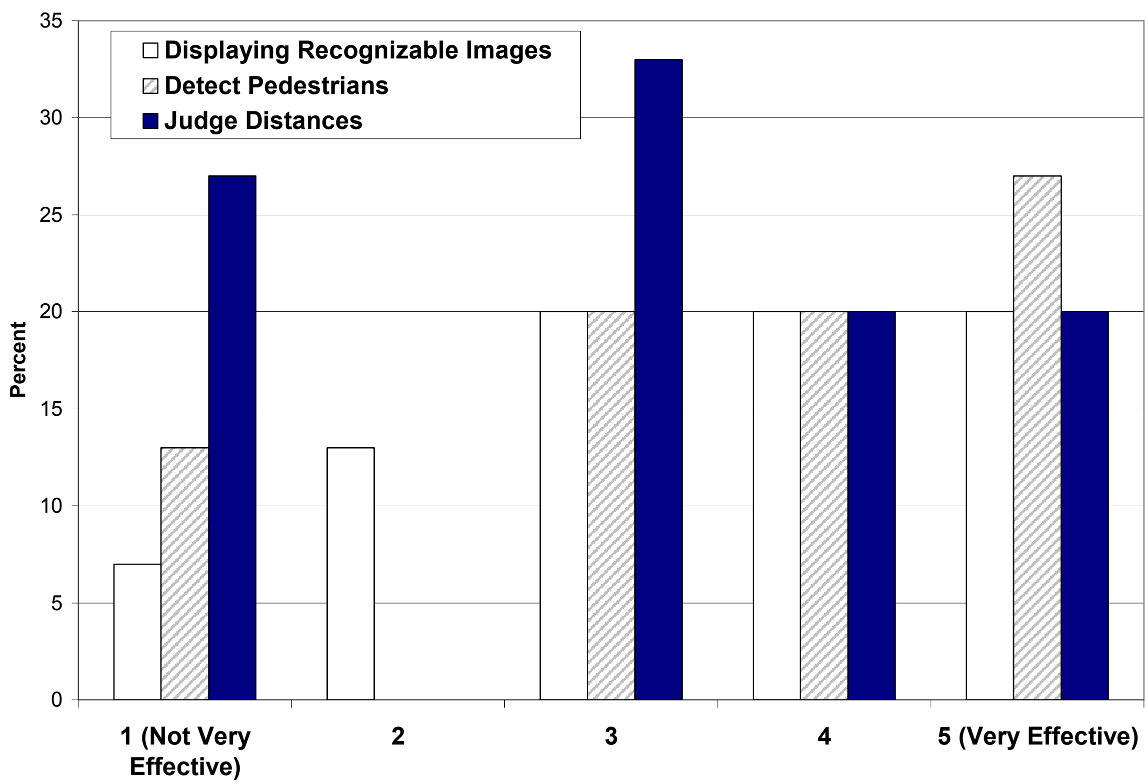


Figure 64 Driver Ratings of Night Vision System Effectiveness

Data suggest that the ability to recognize objects improves with experience and system use. In general, a substantial percentage of drivers (47%) agreed that their ability to recognize displayed objects increases with experience. Reponses to this item also varied substantially for drivers with “low” versus “high” night vision system experience. As shown in Figure 65, proportionately more high experienced users felt their ability to recognize displayed objects improved with experience, versus low experience users. This suggests that when drivers in fact exercise the system, their ability to recognize displayed images improves with experience. Objects reported to be difficult to recognize in the night vision display included parked cars, building, fences, and small animals. Objects easily recognized in the display included pedestrians, large animals, and moving vehicles.

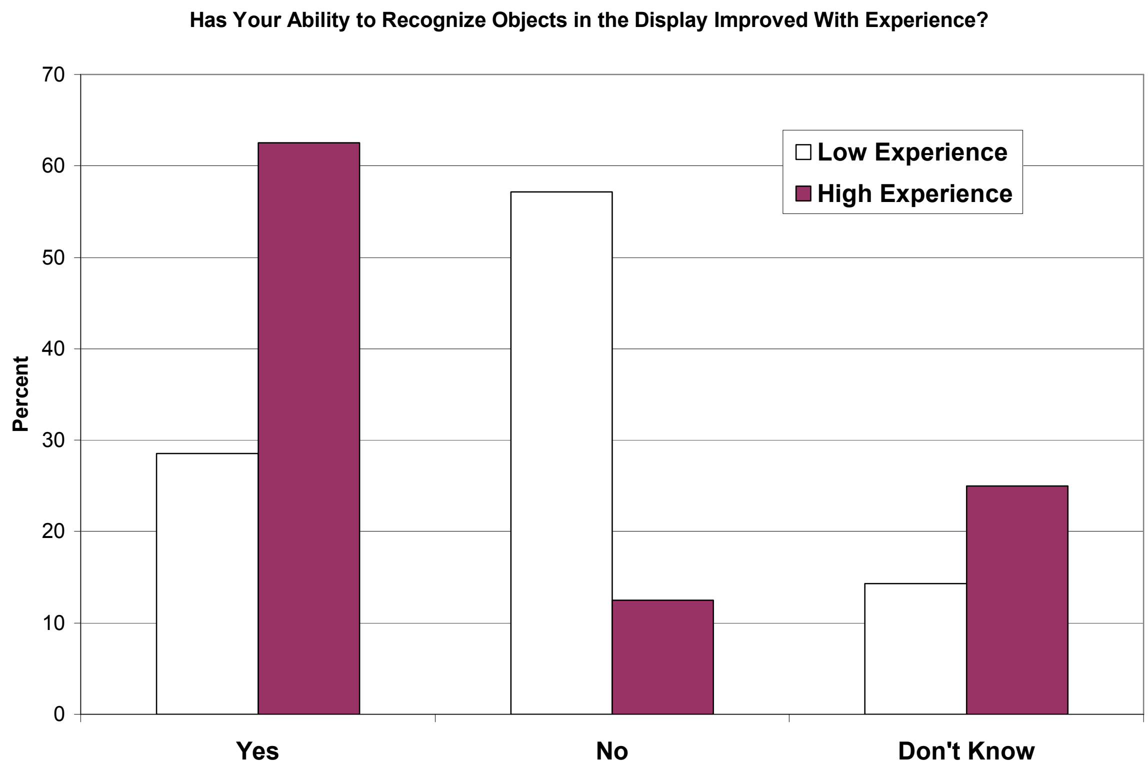


Figure 65 Self-Reported Ability to Recognized Displayed Objects as a Function of Experience

System Knowledge & Learning

Most owners report reading all about the system (60%) or a little about the system (27%) in their owners' manual; only about 13% (or 2 out of 15) of those interviewed failed to read the information presented in their owners' manual. Of those cases in which drivers failed to read the information in the owner's manual, both were middle-aged users (see Figure 66). Many drivers also learned about how to use their night vision system through system demonstrations by sales staff, as well as on-road experience with the system (see Figure 67).

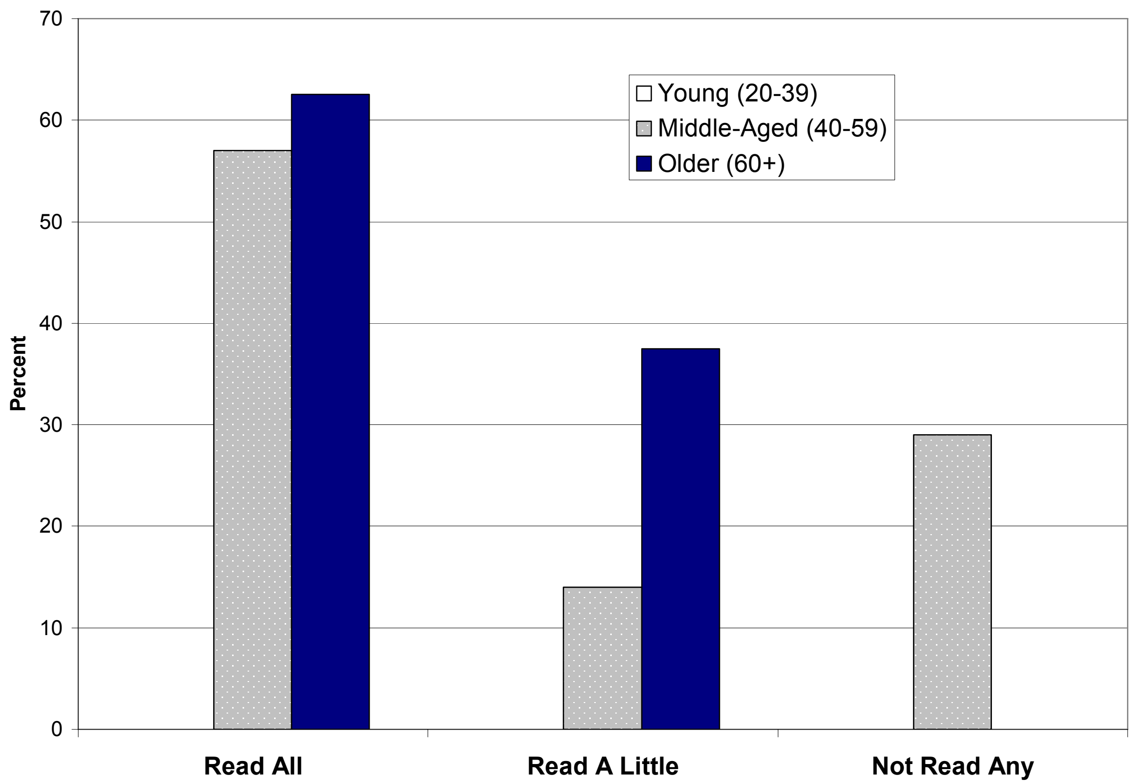


Figure 66 Percent of Drivers Reporting Reading Owners Manual as a Function of Age Group

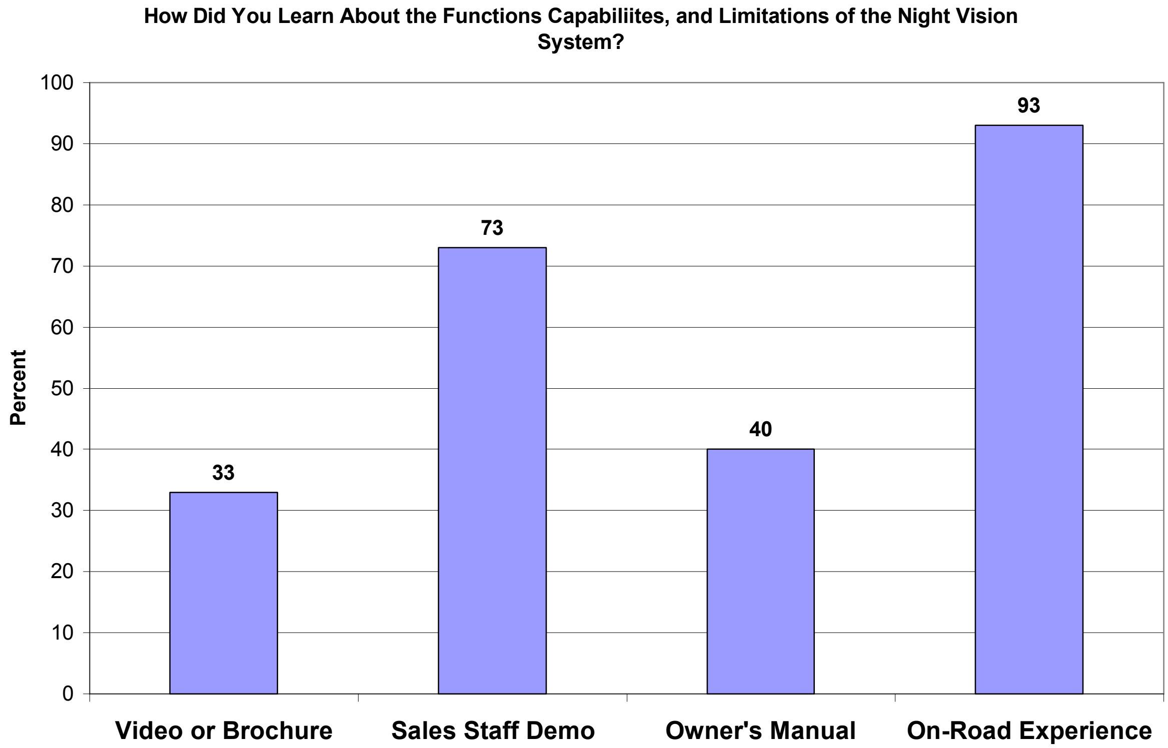


Figure 67 Information Sources Used by Vehicle Owners to Learn About System Capabilities, Limitations, and Functions

Although 60% of drivers felt comfortable using the system within the first week of using it, a substantial percentage of users (33%, or 5 out of 15) reported that they have never fully felt comfortable using the system. Many of these individuals used the system infrequently, despite traveling between 10,000 and 39,000 miles with the equipped vehicle. Thus, it appears that comfort with the system is highly related to exposure to the system (those who did not feel comfortable also tended not to use the system often).

Safety & Behavioral Impacts

Night vision systems are specifically intended to increase safety associated with nighttime driving by enhancing drivers' ability to detect potential road hazards. As detailed in this section, data from this limited sample of vehicle owners does not provide a clear indication of the system's safety impacts. Some drivers in our sample, for example, found that the night vision system aided them in detecting and avoiding potential hazards. Specifically, 33% of drivers (5 out of 15) reported that the system enabled them to avoid hitting something while driving at night which they otherwise might not have seen in time to avoid. In all of these cases, drivers indicated that the system enabled them to detect and avoid striking an animal (deer, dog, cat, etc.). Total cumulative miles traveled across the 5 drivers who reported these types of "near-crash" situations was 126,000 (includes both day and night time travel). As shown in Figure 68, experienced drivers (drivers who use the system frequently) were more likely to experience these types of events compared to low experience drivers. Driver ratings of the system's safety impacts were also strongly correlated (r = .58) with system use (average number of times drivers used the system per week), suggesting that the more often drivers used the system, the more likely they were to perceive a safety benefit associated with the system.

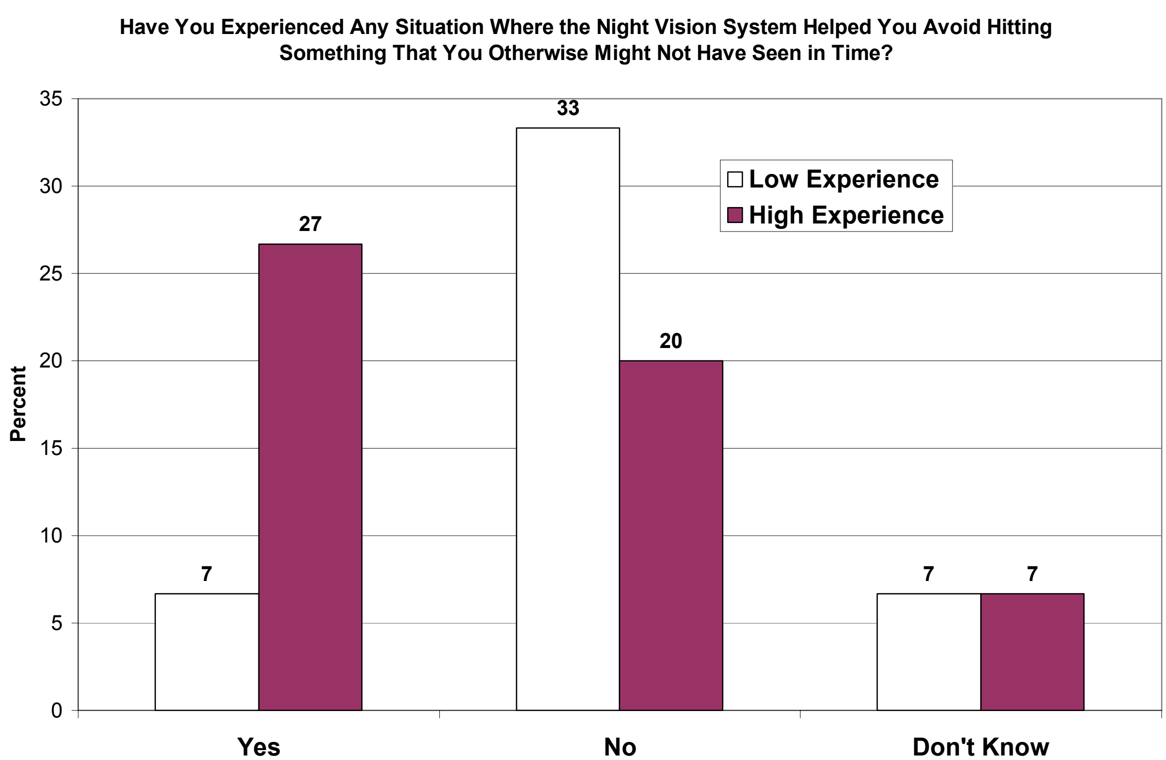


Figure 68 Percent of System Owners Who Attributed a Crash Avoidance Event to the Night Vision System

Drivers were also asked to rate both the overall safety impacts of the system as well as their likelihood of being involved in a crash while using the system. When expressed generally, some drivers (27%, or 4 out of 15) felt that the system actually decreases safety. However, when specifically asked to rate their likelihood of being involved in a crash while using the system, none of the drivers felt the system increased their chances of being involved in a crash. As shown in Figure 69, approximately 60% felt the system did not change their crash risk, and approximately 40% of drivers felt the system reduced their likelihood of being involved in a nighttime crash (assigned ratings of 1 or 2). Although speculative the discrepancy in viewpoints (general vs. specific) may stem from the distinction between driver perceptions about their own ability versus perceptions of the system itself.

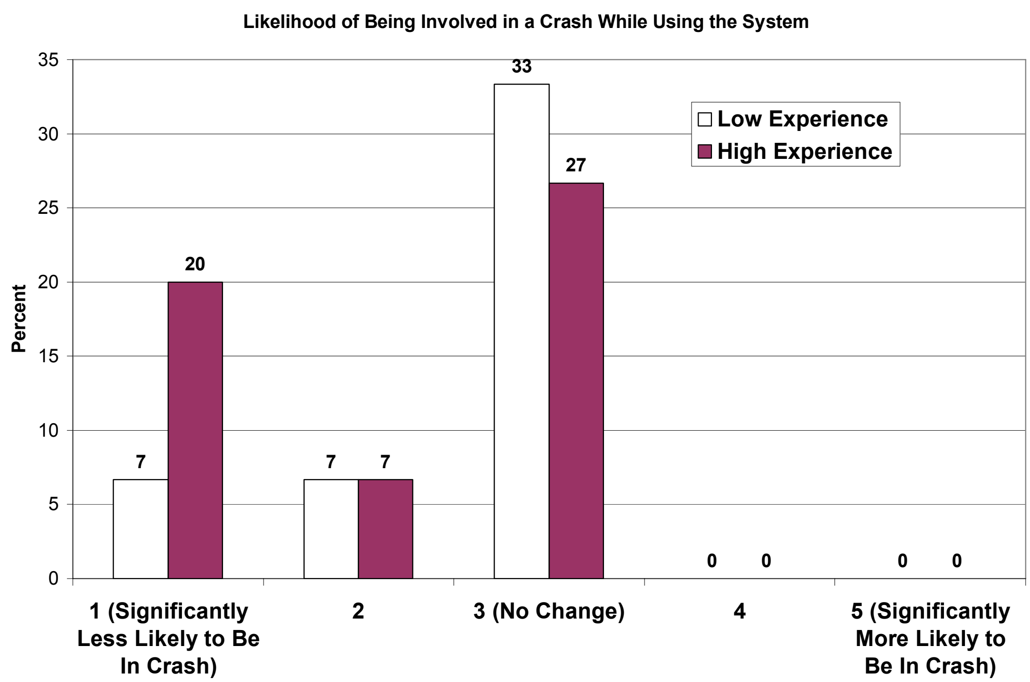


Figure 69 Driver Perceptions of Crash Likelihood While Using the Night Vision System

Concerns related to the distraction potential of the display may explain why some drivers felt the night vision system could actually decrease overall safety. As shown in Figure 70, approximately 33% of the sample (5 of 15 users) rated the night vision system display as very or somewhat distracting. Even experienced drivers found the display to be distracting, suggesting that extended exposure to the system did not necessarily negate any potential distractive aspects of the display. Nevertheless, as illustrated in Figure 71, drivers (particularly experienced users) tended to glance at the display less frequently over the course of time.

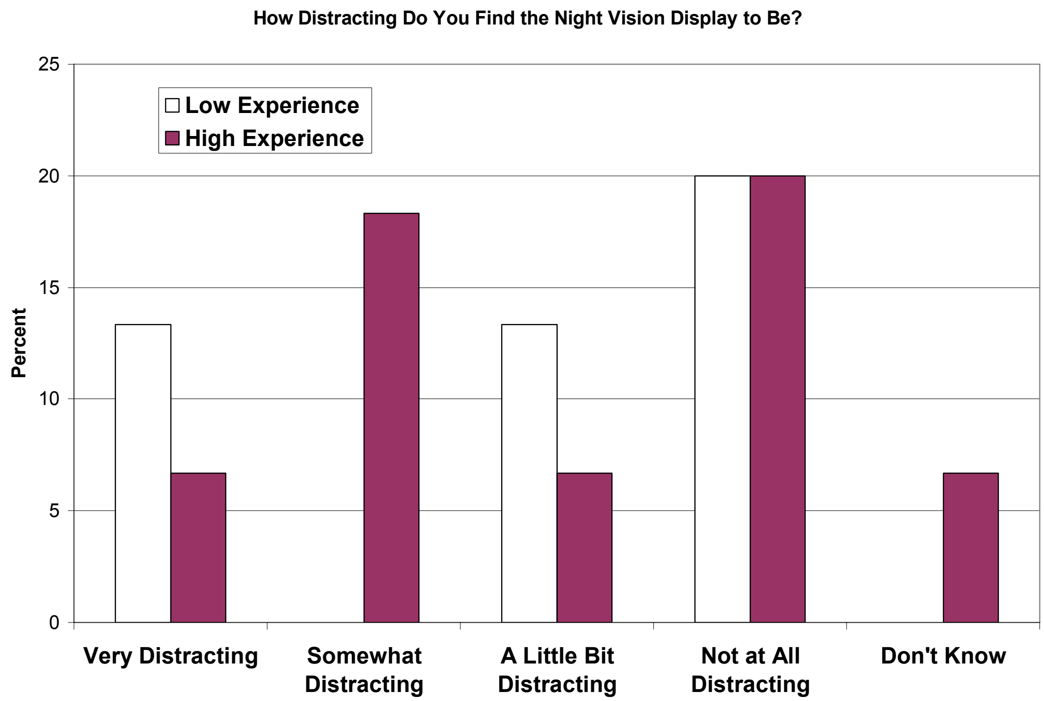


Figure 70 Distraction Rating of Night Vision System's Display

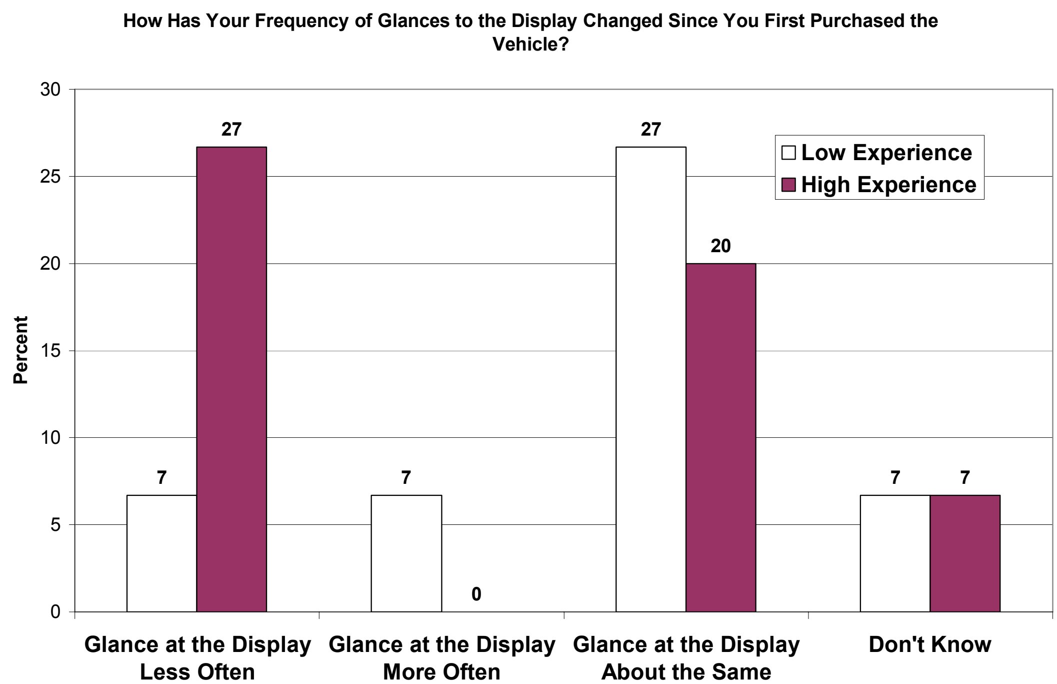


Figure 71 Changes in Glance Frequency to the Night Vision Display Over Time

The presence of the night vision system did not appear to impact driver's use of the vehicle mirrors. Nearly all drivers (93%, or 14 out of 15) reported that the night vision system did not cause them to rely less on the vehicle's rear or side-view mirrors. Some driver's reported that the Head-Up Display (HUD) interfered with their direct view out the windshield; this tended to occur infrequently (e.g., some or a little bit of the time) for many drivers (40%). Glare from on-coming headlights also appeared to be a sporadic but common problem for drivers; 47% indicated their ability to see objects in the display was affected by glare some or a little bit of the time. These data are summarized in Figure 72.

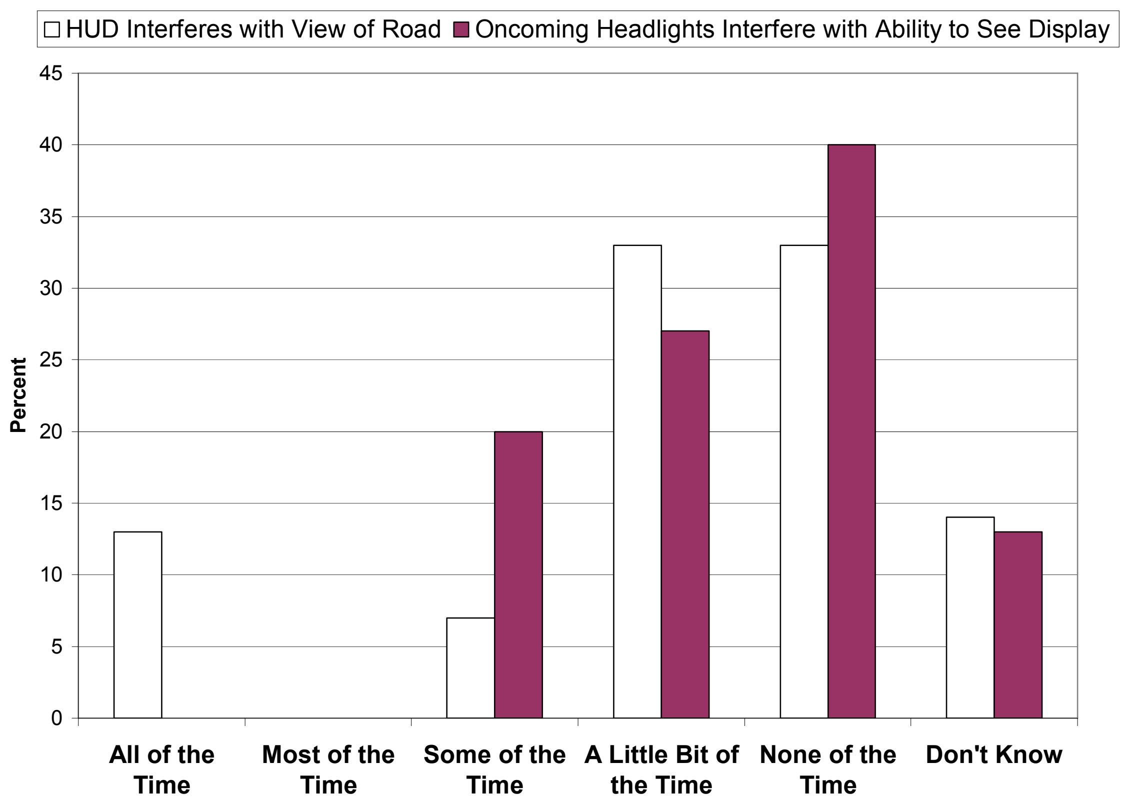


Figure 72 Driver Perceptions of Interference from Head-Up Display and Oncoming Headlights

Some drivers reported that presence of the night vision system increased their willingness to drive at night; approximately 33% of drivers indicated that they drove more frequently at night as a result of having the system. As shown in Figure 73, the system also appeared to increase many drivers' ability to see obstacles or hazards at night; 40% rated the system as increasing their ability to detect hazards at night. The majority of drivers did not appear to compensate for the expanded detection range afforded by the system by driving faster; 86% reported no change in their typical night driving speed. However, two drivers (about 13% of the sample), did attribute increases in their night time driving speed as a result of having the system. Susceptibility to glare from oncoming vehicles also became a bigger problem with the system for about 20% of those sampled.

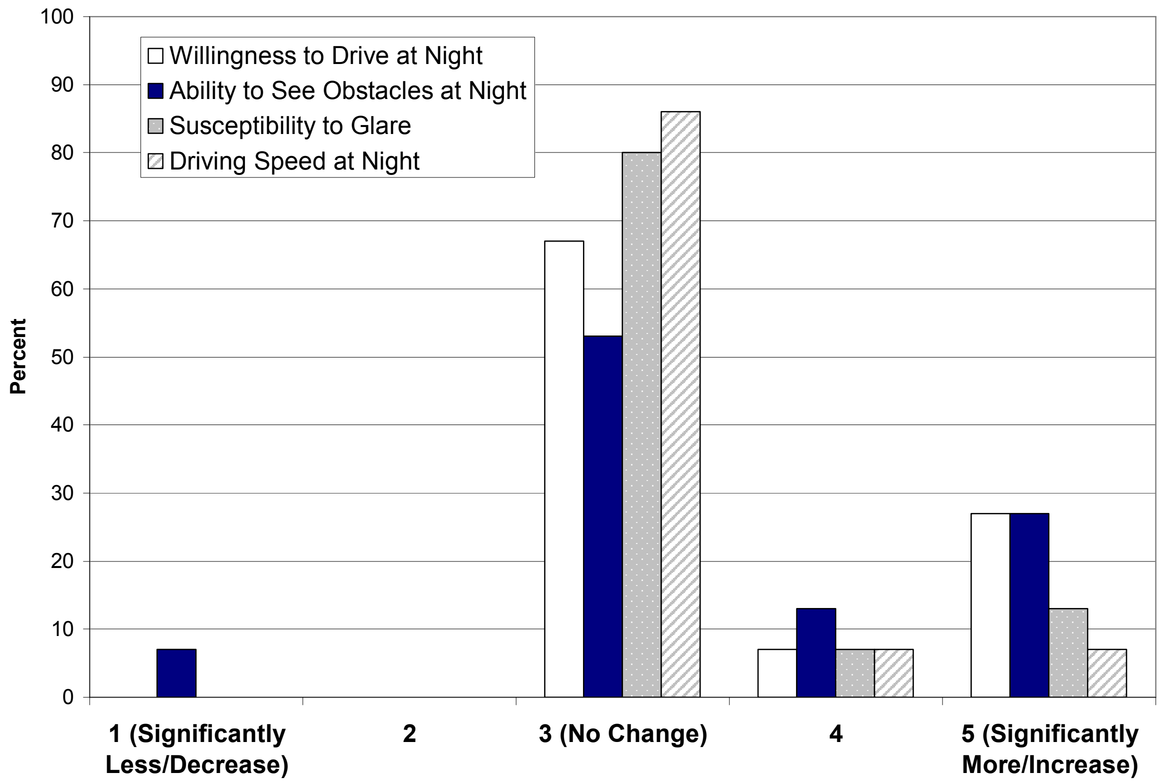


Figure 73 Driver Assessments of How the Night Vision System Has Influenced Their Driving Habits

Interface

In general, drivers found the night vision system to be easy to use; no features were reported to be particularly difficult to learn to use. However, as outlined earlier, 33% of owners indicated they were never comfortable using the system. Suggested recommendations for improving the system included enlarging the display, increasing the brightness of the display, and displaying more realistic and discernable images.

Night Vision System Summary

Two vehicle models currently offer a night vision system - both as an optional feature (the Cadillac Deville and the Lexus LX 470. Our sample of 15 night vision system users was primarily comprised of Cadillac system owners. Night vision system users were older (the average respondent's age was 60), and the sample did not include any drivers under the age of 42. Current system use averaged 2.25 times per week, with usage for most of the sample either staying the same (60%) or increasing (27%) over time. Although a majority of owners feel the system improves comfort and reduces stress, perceived usefulness and safety of the system was mixed and strongly related to experience with more frequent usage leading to higher perceived usefulness and safety.

Many drivers were disappointed with the system's ability to display recognizable images and felt the system made it difficult to accurately judge distances to obstacles and objects. Some reported that parked cars, buildings, fences, and small animals were particularly difficult to recognize in the display. Nevertheless, the ability to recognize objects appeared to improve with experience. Although drivers report glancing to the display less frequently over the course of time, many felt the display was distracting. Furthermore, glare from oncoming vehicle headlights appeared to make it more difficult to extract information from the display; and in some cases the display also appeared to amplify the glare problem.

Both positive and negative behavioral adaptations were reported. These included an increased willingness to drive at night for about 33% of those interviewed, and an increase in nighttime driving speed for about 14% of drivers. The system also appeared to enhance drivers' ability to detect obstacles at night with one-third of drivers experiencing a situation in which the system helped them avoid hitting an object they otherwise might not have seen in time. The presence of the night vision system did not appear to affect mirror usage.

Navigation Systems

Interviews with 228 navigation system owners were analyzed and results are presented in this section. The sample included owners from 16 different vehicle manufacturers (see Table 27); approximately 77% of the completed interviews were from Lexus, Acura, BMW, Mercedes-Benz, Infiniti, and Cadillac system owners. The vast majority of respondents (78%) were recruited by means of mail-outs using ownership contact lists acquired from R.L. Polk; other system owners were recruited from Internet (12%); magazine (5%); outbound calls from lists of telephone numbers (3.5%); and newspaper (1%) methods. Although drivers from 20 states were represented, the majority resided in Florida (22%); New York (13%); Illinois (13%); Michigan (12%); and Virginia (12%) – R.L. Polk sampled states.

Table 27 Breakdown of Navigation System Respondents by Vehicle Make and Model

Vehicle Make	Vehicle Model	Total Number In Sample	Percent of Sample
Acura	MDX (12); RL (17); TSX (3)	32	14%
BMW	7 Series (27); 5 Series (4)	31	14%
Cadillac	Deville/DHS/DTS (17); Escalade (4)	21	9%
GMC	Denali (1)	1	--
Honda	Odyssey (1); Accord (3); Pilot (3)	7	3%
Hummer	H2	1	--
Infiniti	Q45 (26)	26	11%
Jaguar	XKR/X-Type (5)	5	2%
Land Rover	Range Rover (6); Discovery (5)	11	5%
Lexus	LS 430 (20); RX (10); GS/GX 470 (7)	37	16%
Lincoln	Aviator (2); Navigator (7)	9	4%
Mercedes-Benz	SL (4); S-Class (13); CLK 320/500 (1); E/M500 (11);	29	13%
Nissan	350Z (2)	2	1%
Porshe	Boxter (1)	1	--
Toyota	Avalon (2); Sienna (10); 4Runner (2)	14	6%
Volvo	S40	1	--

For many drivers (82%), the presence of an in-vehicle navigation system influenced their decision to purchase the vehicle with most vehicle owners specifically asking for the navigation system (62%). The vast majority of drivers were male (71%) with few young drivers (16%) and an equal number of middle-aged and older drivers (42% respectively). Key driver demographic information is presented in Table 28. For purposes of analysis, drivers were classified into three experience levels ("low", "intermediate", and "high") based on self-reported system usage and the number of miles driven since the vehicle was purchased.

Table 28 Key Demographic and Experience Data for the Sample of Navigation System Vehicle Owners

n = 228	Mean	Standard Deviation	Min	Max	25th Percentile	50th Percentile	75th Percentile
Age	55.02	13.95	23	87	44	56	65
Years Driving Experience	37.99	14.29	4	70	26	40	50
Miles Driven in Vehicle	15,251	12,568	100	70,000	6,000	12,000	22,000
System Usage (per week)	4.078	5.87	0	25	1	2	5

System Usage

Most drivers (70%) reported using the system frequently (i.e., very often or often) after first purchasing the vehicle; as shown in Figure 74, initial use does not appear to differ substantially across driver age groups. System use over time remained the same for most drivers (55%), increased for some (30%) and declined for a small percentage of drivers (15%). As shown in Figure 75, changes in the frequency of use were also not substantially different across driver age groups. Increases in use were generally attributed to increased familiarity with the system which was perceived to require some degree of learning in order to understand its operation and range of options. Current system use measured in terms of average weekly use also did not appear to differ substantially across age groups; mean usage for young, middle-aged and older drivers was 3.86, 4.25, and 3.53 respectively. Approximately 50% of drivers used the system one or two times per week, irregardless of age (see Figure 76). Drivers whose system usage decreased over time felt the system was too complex, or limited in its application (many tended to use the system only on long trips since they typically travel in familiar areas), others indicated that the novelty of having the system wore off and so did their use of the system.

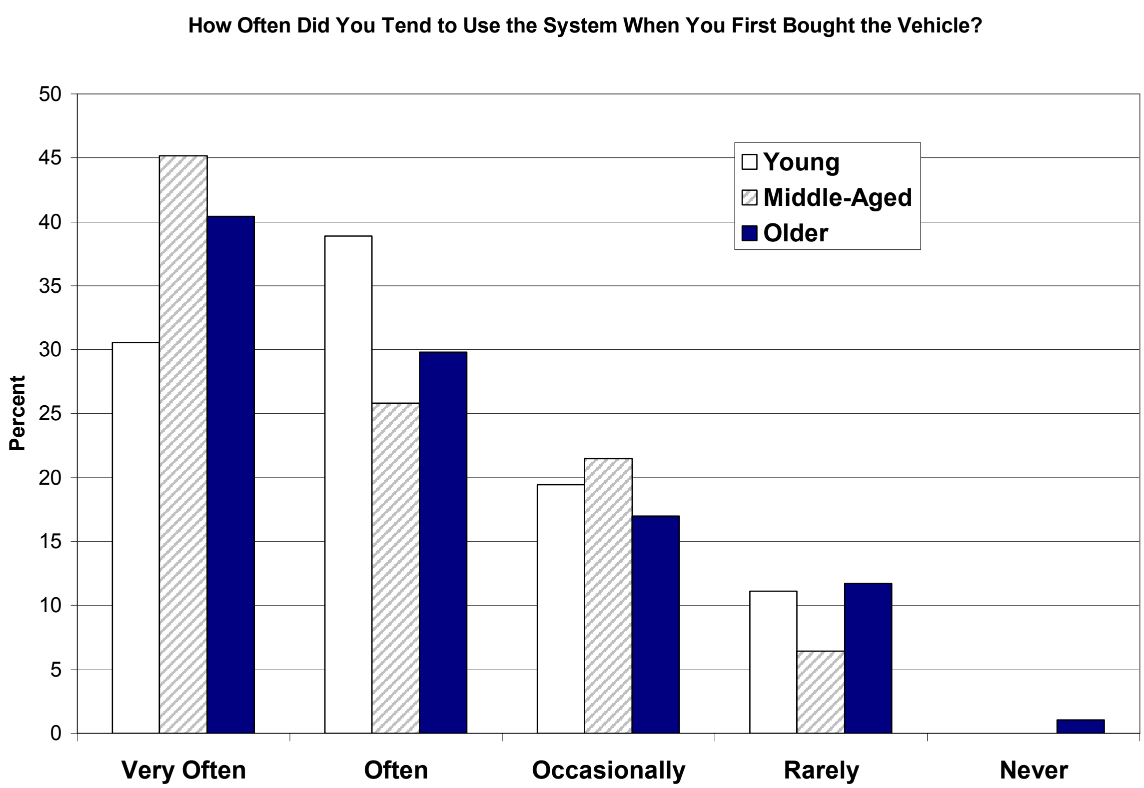


Figure 74 Frequency of Initial Navigation System Use by Age Group

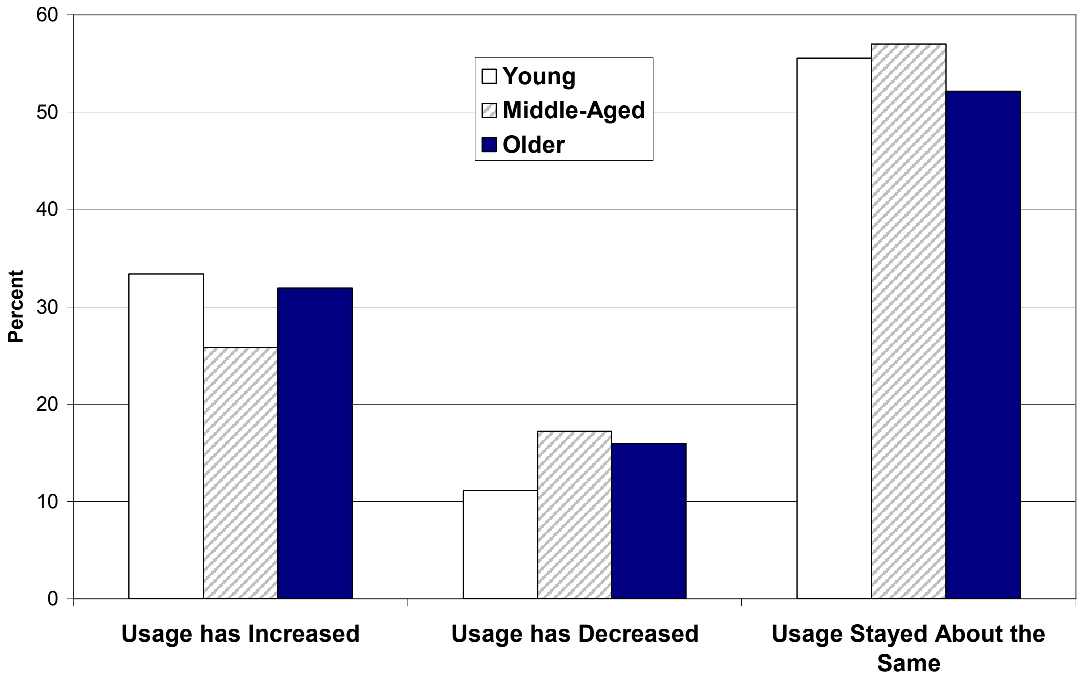


Figure 75 Change in Navigation System Usage Over Time as a Function of Driver Age Group

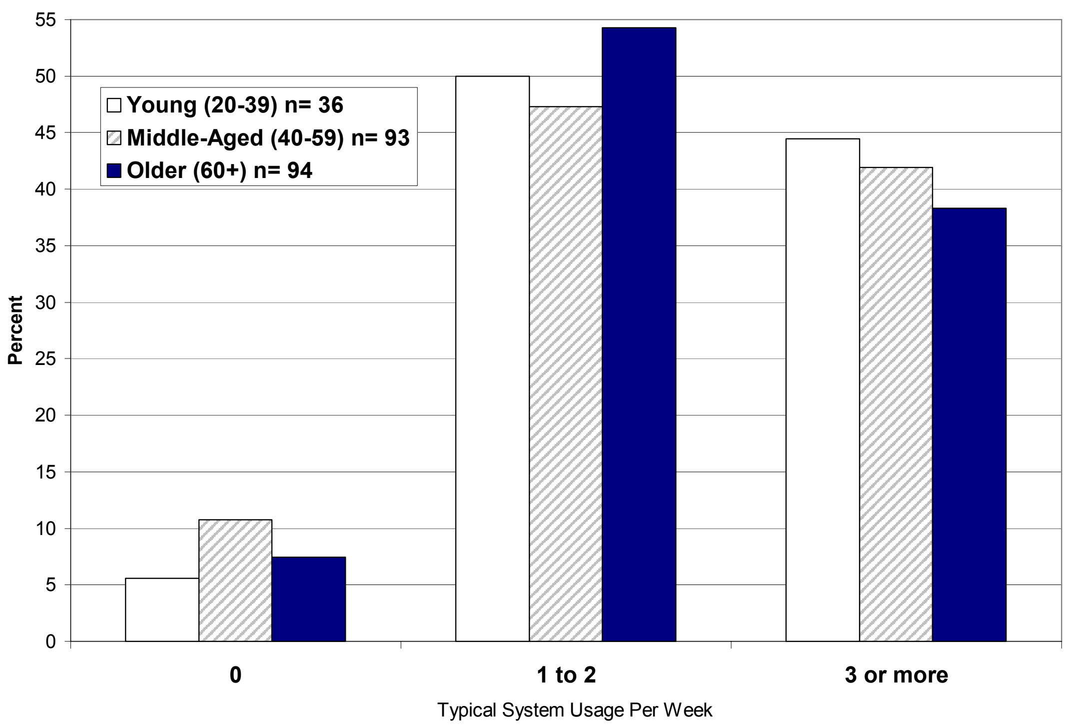


Figure 76 Percentage of Drivers Reporting System Usage of Between Zero and 3 or More Times Per Week

Although drivers reported using a range of methods for programming a destination into the navigation system (as shown in Figure 77), street address entry was by far the most frequently used destination entry method among drivers; ironically, this method also typically requires the most intensive level of interaction (e.g., button presses, menu levels, etc.). The relatively simpler method of programming via address book was used with much less frequency by drivers (half as frequently as street address). Driver age or experience levels did not appear to influence use of the street address method. However, experienced drivers appeared more likely than low experience drivers to use map, address book, point of interest, and intersection destination entry methods (see Figure 78). Older drivers were also less likely to use voice commands to program a destination compared to younger drivers; 40% of older drivers reported never using voice commands for destination entry compared to 25% of younger drivers (see Figure 79).

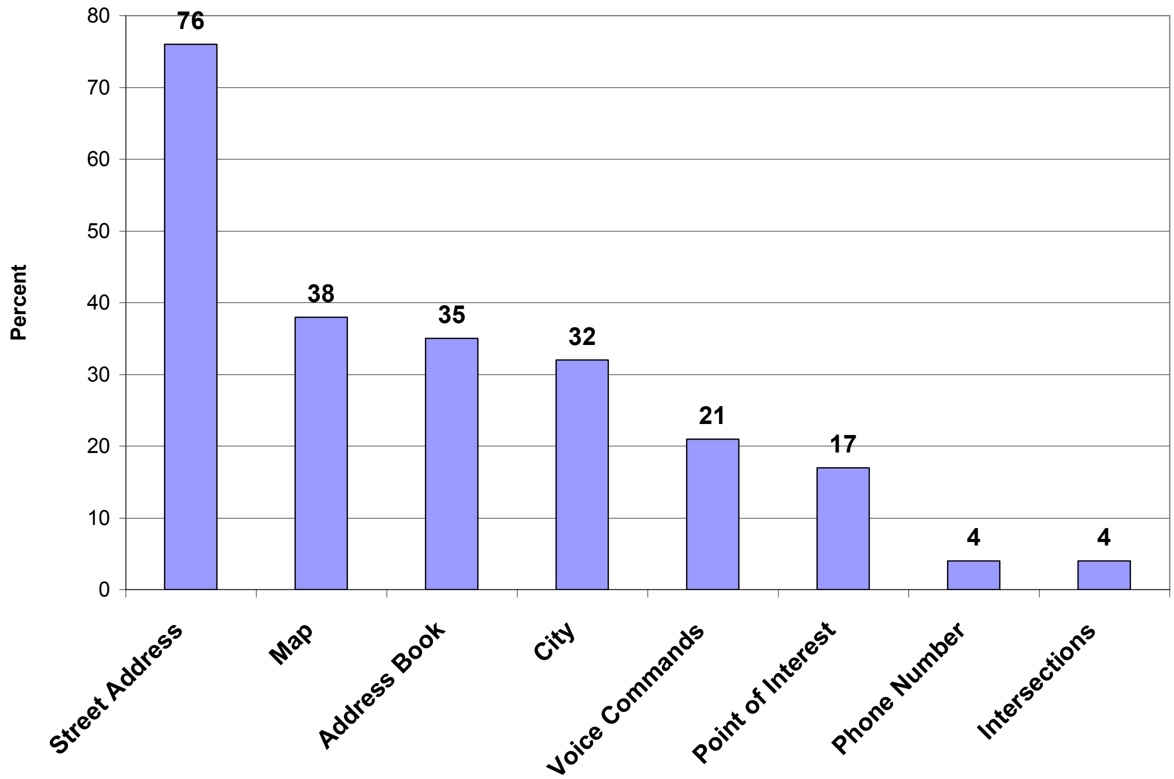


Figure 77 Frequency of Use for Various Destination Entry Methods (Graph Shows the Percent of Drivers Who Use the Method All of the Time or Usually)

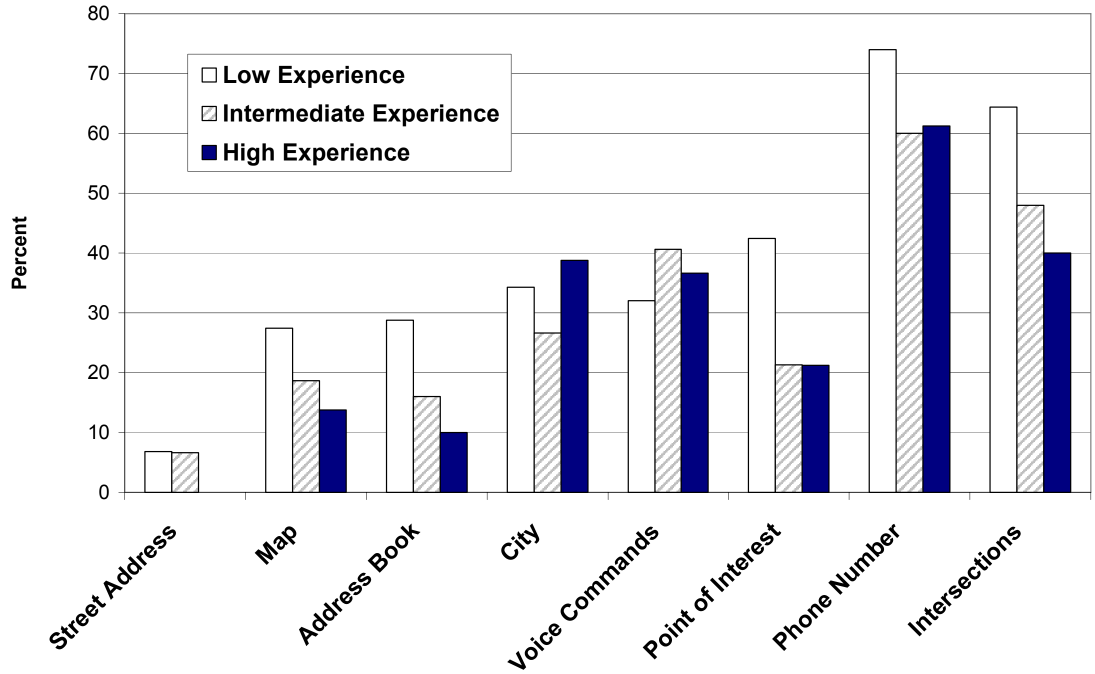


Figure 78 Percent of Drivers Reporting "Never" Using the Destination Entry Method as a Function of Experience

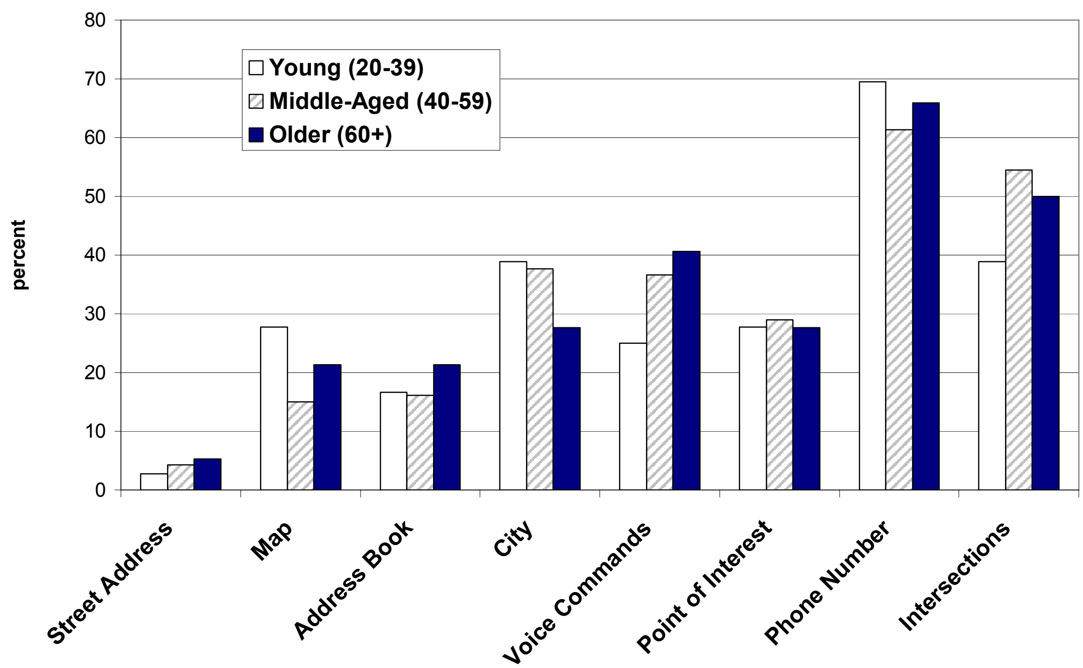


Figure 79 Percent of Drivers Reporting "Never" Using the Destination Entry Method as a Function of Age

Effectiveness and Acceptance

Drivers were generally pleased with their navigation system with 88% of the owners rating the system as moderately to very useful (assigning a value of 4 or 5 on a five point scale. More importantly, the vast majority of drivers (95%) would recommend a navigation system to a friend, and 99% would like such a system in their next vehicle. Most advocates would recommend the system because of the added convenience and safety of not having to ask for directions when traveling in unfamiliar areas, finding the closest store, gas station or ATM. Some mentioned that navigating with the system is better than with a map, particularly at night when street signs may be difficult to read. Those who would not recommend the system felt it was too costly relative to the value added, and was too difficult to use. Perceptions of the system's utility were moderately influenced by experience with the system. As shown in Figure 80, experienced users (drivers who used the system frequently) tended to have more extreme positive ratings of system usefulness compared to low experience users (99% of experienced drivers assigned usefulness ratings of 4 or 5 to the system). Most drivers (89%) indicated that the navigation system lived up to their expectations; those who were disappointed with the system tended to feel it is too difficult to use and understand.

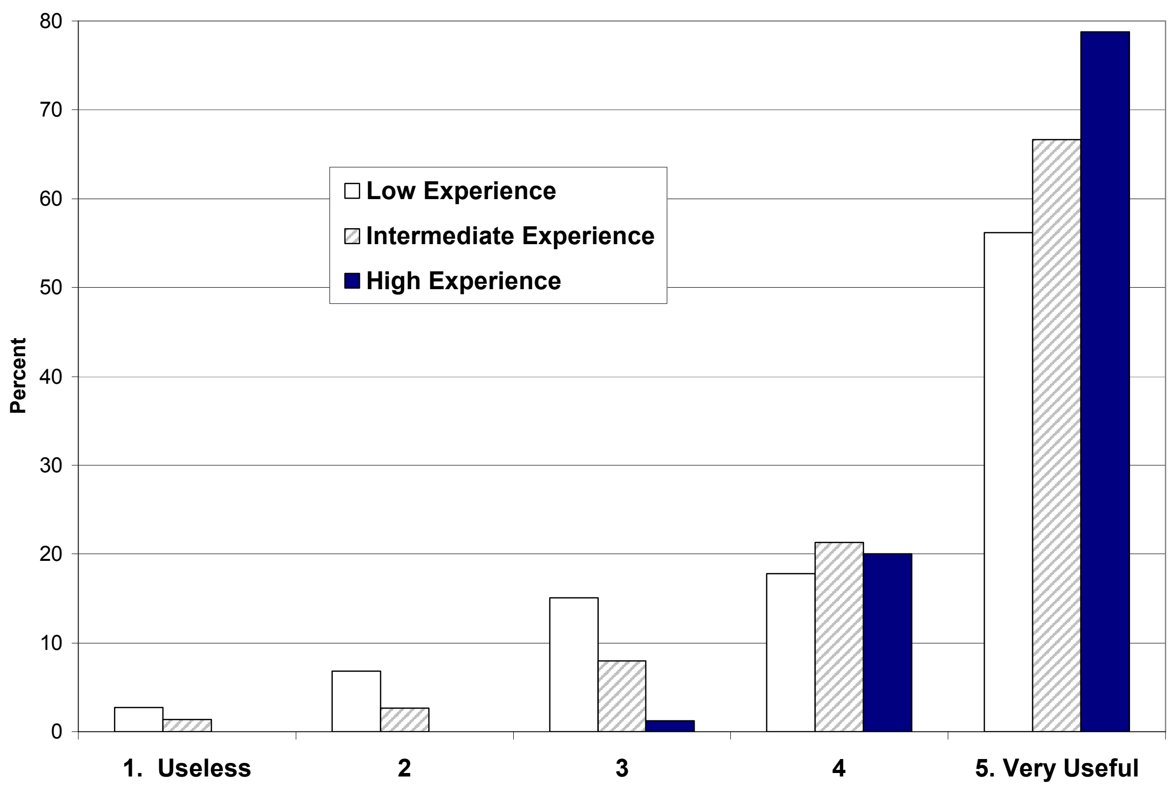


Figure 80 Ratings of the Navigation System's Usefulness as a Function of Experience with the System

As shown in Figure 81, most drivers felt the system was effective in terms of its ability to operate in a wide range of environments, providing sufficient notice of upcoming turns and maneuvers, and in positioning the display so that it reduces glare. Driver trust in the system also tended to increase somewhat with usage.

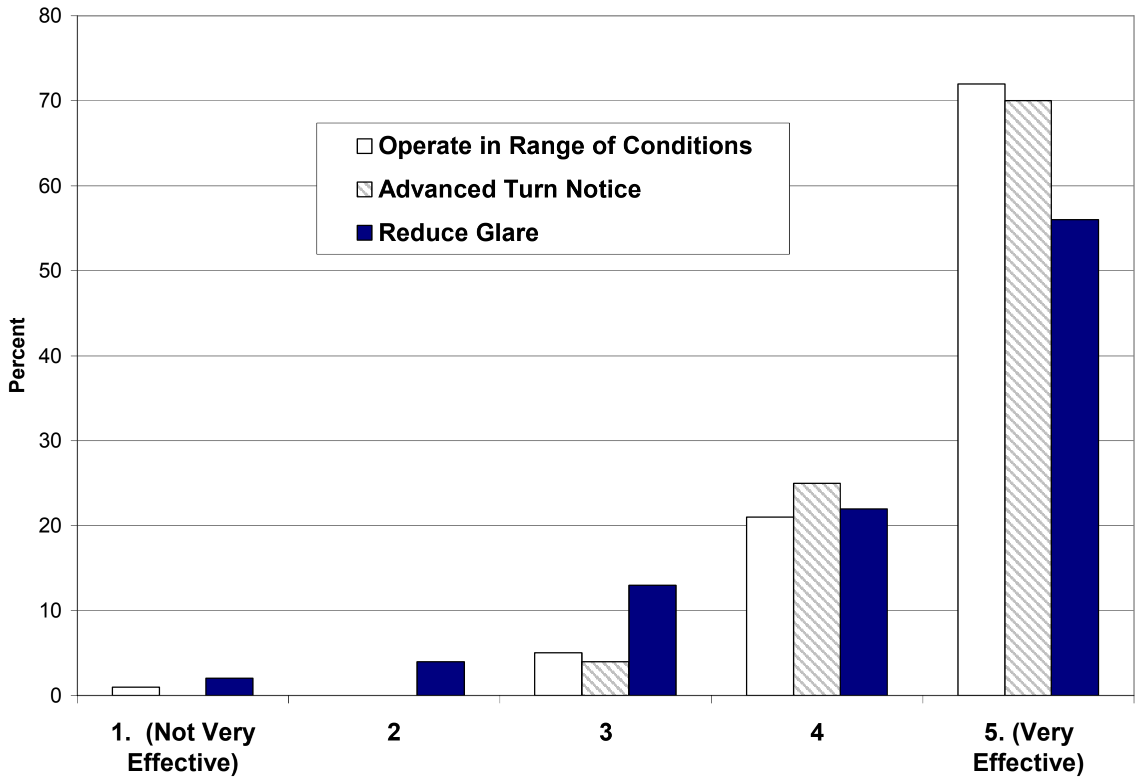


Figure 81 System Effectiveness Ratings for Key System Attributes and Functions

System Knowledge & Learning

Arguably, navigation systems represent one of the most complex systems on the market, incorporating a relatively large number of features and options for configuring displayed information and executing tasks. Many offer a separate owner's manuals or supplement dedicated to providing directions for programming and using the system, making the information contained in the owner's manual is particularly relevant and important. Over 93% of drivers reported reading some or all of the information relating to their navigation system in the owner's manual. As shown in Figure 82, older drivers appear much more likely than younger drivers to read information about the system in their owner's manual; nearly 75% of older drivers reported reading all of the system information contained in their owner's manual compared to 47% of younger drivers. Over 22% of younger drivers did not read any part of their owner's manual.

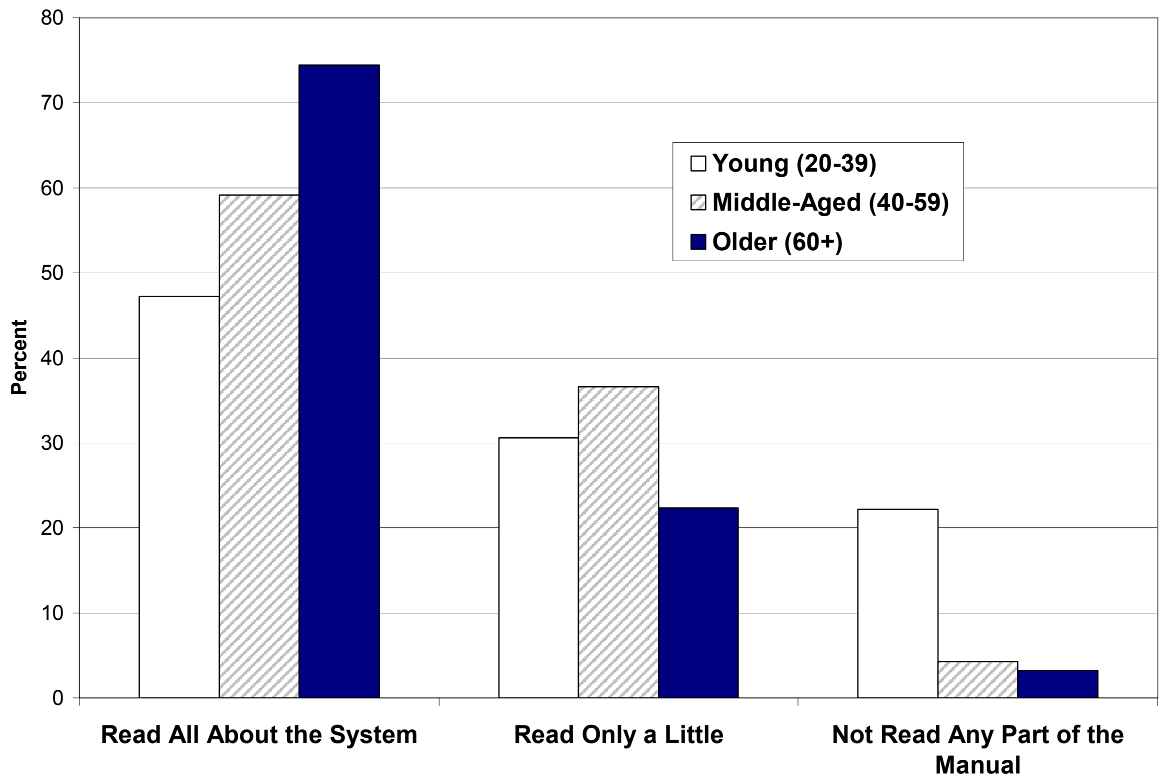


Figure 82 Percent of Drivers Reporting Reading Owners Manual as a Function of Age

Although drivers relied on a wide variety of information sources to learn about the functions and limitations of their navigation systems, on-road experience with the system was the most widely reported method used (see Figure 83). Nevertheless, a surprising percentage of drivers were unsure about even the most basic features of their systems, including the ability to repeat verbal turn instructions or configure the system to provide voice-only turn information (turn-off the visual display). For example, 31% of system owners were unsure if the system could repeat a verbal instruction if so desired - a common feature on most if not all systems.

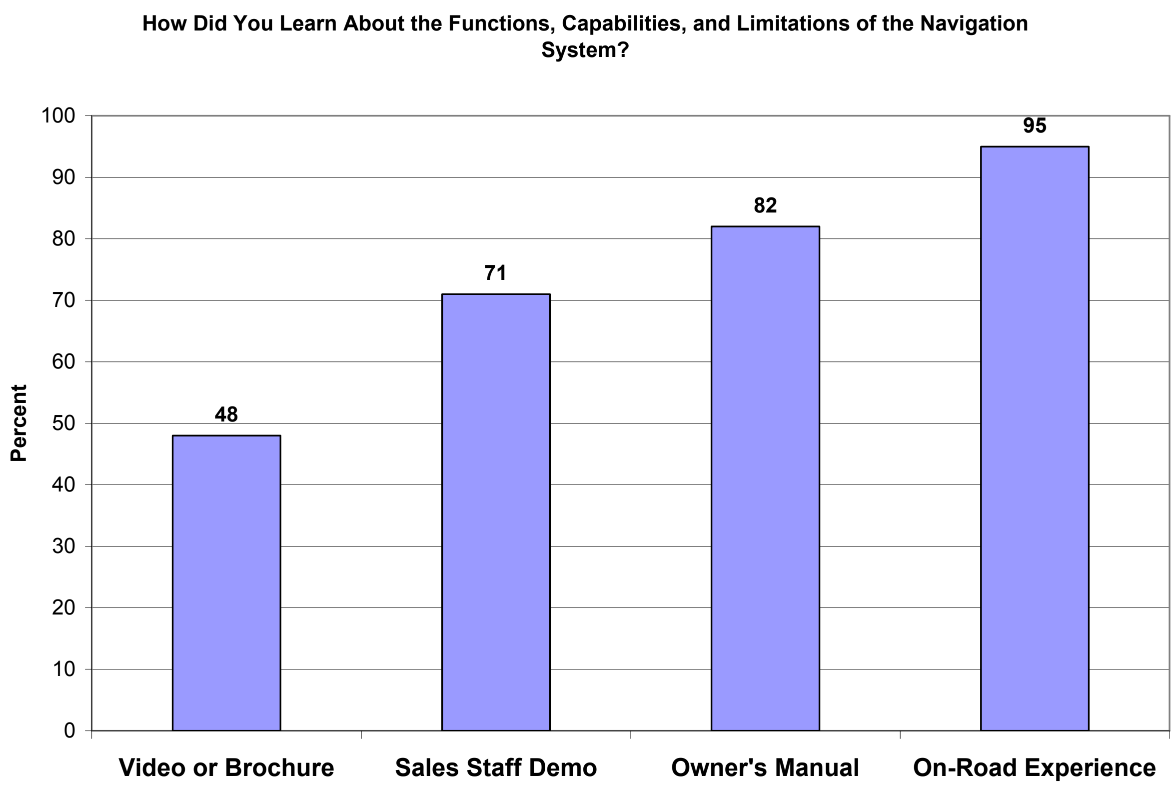


Figure 83 Information Sources Used by Vehicle Owners to Learn About System Capabilities, Limitations and Functions

For most, learning to operate the navigation system was measured in terms of weeks rather than days. Although roughly 28% of drivers felt comfortable operating the system within 2-3 days of using it, about 45% of drivers took a month or longer to feel comfortable with the navigation system. Age appeared to have a marginal impact on the length of time reported to feel comfortable using the navigation system. After the 1st week of use, approximately 58% of younger and middle-aged drivers reported feeling comfortable with the system compared to about 50% of older drivers. As shown in Figure 84, middle-aged drivers were more likely to feel comfortable using the system after the first 3 days of use compared to their counterparts. Most younger drivers felt comfortable with the system after the first week. A substantial percentage of drivers across all age groups report never feeling comfortable using the system.

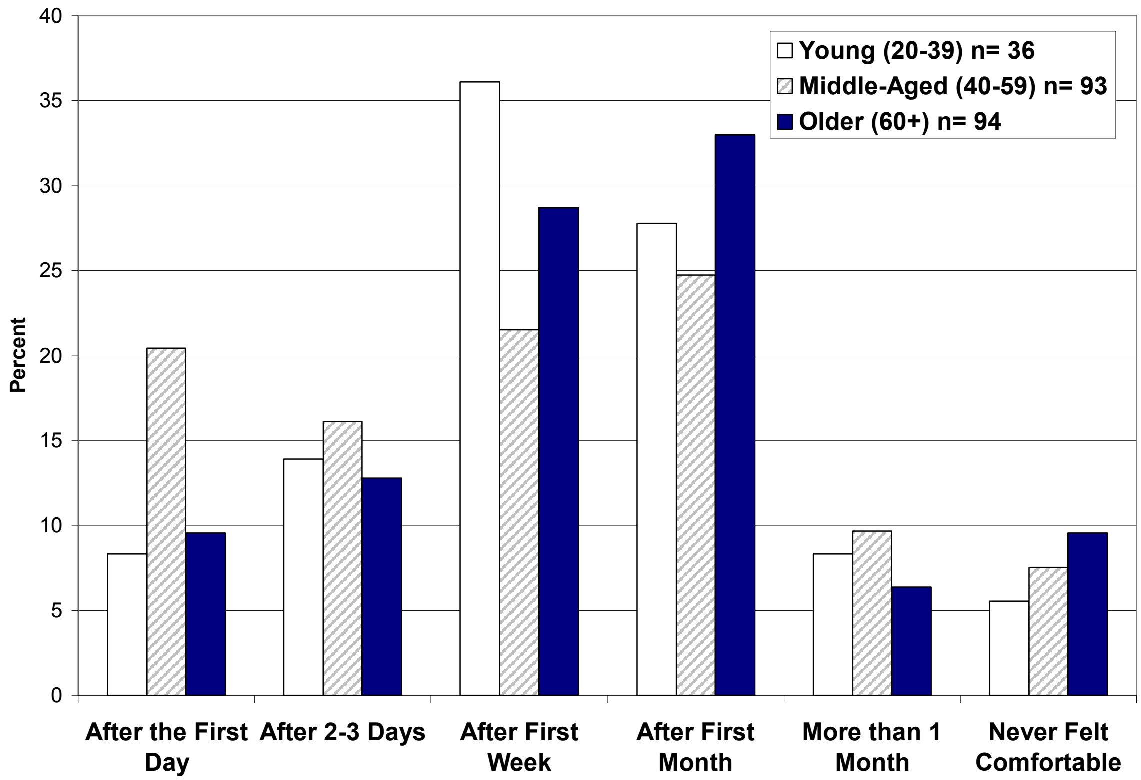


Figure 84 Length of Time for Drivers to Become Comfortable Using the Navigation System

Although many owners felt their system was somewhat or very easy to learn to use (60%), over one-quarter of drivers (26%) felt their system was somewhat or very difficult to learn to use. As illustrated in Figure 85, this perception was shared among drivers across different age groups and was not necessarily limited to older drivers. A large percentage of system owners (43%) felt the navigation system posses some features or aspects which were particularly difficult to learn, including programming a destination, navigating through the menu structure, changing routes and adding stops, and memorizing voice commands.

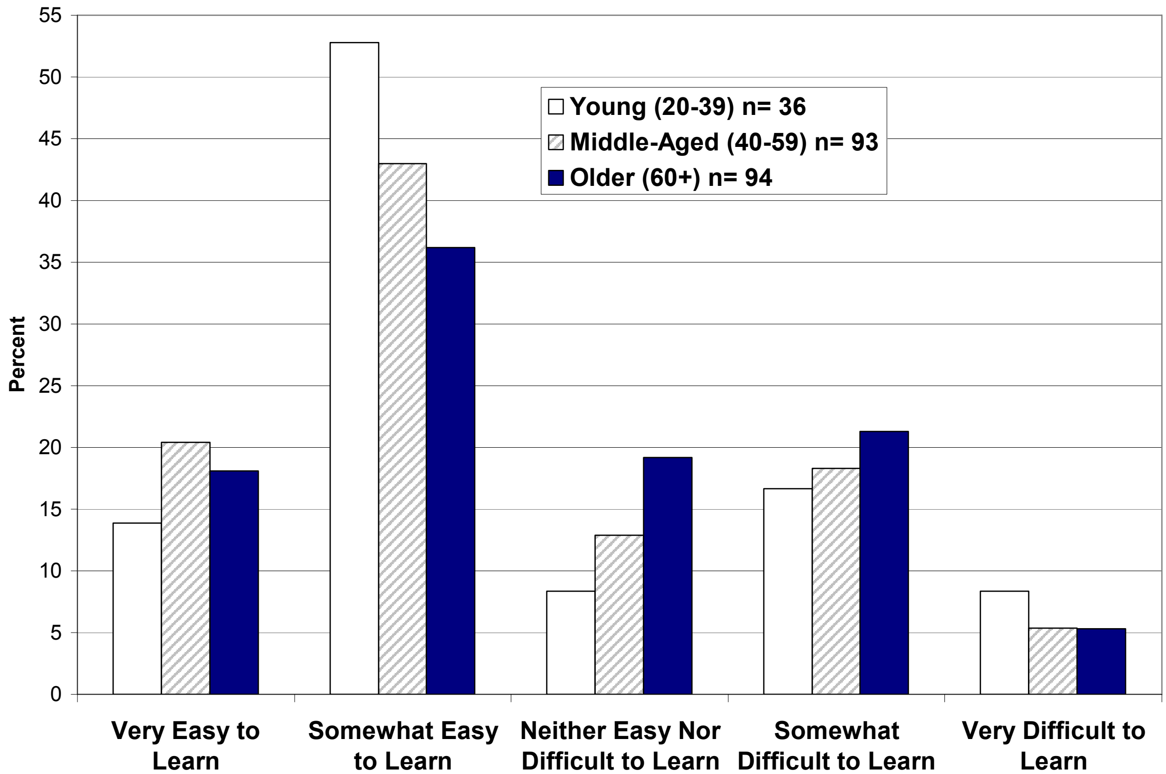


Figure 85 Driver Ratings of Navigation System Ease of Learning

No particular vehicle's navigation system stood out as being particularly easy or difficult to use based on mean "ease of use" ratings, or in terms of the extreme scores for these ratings. While all systems averaged scores above 3, none of the systems averaged scores above 4 on a 5 point scale.

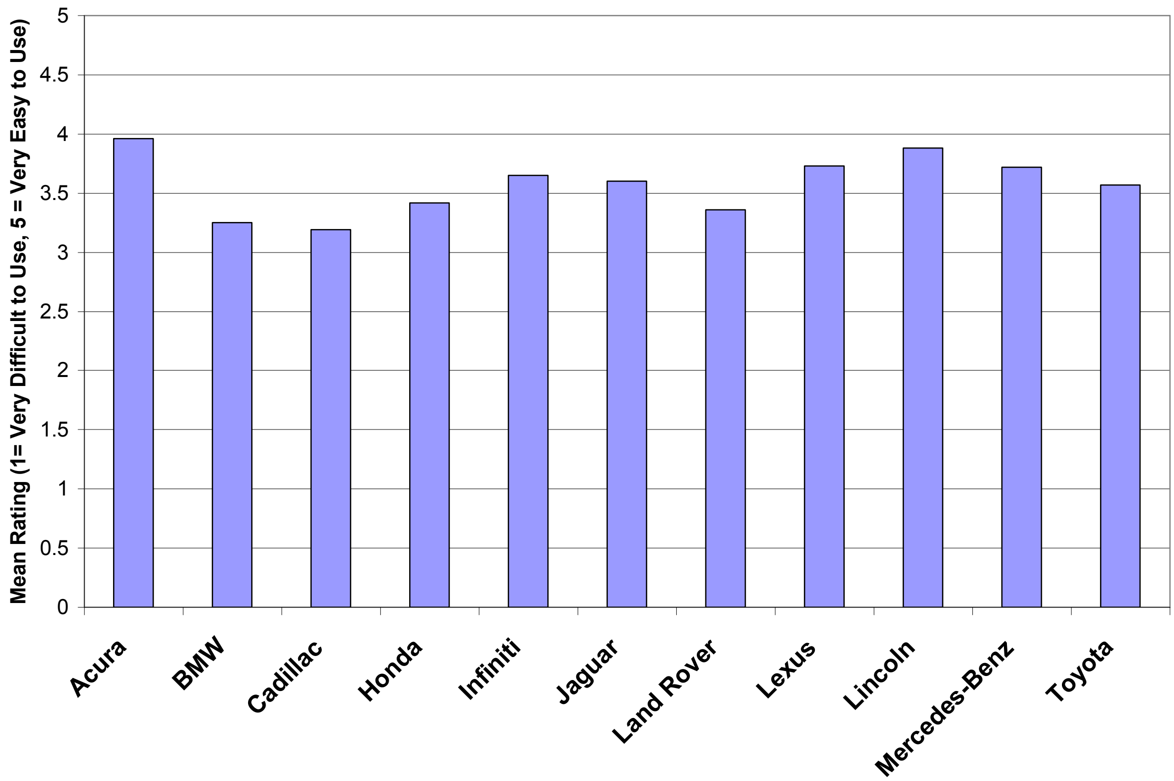


Figure 86 Mean Ease of Use Ratings for Navigation System by Vehicle Make

Safety & Behavioral Impacts

Although the overwhelming majority of drivers (98%) feel using the navigation system is safer than navigating with a paper map, 10% of drivers (23 out of 228) feel the navigation system decreases overall safety (assigned ratings of 2 or less). A number of safety related problems were experienced by drivers in our sample. For example, 3% of users (7 out of 228) report inadvertently running a stop sign or traffic signal because they were glancing at the display, and 4% (9 out of 228) report experiencing a close call when programming the system while driving. No crashes were reported, and most drivers (82%) believe their chances of being involved in a crash are no greater or lesser when using the system compared to not using the system. However, as shown in Figure 87, 18% of users believe that using the system elevates their risk of being involved in a crash to some degree (assigned ratings of 4 or 5). Experienced system users were somewhat less likely to feel that the system increases their crash risk compared to low or intermediate experience level users; 10% of experienced users indicated an elevated risk level with the system (assigned ratings of 4 or 5) compared to 23% of inexperienced users and 21% intermediate level users. Also, approximately 22% of middle-aged drivers feel the system increases crash risk, compared to 11% of younger drivers (older drivers fell in between these two groups with 17% feeling the system increases their crash risk).

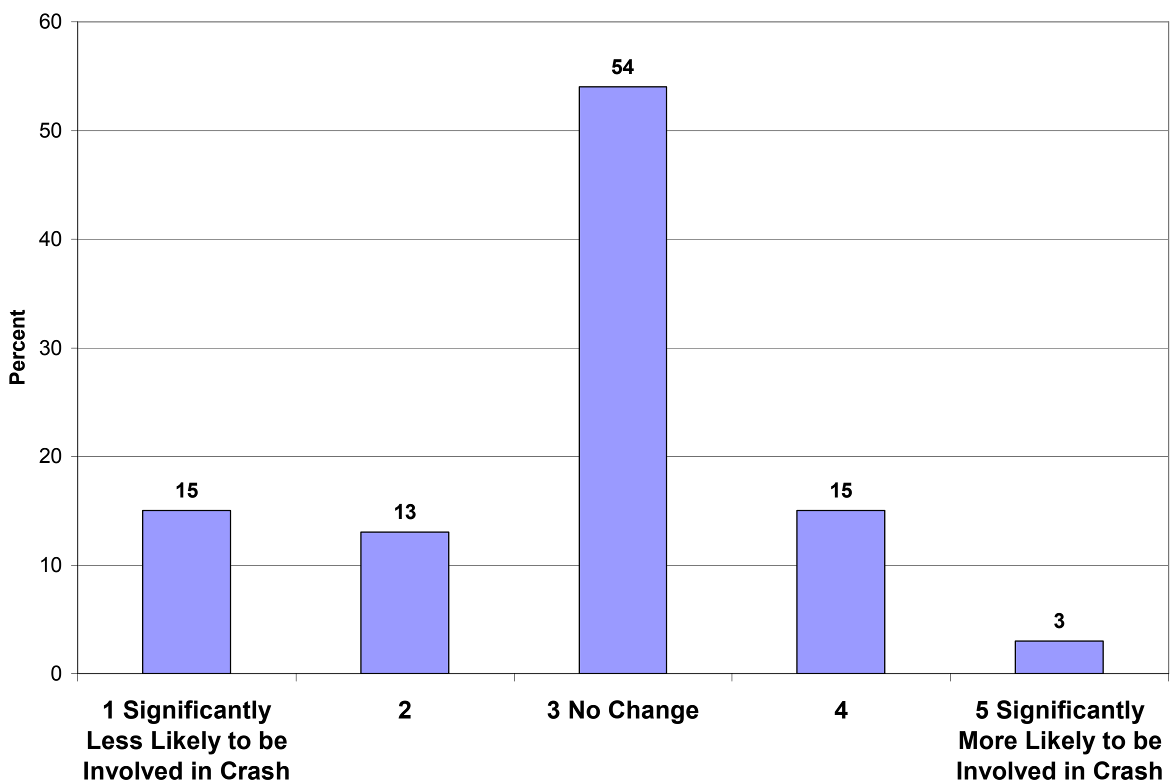


Figure 87 Ratings of Crash Likelihood While Using the Navigation System

Perceptions of increased crash risk appear to result from a number of factors, including a degraded ability to predict and respond to road hazards when using the system, increases in erratic maneuvers in response to navigation commands, and an increase in glances away from the road resulting in less scanning of the environment. Nearly one-third of drivers (32%, or 73 out of 228 drivers) admitted that they tend to look away from the road more frequently and for longer periods of time when driving with the navigation system. Young and middle-aged drivers appeared more likely to report that the system causes them to look away from the road more often and for longer periods of time compared to older drivers (see Figure 88). A trend in the data also suggests that more experienced navigation users (high or intermediate experience levels) may reduce their frequency of glances to the environment or mirrors compared to novice system users; 9% of experienced users indicated reduced scans compared to 3% of novice users.

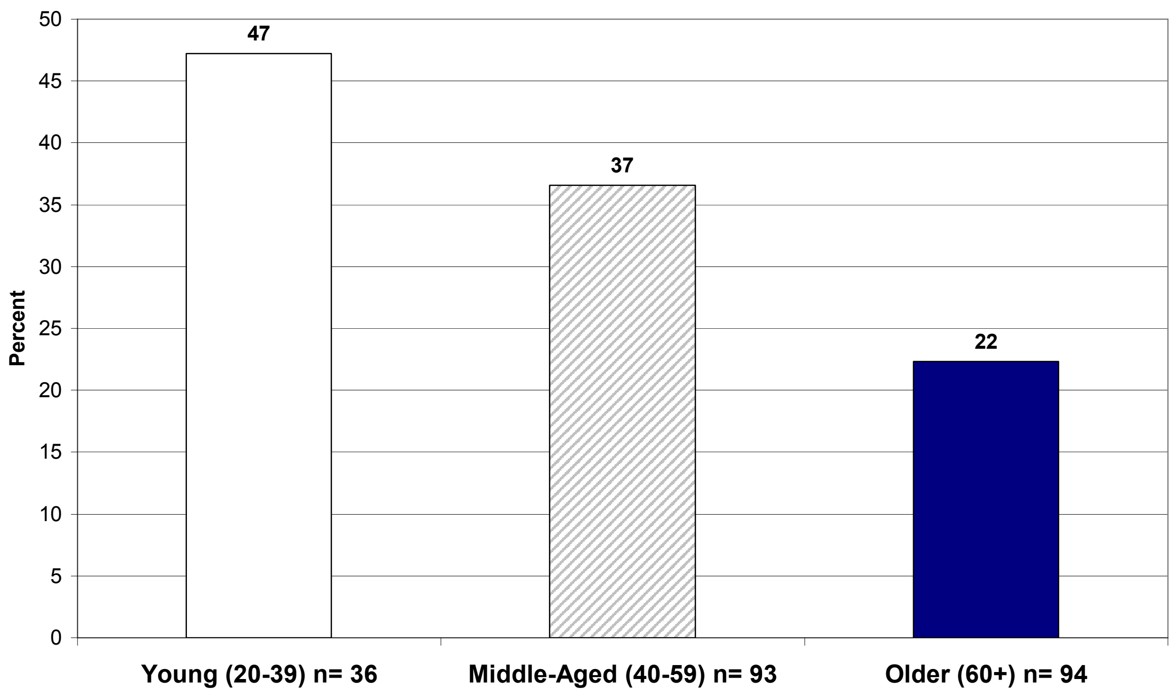


Figure 88 Percentage of Drivers Indicating that the Navigation System Causes them to Look Away from the Road More Frequently and for Longer Periods of Time as a Function of Age

The navigation system also influenced certain types of behaviors, including driver willingness to travel in unfamiliar areas, and the types of roads traveled. In all, 76% of drivers in our sample indicated the navigation system increased their willingness to drive in unfamiliar areas (assigned ratings of 4 or 5). As shown in Figure 89, this trend was consistent across drivers of all ages, and was not necessarily restricted to older drivers.

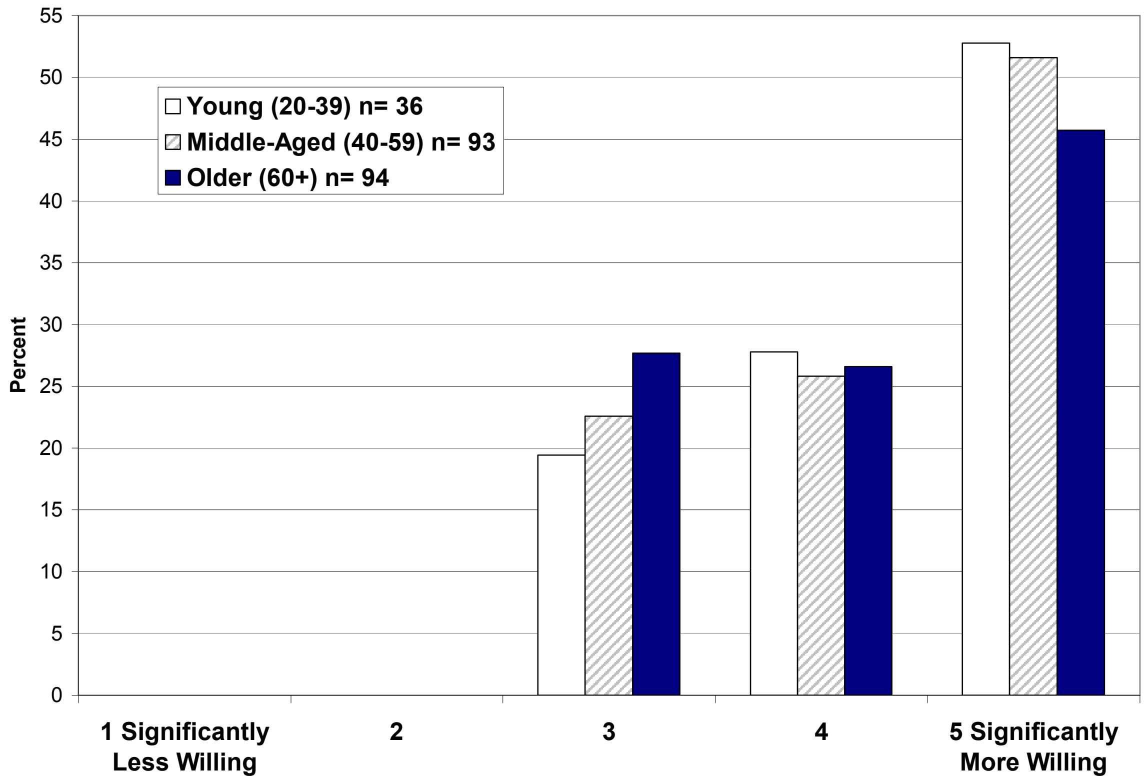


Figure 89 Driver Ratings of their Willingness to Drive in Unfamiliar Areas as a Result of Having the Navigation System by Age Group

Although most drivers in our sample (72%) indicated that they do not travel more on neighborhood streets to avoid congestion with the navigation system, a substantial number of drivers (27%, or 61 out of 228) do use their navigation system to re-route and avoid congestion by traveling on neighborhood streets. As shown in Figure 90, young drivers appear somewhat more likely than older drivers to travel on neighborhood streets in order to avoid congestion.

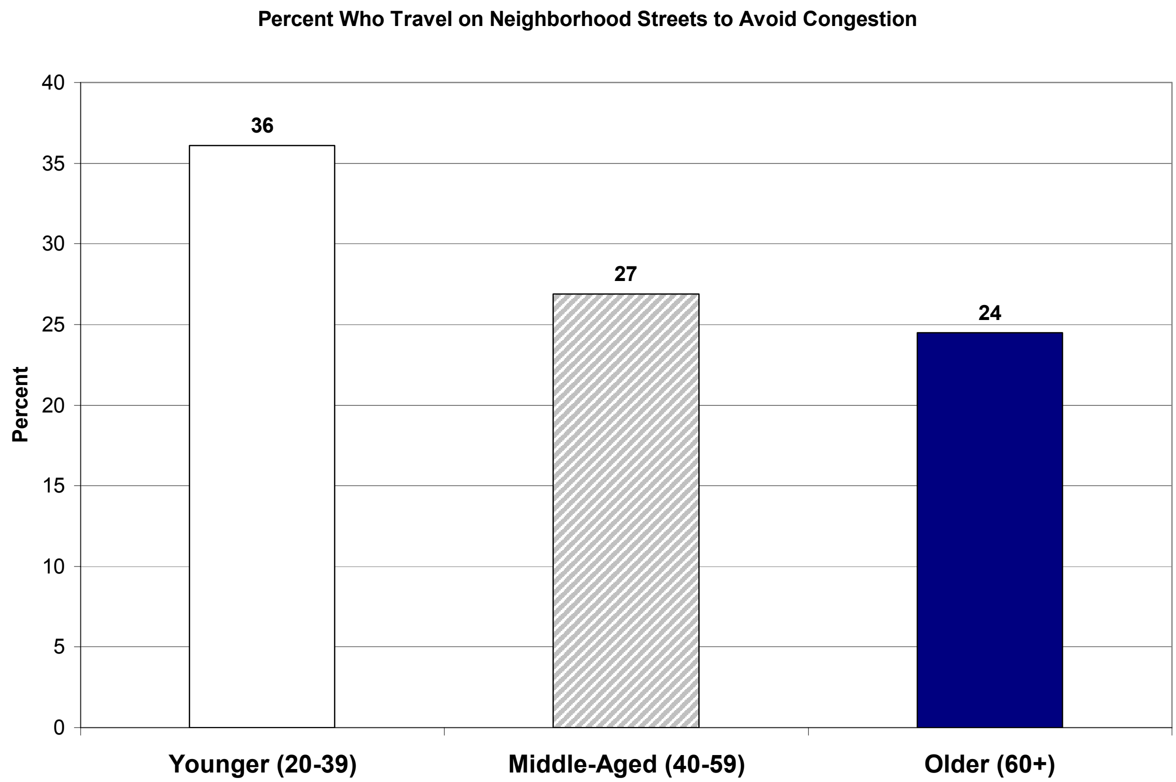


Figure 90 Percent of Drivers Indicating They Travel More on Neighborhood Streets to Avoid Congestion with the Navigation System by Age Group

Interface

Navigation system users are provided with a range of visual display options for guidance and route navigation, including maps and turn lists. In general the vast majority of users (93%) found the visual displays to be somewhat or very easy to use; approximately 6% of users found the visual displays to be somewhat or very difficult to use. Although age did not appear to impact driver perception of the ease of use of the visual displays, driver experience with the navigation systems did affect perceived ease of use to some degree. As illustrated in Figure 91, more inexperienced users (11%) tended to rate the system visual displays as somewhat or very difficult to use compared to intermediate (5%) and high experience (2%) users.

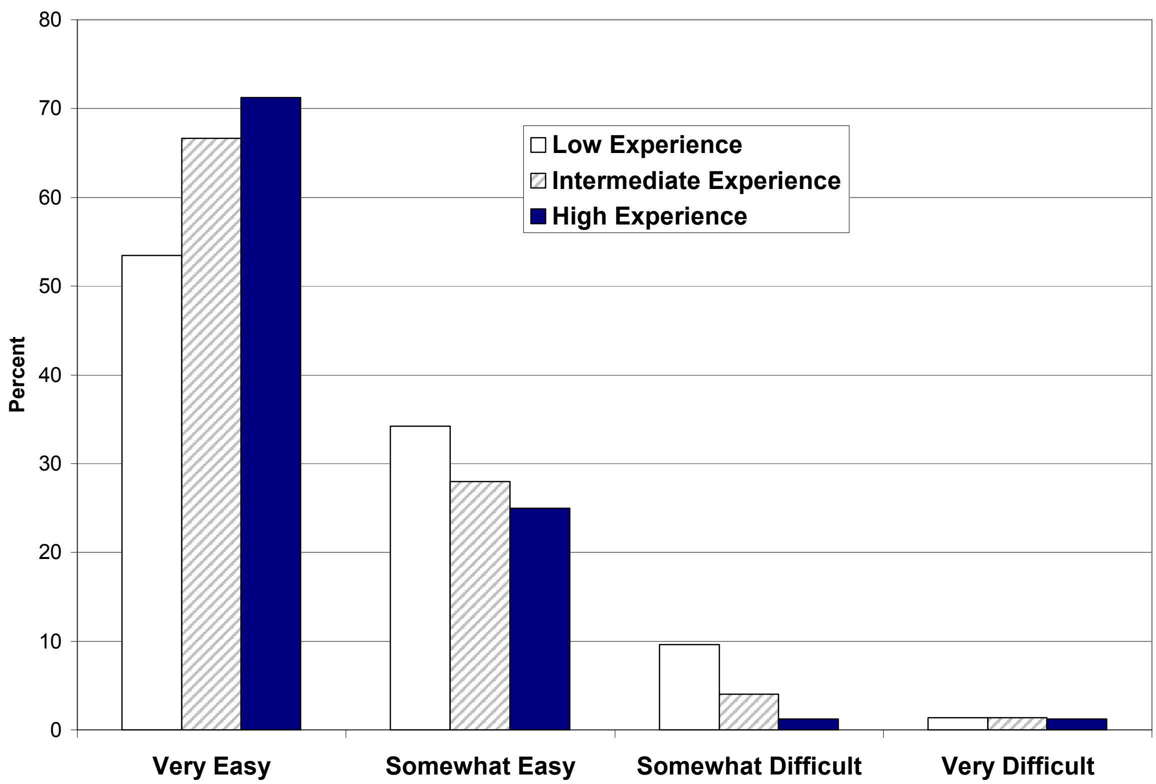


Figure 91 Perceived Ease of Use of System Visual Displays by Experience Level

In general, voice instructions provided by the system were perceived to be comparable in terms of ease of use as the visual displays with 93% of users rating the voice instruction to be somewhat or very easy to use. Approximately 5% of users found voice instructions to be somewhat or very difficult to use. In contrast to the visual displays, experience with the navigation system did not appear to influence perceived ease of use of the voice instructions.

However, more young drivers (11%) rated the voice instructions to be somewhat or very difficult to use in comparison to middle-aged (4%) or older (2%) drivers.

Overall, most drivers (52%) indicated that they relied on the voice instruction provided by the navigation system as opposed to the visual display for route guidance information. Young drivers were more likely than older drivers to rely on displayed information for routing directions (see Figure 92). Experienced system users also tended to rely on visually presented information as opposed to voice instructions; 46% of experienced drivers preferred the visual display outputs compared to 37% of inexperienced system users. Of he visual presentation forms, maps were used by 24% of the drivers for active guidance while driving. Surprisingly, older drivers appeared as likely as younger drivers to use maps while driving; 25% of older drivers used maps compared to 19% of younger drivers. 68% of women prefer verbal instruction, compared to 35% of men. Only 17% of women relied on maps compared to 27% of men. Experience with the system did not appear to substantially influence the method drivers relied on for guidance while driving.

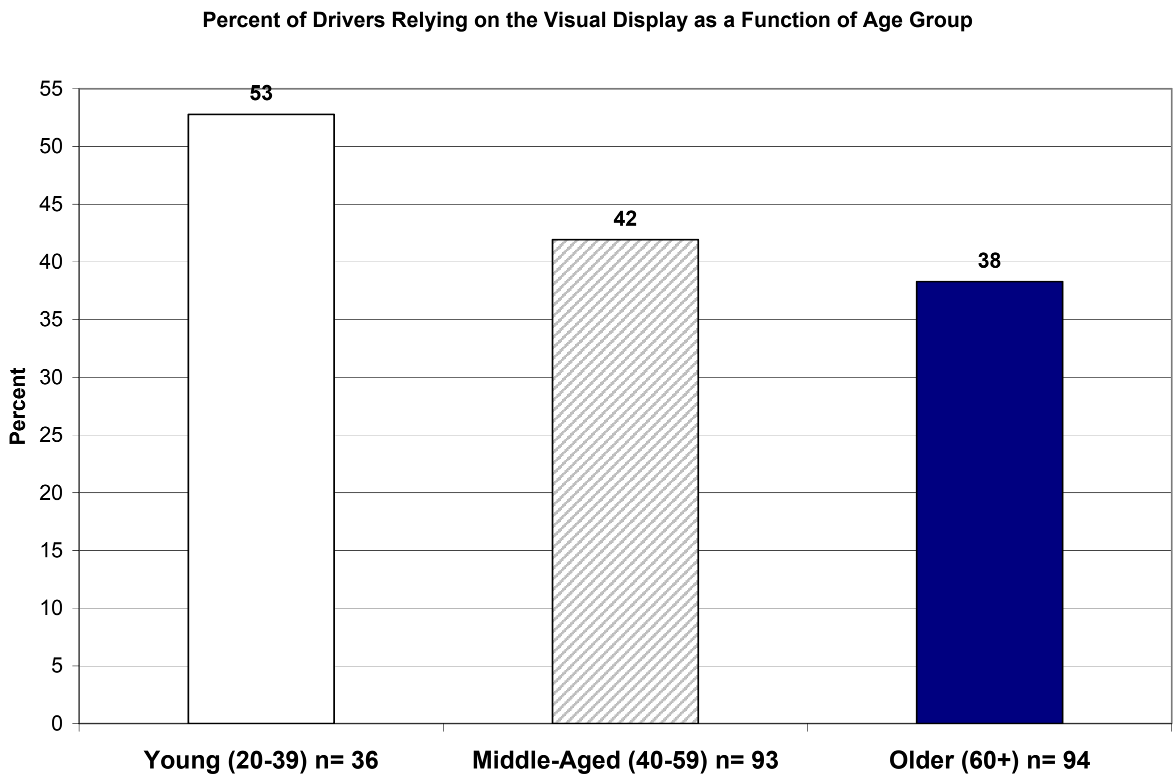


Figure 92 Reliance on Visual Display Outputs as a Function of Age

Our sample of 228 navigation system users included 87 voice recognition systems enabling drivers to make selections and interact with the system through voice commands. Nevertheless, the majority of drivers with voice recognition systems (68%) prefer to use manual inputs for most system functions. These preferences did not appear to change substantially as a function of experience with using the navigation system or driver age. Re-routing and setting a destination (e.g., "home") were common function executed using voice commands. As shown in Figure 93, while most users (58%) reported that the system reliably recognized their voice commands, nearly one-third (31%) found that the voice recognition technology functions unreliably (e.g., recognized commands some of the time or none of the time).

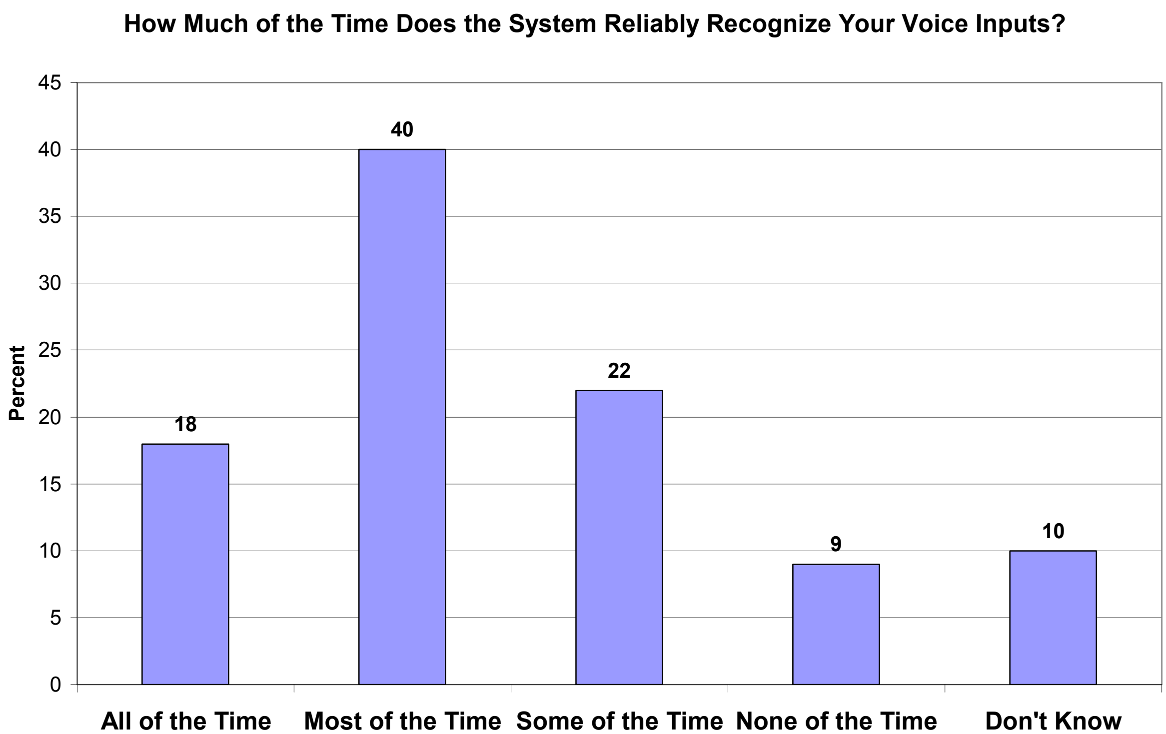


Figure 93 Rated Reliability of Voice Recognition System

Most users (60%) believe that voice inputs are safer than conducting manual interactions with the system. As shown in Figure 94, experience with the system appears to change perceptions about the safety of manual control inputs by the driver; inexperienced users tend to feel manual input is safer, but fewer experienced users agree.

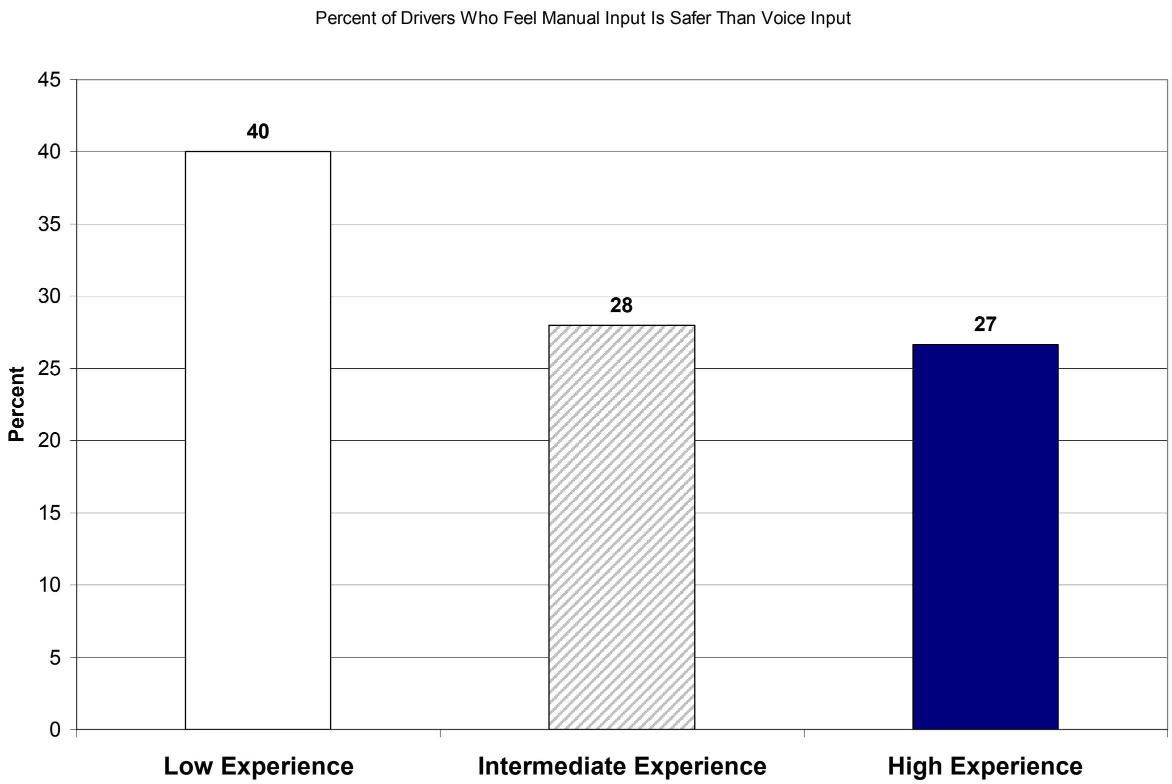


Figure 94 Perceived Safety of Manual Inputs as a Function of Experience

Although drivers of all ages reported experiencing problems recalling specific system commands (see Figure 95), middle-aged and older drivers tended to have more difficulty remembering voice commands compared to younger drivers. Only 8% of young drivers reported having frequent difficulty (all or most of the time) recalling voice commands compared to middle-aged drivers (34%) and older drivers (28%).

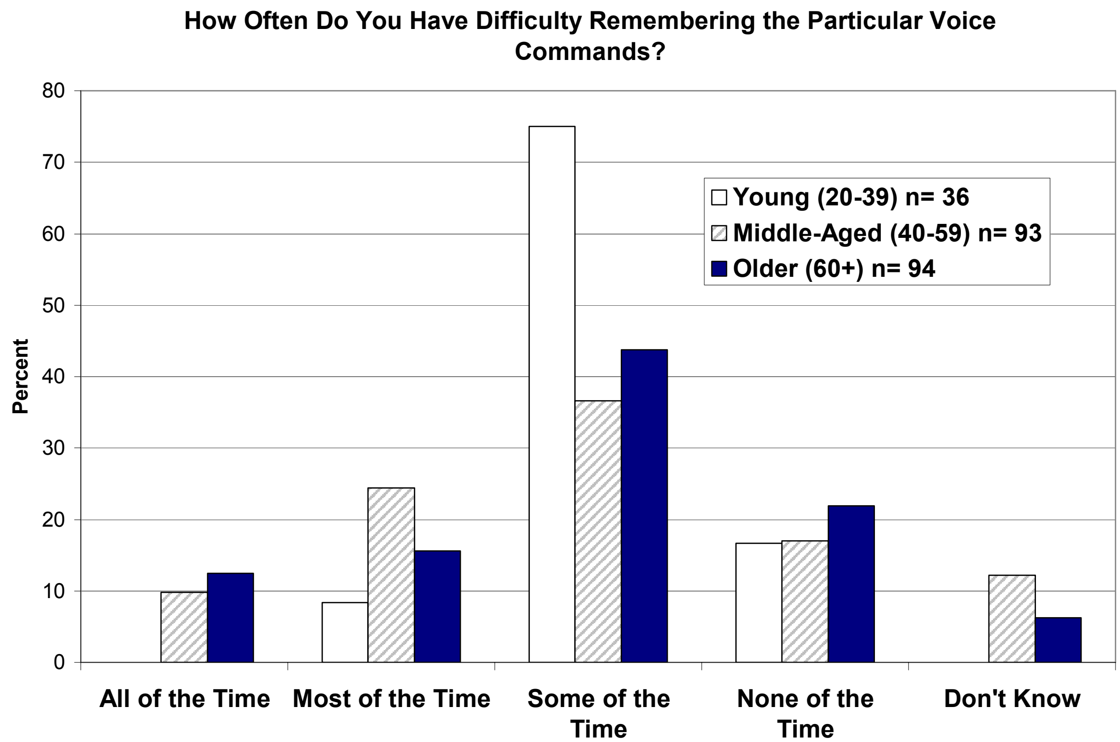


Figure 95 Frequency With Which Drivers Report Experiencing Difficulty Recalling System Voice Commands as a Function of Age

Figure 96 summarizes the various types of navigation system improvements or changes suggested by owners in our sample. By far, ease of system use and operation was the single largest improvement desired by navigation system owners. Many felt that their navigation system is overly complicated and that the task of entering a destination needs to be simplified. Systems were perceived to provide too many options and features with overly complicated and confusing user manuals. Many called for destination entry via telephone (where the destination's street address is automatically programmed into the system by entering a telephone number), voice commands, or touch-screens. Drivers whose system did not have voice recognition desired this feature, many with voice recognition called for improved reliability. Drivers also desired larger and better located displays which would not require them to take their eyes off the road (e.g., "displays presented on the windshield"). Some drivers desired the ability to program their system while driving and wanted to eliminate any lockouts preventing them from interacting with the system when the vehicle is moving, or allow passengers to interact with the system.

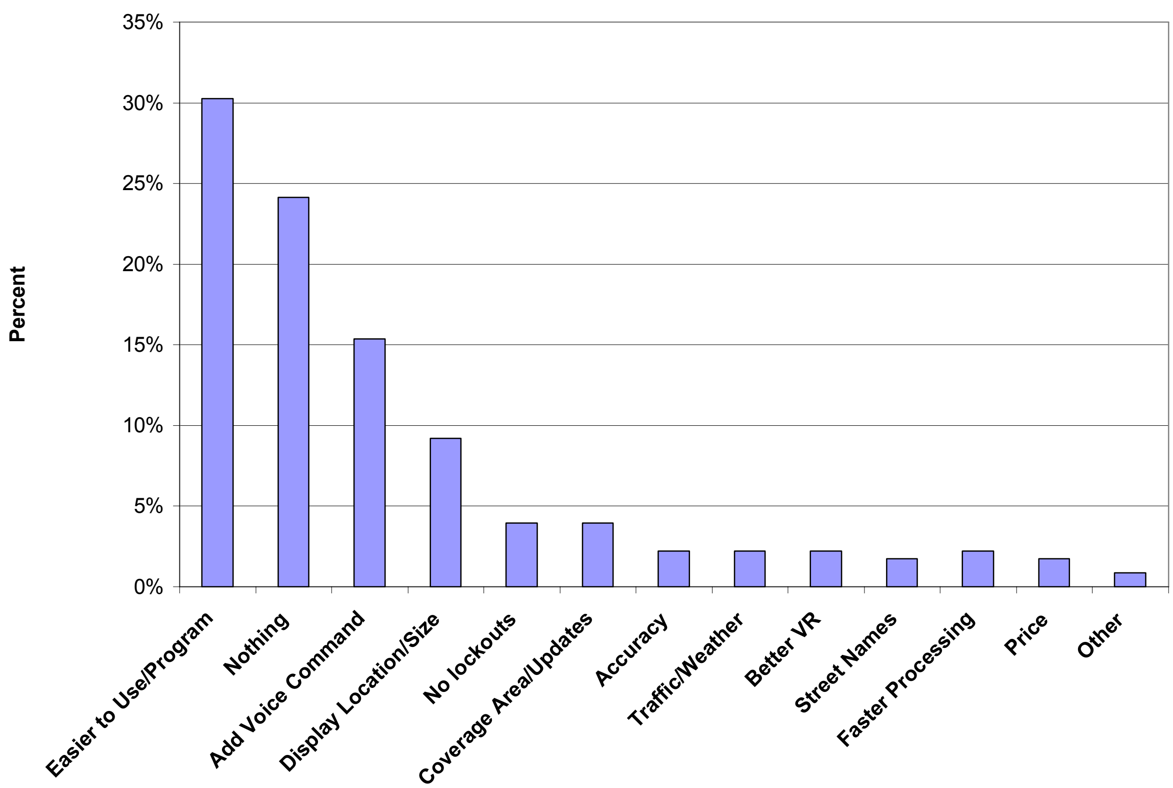


Figure 96 Recommended Changes to Navigation Systems

Navigation System Summary

A sample of 228 navigation system owners was interviewed with representation from 16 different vehicle manufacturers. The vast majority of the sample was comprised of males (71%) between the ages of 44 and 65. The majority of owners (62%) specifically asked for the navigation system when purchasing their vehicle with many (50%) using the system between one and two times per week. Most (88%) felt the navigation system was moderately to very useful, and much safer to use than navigating with a paper map. The system was also perceived to be fairly complex and somewhat difficult to learn to use with about 45% of the sample taking a month or longer to feel comfortable using the system. Difficult to learn functions included programming a destination, changing routes, and adding stops or waypoints. Although drivers exercised a range of different destination entry methods, street address was the most prominent type of destination entry method used. Approximately 28% of the sample owned system with voice recognition technology; nevertheless, 68% of these drivers prefer to use manual inputs for most system functions. Middle-age and older drivers tended to have more difficulty remembering voice commands compared to younger drives. Nearly one-fifth of the sample (18%) felt that using the system while driving increases their crash risk. The increased tendency to glance away from the road (and for longer periods of time) was among one of the reasons for the perceived increase in crash risk. No drivers reported crashing while using the system, but there were reported instances of close calls and inadvertent acts such as running a stop sign or traffic signal while using the system. The vast majority of drivers (95%) would recommend the system to a friend, and felt the system lived up to their expectations. Owners provided a range of suggested system improvements including making the system easier to use and program, improving the interface options (adding voice commands), using larger displays and positioning displays along a drivers line of sight, and integrating real-time traffic and weather information. Some behavioral changes were reported, including an increased willingness to travel in unfamiliar areas. Experienced system users may also be more likely to reduce their frequency of glances to the roadway and mirrors compared to intermediate and novice level users when using the system.

SUMMARY & CONCLUSIONS

Early adopters of advanced in-vehicle technologies (Adaptive Cruise Control, night vision, park aid, and navigation systems) were interviewed in an effort to understand how these types of systems are influencing driver behavior (modifying behavior in potentially positive or negative ways) and to assess the extent to which drivers accept these systems, and come to understand the performance capabilities and limitations of these types of advanced systems. Understanding how drivers modify their behavior resulting from the use of these types of systems can lead to improved designs and educational programs, and can also provide an early indication of the safety benefits or problems that new technologies may bring when they are more fully deployed.

A ten-week telephone survey campaign was undertaken. The survey served as a pilot effort intended to collect data on driver acceptance and adaptation to advanced technology, and also as a feasibility study intended to determine successful methods and approaches for identifying and contacting system owners. Thus, although the current effort included a substantial data collection effort (useful in assessing each targeted technology in terms of such parameters as acceptability, usability, and reported influence on safety-related driving behavior), its primary role was as a feasibility study to lay the foundation for larger and more representative data collection efforts.

During the course of the 10 week telephone survey, 620 calls were fielded resulting in 846 interviews with in-vehicle technology users (325 park aid interviews, 249 navigation system interviews, 213 Adaptive Cruise Control interviews, and 59 night vision system interviews). Invalid cases significantly impacted the effective number of usable surveys, particularly for night vision and adaptive cruise control systems. Of the 846 completed surveys, 155 (or approximately 18%) were invalid - cases in which the vehicle indicated by the survey respondent did not in fact include a factory installed system. Although all of the recruitment forms suffered from this problem to varying degrees, the majority of these invalid cases originated from the Internet and magazine recruitment. As a result, the available sample of usable cases was reduced to 480 vehicle owners or 691 completed surveys (150 Adaptive Cruise Control, 15 night vision, 298 park aid, and 228 navigation).

Effectiveness of Driver Recruitment Methods

Although various driver recruitment methods were used (newspaper, magazine and Internet advertisements), the most effective method for recruiting system users was mail-outs to lists of registered vehicle owners, providing 81% of the valid completed interviews. This method also proved to be the most reliable in terms of accessing valid system users. Although different levels of monetary incentives were examined ($25 versus $50), both yielded a similar response rate, suggesting that the added incentive did not appreciably increase the response rate above the base level. The relatively low response rate for mail-outs (e.g., 4.2 and 4.7%) is somewhat artificially low since recruitment letters were mailed to individuals who purchased a vehicle model offering a particular technology, but they may not actually have purchased the system when offered as an option.

Thus, for this particular population, the real incentive to participate in this type of survey may not be monetary, but simply the opportunity to influence the design of systems and have their opinions heard by an authoritative organization (e.g., NHTSA). Future recruitment materials therefore should be specifically designed to highlight the uniqueness of these drivers and appeal to their status and ability to offer insights based on their experience with the systems. The relatively large number of invalid cases experienced during this pilot effort highlights the importance of recruitment and screening procedures and suggests that future survey efforts should conduct more aggressive screening and/or limit the use of Internet and magazine recruitment.

Adaptive Cruise Control Systems

At present, ACC systems are offered by 8 light vehicle manufacturers in the U.S. market. Data representing driver experience and use associated with these systems were captured in interviews with 150 ACC system owners. The sample was heavily represented by systems from Toyota, Infiniti, Lexus, and BMW – together these comprised 88% of the sample. The vast majority of system owners (88%) were recruited by using lists of known vehicle owners acquired from R.L. Polk (includes mail-outs and follow-up outbound telephone calls). Drivers ranged in age from 27 to 87 years with approximately 12% younger (20-39 years of age), 41% middle-aged (40-59 years of age), and 47% older (65 and above). Sixty-five percent of the sample was male. A range of experience levels was represented including "low experience" users who typically exercise the system about 3 times per month, and "high experience" users who operate the system an average of 22 times per month. Although 28% of vehicle owners specifically asked for this system, 97% indicated they would buy a future vehicle equipped with an ACC system.

Although most owners (61%) feel comfortable using the system after the first 2-3 days of use, many held misconceptions about the functional capabilities of the ACC system. For example, 99% of drivers were either unsure or mistaken about how the system would respond to a stopped vehicle in their lane ahead, and many (29%) were not aware that their system provided an approach warning indicating the need for manual intervention. No drivers reported crashing or being rear-ended while using the ACC system; however, situations in which the ACC system reacted in unexpected or unusual ways were reported by some drivers. Instances where the system caused the vehicle to slow-down unexpectedly were experienced by 22% of drivers, and situations where the ACC system braked hard or abruptly causing the following vehicle to brake hard or get uncomfortably close were reported by 9% of users.

Data suggest that ACC system owners tend to use the system more frequently than conventional cruise control, tend to adopt the same or greater headways when using the system, and are likely to use the system under a wider range of environments (including heavy traffic) yet may not adjust following distance settings to suit the prevailing environmental conditions. The following additional results were highlighted and presented:

- Drivers tend to view the system as both a safety and convenience system; only 41% regarded the system as strictly a comfort and convenience feature.
- Experience with the ACC system influences driver willingness to operate the system under a range of different and sometimes degraded environments.
- While most drivers found the system displays and sounds to be intuitive, some suggested using larger displays and more defined sounds; a substantial percentage of drivers (12%) were not aware that the system provided audible outputs.
- Older drivers (age 60 and above) were most likely to read the entire ACC section in the owners manual, while younger driver (ages 20-39) were least likely to read the manual.
- On-road experience using the system was the most frequently cited means of learning about the ACC system; 95% of drivers relied on trial and error through experience with the system.
- Ratings of learning difficulty were similar across age groups, suggesting that older drivers did not find the system more or less difficult to use than younger or middle-aged drivers. Difficult to learn features included, setting the system speed and headway, and switching between ACC and conventional cruise control.
- Eighty-four percent of owners sampled feel the system improves safety over conventional cruise control. Forty-three percent of drivers believe that the system reduces their likelihood of being involved in a crash while using the system, and 38% of drivers feel the system increases their ability to predict and respond to roadway hazards and their awareness of the environment.
- Data suggest that displays need to be more effectively designed to communicate specific information items including distance and speed settings, and operational modes to drivers. Thirteen percent of drivers report being somewhat or very confused about the set following distance, and 5% about the vehicle's set speed. Moreover, where systems integrate both conventional cruise control and ACC, approximately 22% of owners (15 out of 68 owners) have been confused to some degree about which system is operating.
- Different manufacturers take different strategies with the approach warning feature – most only activate the feature when ACC is operating, although not all (some provide the feature even when the ACC system is not active).

Park Aid Systems

Park aid systems represent one of the most widespread technologies examined as part of this effort, and users of this technology yielded the largest number of completed interviews (298 valid interviews). Data captured are reflective of 15 different vehicle manufacturers and includes systems equipped with front and rear sensor coverage as well as in-vehicle camera displays. The sample of owners was heavily represented by males and older drivers, but included a range of driver ages (25 to 84 years) and system experience and usage levels. Most drivers in the sample (75 percent) had driven under 18,000 miles in their equipped vehicle using the system an average of 16 times per week – this represents one of the most heavily utilized systems examined. Usage patterns did not vary considerably across age groups and remained about the same across time for most drivers.

For most drivers (54%), park aid systems serve as supplements or enhancements to their vision when parking and backing with no change to their reliance on direct glances/mirror use. However, evidence suggests that some drivers may come to over-rely on park aid systems effectively altering their behavior when parking and backing. Changes in driver scan patterns, particularly with camera-based systems, and over-reliance on the park aid system appear to be key concerns. For example, 20% of users reported a decreased reliance on the vehicle's mirrors and on direct glances while backing with the system. Thirty-six percent of drivers also indicate that they postpone or delay looking to the rear or glancing in the mirrors when backing with the system engaged, suggesting that some drivers use the system to cue their search behavior. Driver experience appears to moderate this type of behavior; inexperienced drivers appear more likely to use the system as a replacement for direct search and mirror checks compared to more experienced drivers. Use of camera-based systems also appeared to result in behavioral changes with 28% of drivers reporting that they rely on the in-dash display more so than the mirrors or direct glances (4% reported that they rely on the in-car display exclusively while backing). Highlights of key findings presented in the Results section include the following:

- Most drivers rely on the audible warning sounds to guide their backing and parking behavior despite the presence of in-cab visual displays.
- Many camera-based users desire an active warning feature (so they would not need to monitor the display), while drivers with active warning systems tend to desire a camera display to allow them to confirm the presence of obstacles.
- Data suggest that drivers need to be better educated about the system's capability and limitations, including the operational range of the system and basis for issuing alerts (distance rather than speed and distance). Aspects of the system perceived to be particularly difficult to learn included: understanding how the scale units of the visual display relate to actual external distance, interpreting the meaning of the audible beeps (how the tones relate to actual distance), discriminating real from false alarms, and coming to understand the reliability and accuracy of the system.
- Few owners disarm the system (under 4%); those who do tend to do so in response to poor weather and heavy pedestrian traffic.
- Some older drivers commented that the system reduces their need to turn around and look backwards which is helpful in cases of limited range of motion.
- Sixty-seven percent of owners believed that their park aid system operates under any speed when backing; however, most systems only operated at speeds under 6 mph. Experience with the system also did not appear to improve understanding of the system's functional speed range.
- Middle-aged and older drivers appear sensitive to potential behavioral adaptations caused by the system and are more likely to feel the system increases crash risk compared to younger drivers. Inexperienced system users and those with an intermediate level of experience also appear more likely to report an elevated crash risk when using the system compared to experienced users. Perceptions of elevated

crash risk may be due to the perception that drivers may come to over-rely on the system and reduce or delay searching the environment.

- Owner-based recommendations for improvements generally centered around increases in system performance capability (greater detection range, side coverage, forward coverage, integration with camera views) and improvements to the interface (more visual displays, better placement of displays, added detail regarding actual distance to objects, etc.).

Night Vision Systems

Only two night vision systems are currently available on the market: one produced by Cadillac and the other sold by Lexus. Both systems rely on infra-red cameras and are intended to enhance drivers' nighttime vision by displaying images on a Head-Up Display. Driver acceptance and use of these systems were explored during interviews with 15 night vision system owners; 13 of the 15 interviews were conducted with Cadillac system owners. The small number of completed interviews likely reflects the limited availability of these types of systems. Although the sample was nearly balanced in terms of gender (47% males and 53% females), it was biased towards older drivers with 53% of the sample above 60 years of age and no drivers under age 42 (mean age was 60). System use averaged about 9 times per month (2.25 times per week), with usage for most of the sample either staying the same (60%) or increasing (27%) over time.

The night vision system was specifically sought after by a majority of drivers sampled (60%) as a means of improving their ability to see at night. Although a majority of owners feel the system improves comfort and reduces stress, perceived usefulness and safety of the system was mixed and strongly related to system use (with more frequent usage leading to higher perceived usefulness and safety). Many drivers were disappointed with the system's ability to display recognizable images and felt the system made it difficult to accurately judge distances to obstacles and objects (parked cars, buildings, fences, and small animals). Only 40% of the drivers felt the system lived up to their expectations. Although drivers report glancing to the display less frequently over the course of time, many felt the display was distracting. Furthermore, glare from oncoming vehicle headlights appeared to make it more difficult to extract information from the display; and the display also appeared to amplify the glare problem in some cases.

Data suggest that the availability of a night vision system can be expected to increase willingness to drive at night for some drivers (about 33% of those in our sample), increase nighttime driving speed for a small percentage of drivers (about 14% of drivers in our sample), and is not likely to negatively affect mirror usage. The system also appears to enhance driver ability to detect obstacles at night with one-third of drivers experiencing a situation in which the system helped them avoid hitting an object they otherwise might not have seen in time. Other key findings included the following:

- Drivers tend to use their night vision system under a range of driving environments, including freeways, hilly, and curvy roads. Relatively few drivers, however, reported a willingness to use the system on streets with lights, and to a lesser degree in heavy traffic, poor weather, and when driving on unfamiliar roads.
- Ratings of the system's usefulness were strongly correlated (r = .84) with system use as measured by the number of times the system is typically used per week.
- The ability to recognize objects in the HUD appears to improve with experience.
- Although 60% of drivers report feeling comfortable using the system within the first week of using it, a substantial percentage of users (33%) reported that they have never fully felt comfortable using the system.
- Experience with the night vision system is likely to improve one's ability to interpret displayed images, and enhanced perceived system utility and safety impacts.
- Approximately 33% of the sample found the night vision system display to be very or somewhat distracting. Even experienced drivers found the display to be distracting, suggesting that extended exposure to the system may not necessarily lessen the distraction potential of the display.
- Drivers did not appear to compensate for the expanded detection range afforded by the system by driving faster; 86% reported no change in their typical night driving speed. However, two drivers (about 13% of the sample), did attribute increases in their night time driving speed as a result of having the system.
- Owner suggested recommendations for improving the system included enlarging the display, increasing the brightness of the display, and displaying more realistic and discernable images.

Navigation Systems

Recruitment efforts for in-vehicle navigation system owners resulted in the second largest number of completed interviews (228 interviews). Systems from 16 different vehicle manufacturers were represented with high concentrations of systems from Lexus, Acura, BMW, Mercedes-Benz, Infiniti, and Cadillac. System owners in the sample were generally males between the ages of 44 and 65. Approximately 16% of the sample was younger drivers (ages 20-39). Approximately 50% of navigation system owners use the system once or twice a week; however, the sample included a range of experience levels with approximately 32% low, 33% intermediate, and 35% high experience users. System usage tended to stay about the same or increase for most drivers (85%); drivers whose usage declined over time tended to restrict system use to trips or felt the system was too complex. Unlike other system examined here, navigation systems required a substantial effort to learn to operate. Many drivers (45%) reported taking a month or longer to feel comfortable using the navigation system, and a substantial percentage of drivers (8%) reported never feeling comfortable using the system. Programming a destination into the system was among the most difficult functions to learn; not surprising, the vast majority of users relied on street address as their primary means of inputting a destination.

Data tend to suggest that as drivers become more experienced with using navigation systems, they tend to adopt a greater range of input methods (address book, voice commands, etc.), are more likely to reduce their glances to the roadway or mirrors and rely on visual information displays provided by the navigation system, and are more apt to feel the system does not increase their crash risk. Few age-related effects were noted. Nevertheless, older drivers appeared less likely to use voice commands to program a destination compared to younger drivers; more likely to read the owners manual compared to younger drivers; less likely to divert their attention away from the road to glance at the visual display compared to young and middle-aged drivers; less likely to travel on neighborhood streets to avoid congestion than younger drivers; and more likely to have difficulty remembering voice commands compared to younger drivers. The following general trends and results were also noted:

- Although 98% of navigation system owners feel using the system is safer than a paper map, approximately 10% believe the system decreases safety when driving. Moreover, 18% of navigation system users believe that the system increases their risk of being involved in a crash to some degree.
- Increases in usage over time tend to result from an increased familiarity with the system which takes deliberate effort to learn how to use and operate.
- Drivers were generally pleased with their navigation system with 88% of owners rating the system as useful and 89% indicating that the system lived up to their expectations.
- A surprising percentage of drivers were unsure about even the most basic features of their system, including the ability to repeat verbal turn instructions or configure the system to hide the visual display and present voice-only turn information.
- Although a range of system designs were represented in the sample, no particular system stood out as being particularly easy or difficult to operate based on driver ease of use ratings.
- Thirty-two percent of owners admitted that they tend to look away from the road more frequently and for longer periods of time when driving with the navigation system.
- Seventy-six percent of drivers in our sample found that having a navigation system increases their willingness to drive in unfamiliar areas; 27% use their system to re-route through neighborhood streets in order to avoid congestion.
- Drivers appear to rely on both visual and auditory system outputs for routing and navigation functions. Young drivers tended to prefer visual displays for route guidance.
- Even when equipped with voice recognition technology, drivers tend to prefer to use manual inputs to execute most system functions; these preferences do not appear to change substantially as a function of experience with the system or driver age.
- Based on feedback provided by system owners, designers should strive to reduce the complexity of navigation systems in order to reduce the required amount of learning and improve ease-of use. Existing systems tend to include too many features that add complexity and go unused.

Comparison Across Systems

Of the four systems examined, drivers tended to specifically seek out night vision and navigation systems when purchasing their vehicles; about 60% of drivers asked for these systems compared to under 30% for park aid and ACC systems. With the exception of night vision systems, use of the technology tended to either increase or remain the same across time. Unlike the other system users, owners of night vision system were less likely to recommend the system to a friend feeling the system did not live up to their expectations. Navigation systems were also perceived to increase crash risk more so than any of the other technologies. As illustrated in Figure 97 ,18% of navigation system owners perceived that their likelihood of being involved in a crash increased (rated 4 or 5) while using the system.

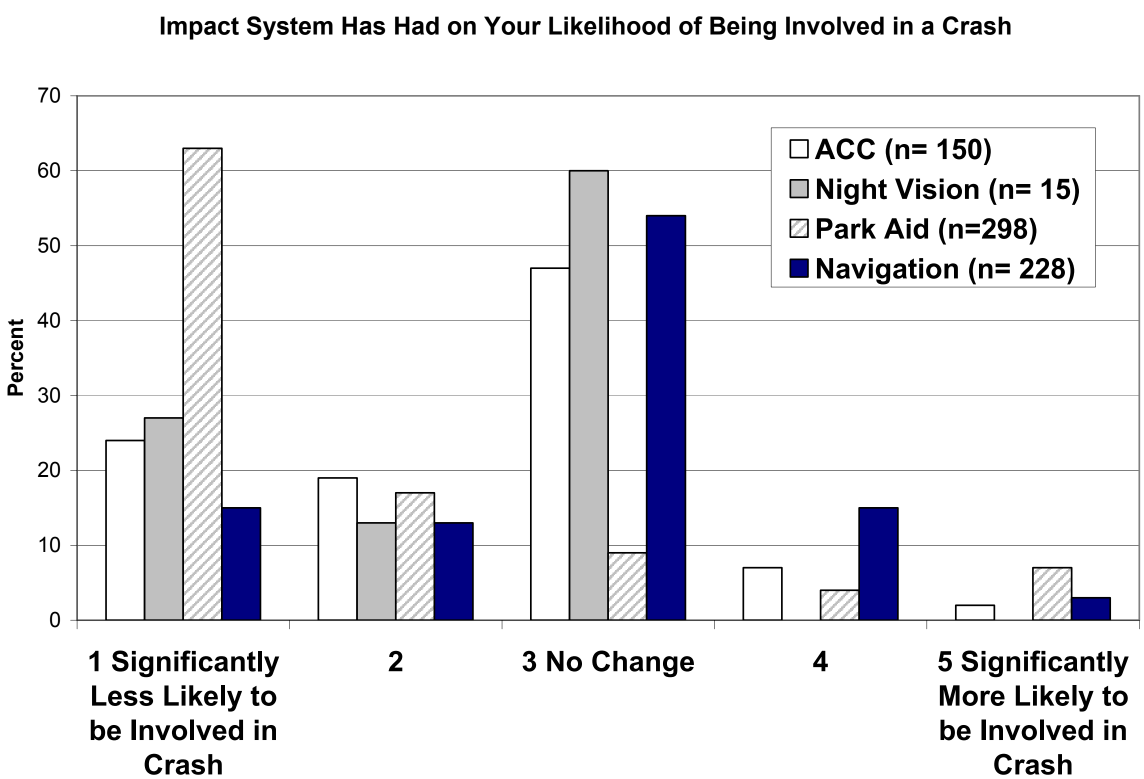


Figure 97 Perceived Crash Likelihood Ratings Across In-Vehicle Technologies

Several common trends in driver behavior and acceptance were noted across the various types of in-vehicle technologies. These included the following:

- Although many drivers referred to their owners' manual for information regarding their advanced systems (ranging from 80 to 93 percent of the sample), older drivers in particular were more likely than any other age-group to consult and read their owners' manual. Nevertheless, drivers tended to rely most on actual on-road experience to learn about their systems.
- Many drivers hold misconceptions about the performance capabilities of their advanced systems, and in many cases experience with the system over time does not appear to alter these misconceptions. For example, 99% of ACC system owners did not know that the system ignores stopped vehicles. Similarly, 41% of park aid system owners did not know that the system warning is tied solely on the distance to objects and does not take into account their closing speed. This suggests that drivers' mental models of how these systems function and perform do not always match reality, and additional efforts are needed to increase driver understanding of how these systems operate. This is particularly important for safety-related misconceptions.
- Some form or degree of driver behavioral adaptation occurred for each of the systems examined. Some changes represented improvements (e.g., enhanced ability to detect obstacles at night or behind the vehicle, adoption of safer following distances, etc.) while others lead to potentially riskier driving practices (e.g., less reliance on vehicle mirrors while backing, longer glances away from the forward roadway, etc.). Some were more widespread than others, and experience with the system tended to moderate these behavioral changes to some degree.
- Driver trust and reliance on their in-vehicle system tended to increase over time, and appeared to be tied to actual system use. Drivers who exercised their system tended to have a more favorable outlook on a system's effectiveness, and in some cases more realistic expectations of the system. However, increased system use did not always lead to increased trust or heightened perceptions of system effectiveness.

Study Limitations

The information collected as part of this effort relied exclusively on driver self-reports gathered during telephone interviews with a convenience sample of system owners. There are inherent weaknesses associated with this type of data, including issues with its reliability and the extent to which it can provide definitive insights into how systems are influencing actual driving practices and driver behavior. As such, it is not intended as a replacement for observational studies. Rather, the work and method were tailored to capture driver perceptions about these systems and their understanding of the functional capabilities of the systems, as well as provide some insights into how the systems may be impacting driver behavior. The insights provided by this work should be confirmed by observational studies.

Furthermore, changes in system usage, attitudes, and knowledge resulting from experience were primarily tracked using a cross-sectional approach as opposed to tracking individual drivers across time. Behavioral changes, for example, were noted by comparing groups of drivers with different experience levels. That is, the survey yielded a range of driver usage and experience levels allowing comparisons across these groups and provided a basis for interpreting how behavior and knowledge with these systems changed across time. In addition, some survey items were also designed to assess behavioral changes by having individual drivers make relative judgments about system interactions over time (e.g., has your usage increased, decreased, or remained about the same since purchasing the vehicle?). Of course, this strategy was heavily dependent upon an individual's memory and ability to recall information. Future work should attempt to track specific individuals across time to examine how system use changes with system use and experience.

A major benefit of this survey approach is that it allowed insights across a relatively large number of vehicle owners to be quickly gathered and examined. It also encompassed a variety of system models and designs, providing the opportunity to make comparisons across designs in an effort to understand how different interface approaches impact driver understanding and performance. Nevertheless, it can be difficult to tease-out impacts of system designs; in our case small sample sizes severely restricted our ability to compare specific system makes and models (the small sample size for the night vision system is an example). A larger-scale effort focused on comparing specific system makes or designs could overcome some of these obstacles. In either case, apparent impacts associated with different system designs would need to be corroborated by controlled testing and experimentation, but the insights provided by a widespread survey could be beneficial in identifying and directing this type of evaluation.

Challenges Associated with Recruiting System Owners

The challenges associated with recruiting system owners is a major factor in this type of work, and the particular sample used in this pilot effort may be biased and is not necessarily representative of the population of system users. The vast majority of system owners were recruited through vehicle registration lists sampled across seven states using data from RL Polk. No significant effort was made to take a statistically representative sample of users since this was intended as a pilot effort. A substantially larger-scale survey effort would be required to generate a statistically representative sample. If implemented, such an effort should seek to overcome many of the challenges to recruit system owners experienced in the pilot. For example, our efforts to enlist the cooperation of vehicle dealerships (both individually and through the National Automobile Dealer Association, NADA) was not successful. Individual dealerships were very resistant to providing lists of vehicle owners due largely to privacy concerns. Some were willing to mail-out materials to vehicle owners but required significant compensation for this activity; others were willing to post recruitment ads in the showroom, but this approach was not very effective and can be difficult to implement on a large-scale without the aid of a national association (e.g., NADA).

Another challenge is focusing the effort to target individuals who are known to actually own a targeted system. Recruitment lists of registered vehicle owners cannot guarantee that the specific system was purchased unless it comes as standard equipment (few of these systems are currently offered as a standard feature). Screening to identify valid system owners can be difficult, but it is an important and necessary step. The pilot effort demonstrated that many individuals will call-in and attempt to complete the survey, but they may not in fact own a factory equipped system (Twenty-three percent of the individuals responding to the recruitment ads were invalid and did not own vehicles equipped with a system of interest). Some recruitment methods appear more prone to this type of activity than others; Internet and magazine recruitment, for example, generated many invalid cases. Recruitment materials should be specific about the types of systems desired in order to avoid confusion, and efforts to discourage opportunistic individuals who may lie simply to collect the reimbursement need to be incorporated (e.g., request individuals to provide their Vehicle Identification Number). Screener items should be developed that allow system owners to be quickly and reliably identified before individuals are administered the survey.

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APPENDIX A: LIST OF VEHICLE MAKES & MODELS SUMBITTED TO RL POLK FOR OWNERSHIP CONTACT INFORMATION

Vehicle Make	Model	Year	Standard (S), Optional (O) Features			
			ACC	Park Aid	Navigation	Night Vision
Acura	MDX	2004		S	O (VR)	
Acura	RL	2004			S (VR)	
BMW	7 Series	2002+	O	O (F&R)	S (VR)	
BMW	5 Series	2003+	O	O (F&R)		
Cadillac	XLR	2003+	S	O	S (VR)	
Cadillac	Deville (DHS or DTS)	2002+		O	O (VR)	O
Honda	Pilot	2003+		O (Cam)	O (VR)	
Infiniti	Q45	2002+	O	O (Cam)	O	
Infiniti	FX	2004	O	O	O	
Ford	Expedition (Eddie Bauer)	2002+		S	O	
Ford	Windstar (Limited)	2003+		S		
Jaguar	XKR	2003+	O	S	O (VR)	
Land Rover	Range Rover (HSE)	2003+		S	S	
Land Rover	Discovery (HSE)	2003+		S	S	
Lexus	LS 430	2002+	O	S	O (VR)	
Lexus	LX 470	2004		S	O (VR)	O
Lexus	RX	2004	O	S		
Lincoln	Aviator	2004		S (Radar)	O (VR)	
Lincoln	Navigator	2003+		O (Radar)	O (VR)	
Mercedes-Benz	SL	2002+	O			
Mercedes-Benz	CL	2003+	O	O (F&R)		
Mercedes-Benz	S-Class	2002+	O	O (F&R)		
Mercedes-Benz	CLK-320	2003+	O			
Mercedes-Benz	CLK-500 Coupes	2003+	O			
Mercedes-Benz	E320 Sedans	2003+	O			
Mercedes-Benz	E500 Sedans	2003+	O			
Oldsmobile	Silhouette (GLS and Premier)	2003+		S		
Toyota	Sienna (XLE and XLE Limited)	2004	S	S (Cam/F&R)	O (VR)	

States Sampled

Michigan
Virginia
New York
Florida
Illinois
Colorado
Texas

(F&R) = Front and Rear Coverage
(Cam) = Camera System
(Radar) = Enhanced Hybrid System
(VR) = Voice Recognition

APPENDIX B: KEY ACC SYSTEM INTERFACE & OPERATING CHARACTERISTICS

	BMW 5 & 7 Series (2003)	Cadillac XLR (2003)	Infinity FX (2004)	Jaguar XK (2004)	Lexus LS 430	Mercedes-Benz S-Class	Toyota Sienna XLE Limited
System Name	Active Cruise Control	Adaptive Cruise Control	Intelligent Cruise Control	Adaptive Cruise Control	Dynamic Cruise Control	Distronic	Dynamic Laser Cruise Control
Control Location	Stalk-Mounted controls for turning system on/off, speed and distance settings.	Stalk-Mounted Mulitfunction Controls for On/Off set speed. Following distance set using control on steering wheel.	Steering Wheel	Six Steering-Wheel mounted controls. Contols allow drivers to set speed, time gap, cancel and resume set speed.	Steering Wheel	Steering Column and Center Console (on/off and distance control on console)	Steering Colum Stalk for On/Off, setting speed. Steering wheel distance switch used to set following distance.
Display Location	Graphic display inset on IP within speedometer. locn of vechicle and distance bars. Shows correct orientation.	Graphic representation on HUD indicates set speed, following distance, vehicle detected, and other warnings including driver action required icon, tight curve, etc.	Dashboard IP	Dashboard IP contains a visual icon to represent ACC and a message center with detailed system information (set speed, gap, etc.) Display is positioned on lower portion of the speedometer.	Multi information display on the instrument panel indicates settings such as the preset vehicle speed, whether a vehicle is present ahead, and the selected vehicle to vehicle distance.	Multifunction display on Instrument Panel. Lighted segments show difference between desired speed (set speed) and speed of vehicle ahead. Graphic shows distance and lead vehicle	Dedicated display mounted on instrment cluster; lower portion of the speedometer. Shows set speed, vehicle detected, and distance setting.
Headway Settings	Four. Manual does not specify values for headway. Lowest is the default.	Six discrete following distance settings ranging from 1 to 2 seconds	Three discrete distance settings; Short, Middle, Long (1.02, 1.47 and 2.21 sec. headway, respectively). Q45 model uses slightly different headways (1.19, 1.70, and 2.21)	Four discrete gap settings. Manual does not specify quantitative values.	Three discrete distance settings; Short, Middle, Long (1.24, 2.04, and 3.03 headway, respectively)	Continuous adjustment between 1 to 2 seconds of separation. Thumbwheel control	Three discrete settings, long (3.03 sec.), middle (2.04 sec.) and short (1.24 sec.).
Operating Range	25 to 110 mph	25 mph and above	25 to 90 mph	20-110 mph	28 - 85 mph	25-110 mph	28-85 mph
Approach/Distance Warning (when system can't decelerate, intervention required)	Yes. Display icon flashes and chime sounds. Indicates system capacity has been reached exceeded, driver intervention required.	Yes. Alert symbol flashes and warning beep sounds when driver action required. Includes situations when ACC cannot apply sufficient braking, vehicle speed drops below 20 mph, etc. System provides visible and audible alerts to the driver	Yes. Buzzer sounds, display flashes	Yes. Three cues provided: audible warning, red warning light, and text "DRIVER INTERVEVE" is displayed on the message center.	Yes. A warning tone warns you to manually apply the brakes if your vehicle gets closer to the vehicle ahead because of insufficient automatic deceleration. In addiiton the multi information display changes and the stop tail lights on your vehicle and the	Yes. Audible signal and visual icon (triangle with car profile) on dash notifies driver if closing speed exceeds system capability (or insufficient following distance to vehicle ahead). Functions even when Distronic system is not active.	Yes. Beep sounds and display flashes. System applies braking.
Vehicle Ahead Detection Indicator	Yes. Vehicle icon lights up when detected.	Yes. Vehicle symbol displayed on HUD when vehicle detected ahead.	Yes	Yes. Icon/Dummy Light illuminates.	Yes	Yes	Yes.
Activation of Brake Lamps When Automatic Braking Applied	Yes	Yes	Yes	Yes.	Yes. Car graphic in display also indicates this to the driver (its brake lamps illuminate)	Not Specified	Not Specified
Max. Braking Force	Not specified	0.3gs (2.95m/sec2)	Up to 25% of vehicle braking power.	Not Specified	Not Specified	Up to 20% of vehicle braking power (max of 6.5 ft/s2/s2)	Not Specified
Type Sensor	Radar	Radar	Laser Radar	Radar	Laser Radar	Radar	Laser Radar
Sensor Detection Range	Not specified	328 ft.	390 ft.	Not Specified	400 ft.	300 ft.	400 ft
Integrated with Convention Cruise Control	No	No	Yes. Pushing ON/OFF switch once acitvates ICC. Holding down ON/OFF Swicth for 1.5 sec. activates conventional cruise control.	No	Yes. Mode can be changed by pushing the lever on the cruise control switch (can move from you can conventional cruise control to the dynamic cruise control). Must re-start to change from ACC to conventional.	No	Yes. When in ACC, display includes distance bars and lead vehicle indicator. These are absent in conventional cruise. Also a "NORM" indicator light is illuminated when in conventional mode. Cannot go from convention to ACC without turning off system.
Number Pages in Manual	7 pages	13 dedicated to ACC	19 dedicated to ICC	6 dedicated to ACC	19 dedicated to Dynamic Cruise	12 pages dedicated	13 pages dedicated
Warnings in Manual	Avoid use in heavy traffic, curvy roads, slippery roads, inclement weather. System will not decelerate for slowing moving or stopped vehicle. May not detect motorycles. System cannot stop vehicle. Not a CWS.	Not a safety system. Will not apply hard braking to bring vehicle to stop. Cautions against operating on windy roads, heavy stop-and-go traffic, slippery roads, low visibility conditions. System may not react to slow moving or stopped objects in	System does not detect slow moving or stationary vehicles. System will not automatically brake vehicle to a stop. System will not detect pedestrains objects in road. Avoid use in sharp curves	Not a collision warning system. Will not deetct stationary or slow moving vehicles belwo 6 mph, pedestrians, oncoming vehicles. Do not use entering/exiting motorway. Will not decelerate to a stop.	Not a collision avoidance system. Appropriate for freeways and roads where the traffic is light or moderate. Vehicle detection difficult under certain conditions (e.g., other vehicles flinging water or snow, etc). Approach warning may not turn on under certain conditions	Convenience system. Does not react to stationary objects. Do not use in fog, heavy rain, now, sleet conditions. Can be dangerous heavy traffic or winding roads.	Not a collision avoidance system.
System Defaults	Longest headway		Long headway setting	A default is used, not specified.	Long headway setting	Unspecified in Manual	Long headway setting
Notes	Set speed indicated by graphic tied to the speedometer. Surprisingly little technical detail in the owners manual; less than most others. System deactivates automatically when speed falls below 20 mph (gong sounds and message appears in the Check Control). Graphic display depicts correct orientation illustrating headway to lead vehicle	ACC settings not visible unless HUD is on and adjusted. Very Important! Drivers might forget set speed value if not visible in HUD. Symbol presented on HUD to indicate when ACC is active. Manual outlines scenarios where system performance may be limited.	ICC automatically cancelled when windshield wipers on LO or Hi position (restricts use in rain). Brake pedal physically depresses when ACC system applies braking force. Q45 uses slightly different display graphics. System automatically cancels if speed falls below 20 mph, sounds alert)	Includes a forward alert feature to provide detection of close objects ahead; works even if ACC is not on. Can be switched on/off, and sensitivity adjusted. No braking is applied. System automatically cancels at speeds below 18 mph; audible and visual alert is provided and braking is slowly released if ACC braking is engaged. Brake pedal moves as braking is applied. Vehicle brake lamps illuminate while braking is applied.	Automatically cancels when the wipers are operated on high or low speeds, speed falls below 25 mph, direct sunlight on the front, driving pattern selector is set to Snow or when the system determines it is difficult to make a measurement because of bad weather. Manual warns against use on freeway on/off ramps. Master warning light is used to signal problems. Approach warning does not activiate when in conventional cruise control mode	System cancels if speed falls below 25 mph. Audible signal sounds and message appears (Distronic Off) on display. Brake pedal physically moves when Distronic automatically applies braking. Distance warning function operates even if system is disengaged. Manual outlines driving situations where special precaution is needed.	System cancels when wipers set to low or high. Also when speed falls belwo 25 mph. System wil neither warn nor decelerate if vehicle ahead is stopped or slows drastically. Manual warns - do not use in bad weather, heavy traffic, sharp bends, slippery roads, when entering or existing highways.

APPENDIX C: KEY PARK AID SYSTEM INTERFACE & OPERATING CHARACTERISTICS

	BMW	Cadillac XLR & DeVille (2004)	Ford (Windstar, F-150, Expedition)	Lexus LS 430 (2003)	Lincoln Navigator (2004)	Mercedes-Benz S-Class (2004)	Nissan Quest (2004)	Toyota Sienna XLE Limited (2004)
System Name	Park Distance Control	Ultrasonic Rear Parking Assist	Reverse Sensing System	Lexus Park Assist System	Extended Rear Park Assist	Parktronic	Rear Sonar System	Park Assist
Camera	No	No	No	No (2004 model has camera)	No	No	No	Yes (Rear View Monitor System)
Control Location	System on/off control locate on dash behind the steering wheel. Indicator lamp illuminates when active.	N/A	Control on IP (disable switch)	Control switches on the left behind steering wheel.	Control on IP Message Center	Upper section of the center console (on/off control)	Off switch located on dash to the left of the steering wheel.	On/Off switch location unspecified in manual.
System Status Display & Location	Control Display located above HVAC in center stack. Optional graphic depicts vehicle and presence and direction of obstacle before they are close enough to generate signal tone.	Display located below the rear window (visible in rearview mirror or direct glances)	Indicator light on control illuminates when off.	On multi information display in IP (depicts car icon and distance bars); shows 6 detection zones (3 in front, 3 in rear). Each uses color coded distance bars.	IP Message Center	Two warning indicator displays are used (right front area, and left front area). Each is divided into 6 yellow and 2 red segments. Both located on front dash. Also, on/off switch includes LED to indicate status of system.	Only a single visual display on the Off switch (illuminates when system has been disabled).	System indicator illuminates when system is on and working. Location not specified.
Warning Modes	Audible and Visual	Audible and Visual	Audible Only.	Audible and Visual	Audible Only	Audible and Visual	Audible Only	Audible and Visual
Warning Levels (staged, imminent)	Staged (continuous). Intervals between tones become shorter, continuous at 1ft (12 inches). Tone indicating distance to nearest object is directional.	Staged (4 levels). 5ft, 40 inches, 20 inches, 1 ft.(12 inches). Audible and visual display. Chime and 3 LEDs. At 1 ft, chime sounds continuously and all three lights flash.	Staged (continuous). Issues tone when obstacle detected. Tone rate increases, steady at 10" from obstacle.	Staged (4 levels). 1.5-3 ft, 1.1-1.5 ft, .8ft-1.1ft, and less then .8 ft (10 inches). Number of bars on the display go down from 4 to 1 while the beeps sound at shorter intervals (continuous tone last stage).	Staged (continuous). Tone rate increases as object nears, steady at 18". If system senses condition where rapid braking is required, a very high rate tone sounds.	Staged. Intermittent acoustic warning sounds when 1st red segment illuminates; constant warning sounds when 8th red segment comes on (acoustic warnings last maximum of 3 seconds). Min warning distance is 8 inches.	Staged (continuous). Beep rate increases, steady at 10" from obstacle.	Three Stages (intermittent, fast intermittent, and continuous). Mininum warning distance is 21 inches.
Sensor Coverage (forward, rear, both)	Front & Rear	Rear Only	Rear Only	Front and Rear	Rear Only	Front and Rear	Rear Only	Front and Rear
Operating Speed	20 mph or below. Deactiveate sonce vehicle travels 165 ft or exceeds 20mph	3 mph or less	3 mph or less	6 mph or less	6 mph or less	11 mph or less (automatically deactivates at higher speeds)	3 mph or less	6 mph or less
Type Sensor	Ultrasonic (4 in fron, 4 in back)	Ultrasonic (4 sensors)	Ultrasonic	Ultrasonic 6 in front and 4 in back	Hybrid (Ultrasonic & Radar)	Ultrasonic (6 sensors in front, 4 in rear)	Sonar	Sonar
Sensor Detection Range	5ft (middle), 2ft (corner)	5 ft.	6 ft.	3ft (rear), 1.5ft (corner)	20 ft.	48" (rear), 40" (front). Corner sensors slightly lower range	6 ft.	Approximately 6 ft (rear).
Manual Override	Yes. Manual deactivation control. System default is on.	No	Yes. Disable switch	Yes you just turn off the main switch.	Yes. Disable switch using message center.	Yes. Switch located in upper section of center console. LED illuminates when system is off	Yes. RSS Off switch on the instrument panel (illuminates when system is off)	Yes. Switch provided.
Number Pages in Manual	2	2	2	6	3	5	3	4 Park Assist; 4 Rear View Monitor
Warnings in Manual	Park aid only. Avoid approaching obtacles at high speed (warning may be too late).	Designed to make parking easier. Does not operate above 3 mph.	System only functions as an aid (assists in detecting large stationary objects to avoid damage to vehicle). Inclement weather may affect performance. May not detect certain angular or moving objects.	The sensors do not detect an obstacle under the bumper, if an obstacle is very close might not be detected, if the sensor is subjected to a strong impact or in extremely cold weather it may not operate properly.	Only an aid in detecting large objects when moving in reverse at "parking speeds". The system may not detect smaller or moving objects closer to the ground. Not effective at speeds greater than 6 mph.	Supplemental system, designed to assist in parking maneuvers. Make sure no persons or animals are in area. Performance affected by dirty sensors.	Not substitute for proper backing procedures. Inclement weather may impact performance. Deisgned to avoid damage to car not prevent contact with small or moving objects. Decreased coverage area to sides.	Not a substitute for personal judgement; make decisions based on your observations; system may not detect certain objects under certain situations.
System Defaults	Automatically activates when ignition is on when reverse is engaged	Automatically activates when in reverse (and car ignition is on).	Automatically activates when in reverse (and car ignition is on).	Off	Automatically activates when in reverse (and car ignition is on).	Automatically activated when ignition is on and parking brake released.	Automatically activates when in reverse (and car ignition is on).	System is on when ignition is on and vehicle is not in Park.
Notes	Uses sound localization (visual display is optional and must be activated by driver; once activates automatically displayed)	System also flashes LED Lights when speed over 3mph, and when system not functioning properly.	If object detected from further than 10" from side of vehicle, tone sounds for 3 seconds only.	System must be manually activated by driver.	Mentions decreased coverage at the outer corners of the bumpers.	The position of the gear selector determines which warning indicators are activated (D= front area, R or N = both rear and front)	If maually turned off, system automatically resets to ON next time ignition switch is turned om.	(Rear View Monitor) Displayed image is a horizontally reversed mirror image of the inside rear view mirror. Intended as a supplement.
			If disabled, system reactivates each time ignition is turned on.	Six zones in display. Detection range and stages slightly different for corner objects (3 levels only)	Advises driver to slow down immediately if high rate tone sounds.	Acoustic warnings deactivate (stop sounding), after 3 seconds. May cause confusion if obstacle still present.	If stationary or receding obstacle detected further than 10", system beeps 3 times.	
			Stereo volume is reduced during alerts (Expedition)	Park assist icon will also appear on the navigation display, if equipped	Stereo volume is reduced during alerts	Unsure whether manual deactivation is overridden each time car is started.		
			Display in Expedition incidates "Back Up Aid <On> Off"	Visual display can be turned off, with audible tone turned on.	IP Display incidates "Park Assist <On> Off"	Min detection range of 8"		
			Also warns of a moving object approaching at 3 mph or less, if the vehicle is in Reverse but is not moving backward.	Warning distance settings can be adjusted (3ft vs 1.5 ft>0				

APPENDIX D: RL POLK RESULTS SHOWING OWNER COUNTS FOR VEHICLES MODELS BY STATE

CELL	CELL NAME	08 COLORADO			12 FLORIDA			17 ILLINOIS			26 MICHIGAN			36 NEW YORK			48 TEXAS			51 VIRGINIA			GRAND
		NO PHONE	PHONE	TOTAL	NO PHONE	PHONE	TOTAL	NO PHONE	PHONE	TOTAL	NO PHONE	PHONE	TOTAL	NO PHONE	PHONE	TOTAL	NO PHONE	PHONE	TOTAL	NO PHONE	PHONE	TOTAL	TOTAL
101	ACURA MDX	0	4	**4**	29	38	**67**	11	20	**31**	6	15	**21**	19	33	**52**	11	11	**22**	5	20	**25**	**222**
102	ACURA RL	10	15	**25**	37	95	**132**	22	46	**68**	10	19	**29**	65	86	**151**	13	39	**52**	9	23	**32**	**489**
103	BMW 7 SERIES	55	64	**119**	694	817	**1,511**	297	364	**661**	78	86	**164**	622	712	**1,334**	343	412	**755**	73	79	**152**	**4,696**
104	BMW 5 SERIES	70	98	**168**	665	827	**1,492**	351	605	**956**	94	157	**251**	698	1,021	**1,719**	319	541	**860**	187	312	**499**	**5,945**
105	CADILLAC XLR	0	0	**0**	7	19	**26**	2	2	**4**	3	7	**10**	1	4	**5**	2	4	**6**	2	1	**3**	**54**
106	CADILLAC DEVILLE DHS	40	108	**148**	253	856	**1,109**	167	361	**528**	165	346	**511**	128	192	**320**	267	675	**942**	67	159	**226**	**3,784**
106	CADILLAC DEVILLE DTS	48	112	**160**	306	701	**1,007**	219	374	**593**	358	546	**904**	248	289	**537**	228	478	**706**	64	135	**199**	**4,106**
Total		**88**	**220**	**308**	**559**	**1,557**	**2,116**	**386**	**735**	**1,121**	**523**	**892**	**1,415**	**376**	**481**	**857**	**495**	**1,153**	**1,648**	**131**	**294**	**425**	**7,890**
107	HONDA PILOT	486	1,038	**1,524**	2,007	3,157	**5,164**	1,470	2,523	**3,993**	579	1,163	**1,742**	1,709	2,734	**4,443**	1,874	3,325	**5,199**	1,056	1,867	**2,923**	**24,988**
108	INFINITI Q45	11	21	**32**	152	282	**434**	99	108	**207**	9	27	**36**	113	168	**281**	81	172	**253**	24	41	**65**	**1,308**
109	INFINITI FX	0	0	**0**	0	0	**0**	0	3	**3**	3	0	**3**	3	6	**9**	0	0	**0**	0	0	**0**	**15**
110	FORD EXPEDITION EDDIE BAUER	445	797	**1,242**	4,322	5,630	**9,952**	929	1,277	**2,206**	704	1,214	**1,918**	738	773	**1,511**	7,078	10,652	**17,730**	858	1,184	**2,042**	**36,601**
111	FORD WINDSTAR LIMITED	11	30	**41**	45	89	**134**	87	225	**312**	124	287	**411**	68	100	**168**	19	45	**64**	36	79	**115**	**1,245**
112	JAGUAR XKR	2	5	**7**	22	22	**44**	9	6	**15**	4	8	**12**	16	16	**32**	4	8	**12**	0	2	**2**	**124**
113	LAND ROVER RANGE ROVER (HSE)	64	64	**128**	273	214	**487**	158	140	**298**	63	58	**121**	254	230	**484**	177	170	**347**	44	42	**86**	**1,951**
114	LAND ROVER DISCOVERY (HSE)	8	17	**25**	39	38	**77**	25	23	**48**	11	11	**22**	31	40	**71**	31	37	**68**	20	19	**39**	**350**
115	LEXUS LS 430	70	127	**197**	1,085	2,383	**3,468**	417	657	**1,074**	142	190	**332**	365	511	**876**	738	1,439	**2,177**	147	288	**435**	**8,559**
116	LEXUS LX 470	2	2	**4**	26	19	**45**	4	10	**14**	6	4	**10**	12	12	**24**	19	30	**49**	0	3	**3**	**149**
117	LEXUS RX	159	305	**464**	987	1,799	**2,786**	569	918	**1,487**	251	458	**709**	652	959	**1,611**	608	1,271	**1,879**	237	357	**594**	**9,530**
118	LINCOLN AVIATOR	0	2	**2**	16	26	**42**	3	2	**5**	16	18	**34**	16	12	**28**	9	10	**19**	4	5	**9**	**139**
119	LINCOLN NAVIGATOR	105	119	**224**	1,070	1,188	**2,258**	381	422	**803**	402	478	**880**	611	542	**1,153**	1,183	1,527	**2,710**	196	247	**443**	**8,471**
120	MERCEDES-BENZ SL	40	67	**107**	761	802	**1,563**	209	192	**401**	72	57	**129**	364	287	**651**	250	236	**486**	62	86	**148**	**3,485**
121	MERCEDES-BENZ CL	5	4	**9**	74	73	**147**	31	17	**48**	8	7	**15**	67	39	**106**	33	21	**54**	5	7	**12**	**391**
122	MERCEDES-BENZ S-CLASS	68	62	**130**	967	1,223	**2,190**	338	398	**736**	113	107	**220**	900	921	**1,821**	459	568	**1,027**	138	201	**339**	**6,463**
123	MERCEDES-BENZ CLK-320	14	23	**37**	375	512	**887**	94	130	**224**	31	33	**64**	180	254	**434**	137	168	**305**	53	78	**131**	**2,082**
124	MERCEDES-BENZ CLK-500 COUPE	8	16	**24**	155	154	**309**	49	55	**104**	11	14	**25**	74	97	**171**	62	79	**141**	21	26	**47**	**821**
125	MERCEDES-BENZ E320 SEDAN	44	58	**102**	1,030	1,512	**2,542**	322	497	**819**	93	127	**220**	765	949	**1,714**	425	668	**1,093**	205	328	**533**	**7,023**
126	MERCEDES-BENZ E500 SEDAN	18	36	**54**	350	487	**837**	153	210	**363**	42	44	**86**	244	319	**563**	221	256	**477**	83	98	**181**	**2,561**
127	OLDSMOBILE SILHOUETTE	8	27	**35**	187	634	**821**	163	444	**607**	453	1,754	**2,207**	99	233	**332**	52	131	**183**	33	82	**115**	**4,300**
128	TOYOTA SIENNA XLE/LMTD	42	104	**146**	186	440	**626**	271	508	**779**	42	129	**171**	170	360	**530**	159	357	**516**	176	345	**521**	**3,289**
Total		**1,833**	**3,325**	**5,158**	**16,120**	**24,037**	**40,157**	**6,850**	**10,537**	**17,387**	**3,893**	**7,364**	**11,257**	**9,232**	**11,899**	**21,131**	**14,802**	**23,330**	**38,132**	**3,805**	**6,114**	**9,919**	**143,141**

ATTACHEMENT E: VEHICLE OWNERSHIP LIST BREAKDOWN

Overall Breakdown By Vehicle Makes	
Acura	322
BMW	1,000
Cadillac	854
Honda	350
Inifiti	1,008
Ford	694
Jaguar	124
Land Rover	350
Lexus	1,199
Lincoln	559
Mercedes	1,006
Oldsmobile	175
Toyota	700
sum	8341

Overall Breakdown by System	Optional	Standard		Total
Adaptive Cruise Control	4,188	754		4,942
Park Aid (Rear Only)	994	2,514		3,508
Park Aid (Rear and Front)	1,657	0		1,657
Park Aid (Camera)	1,343	700		2,043
Night Vision	949	0		949
Navigation (VR)	2,829	1,229		4,058
Navigation	1,148	350		1,498

Overall Breakdown by Make & System					
		ACC	Park Aid	Night Vision	Navigation
Acura		0	147	0	322
BMW		1,000	1,000	0	1,000
Cadillac		54	854	800	854
Honda		0	350	0	350
Inifiti		1,008	1,008	0	1,008
Ford		0	694	0	140
Jaguar		124	124	0	124
Land Rover		0	350	0	350
Lexus		1,050	1,199	149	849
Lincoln		0	559	0	559
Mercedes		1,006	657	0	
Oldsmobile		0	175	0	0
Toyota		700	700	0	700

ATTACHEMENT F: VEHICLE OWNER RECRUITMENT LETTER

[Date]

[Vehicle Owner]
[Vehicle Owner's Address]

Dear [Vehicle Owner],

The U.S. Department of Transportation's National Highway Traffic Safety Administration has asked Westat to survey drivers such as you concerning advanced features on your vehicle (e.g., Advanced Cruise Control, Park Aid, Navigation System, or Night Vision). You may be one of the few drivers that have cars equipped with advanced systems and your unique insights will help us understand the impact these types of systems may have on driving safety; as well as identifying improvements in their design. You will receive $25 for participating in this research. Please call the toll-free number (**1-888-825-4711)** to participate.

What Are We Asking You To Do?

We are asking the **primary driver** of the equipped vehicle to take part in a 15-20 minute **telephone survey**. The survey will ask about your impressions of the system, conditions of use, perceptions about the utility and effectiveness of the system, impacts the system has had on your driving, and safety benefits. We are also interested in learning about positive or negative experiences using the system and any associated issues related to the design or operation of the system.

Why Should I Participate?

Your vehicle may be equipped with a new technology that relatively few drivers have access to currently, but is likely to be included in many more cars in the future. As an owner of a vehicle that may be equipped with these technologies, we need your help to understand how they influence driving safety. **You will receive $25 for participating**; but more importantly, you will be providing information that may lead to safer cars and better system designs. Westat (the organization conducting this survey) is a scientific research firm; it will not be collecting or reporting any sensitive personal information. It is not a marketing research firm, and will not use the information collected for any type of marketing or sales purposes. The researchers at Westat will respect your privacy and set up a convenient time for you to participate in the survey. All your answers will be kept strictly confidential as permitted by law, and at no time will your name be associated with the answers you give.

Who is Sponsoring the Research?

This research is sponsored by The National Highway Traffic Safety Administration (NHTSA) – the agency within the U.S. Department of Transportation responsible for ensuring safety on our highways. New advanced technologies are becoming readily available on passenger cars, but little is known about their safety-related benefits or the usability of their designs and how that affects the driver. NHTSA is interested in getting an early indication of the safety-related experiences drivers are having with these relatively new devices.

Can I Find out About the Research Results?

Yes. If you would like, a report summarizing the findings of the research will be mailed to you once it becomes available. No personal information about individuals will be included in the report; only the combined data on the owners' experiences will be presented.

What Are the Systems Of Interest?

The following list of advanced in-vehicle technologies are of interest; these systems may have come as either standard or as an option on your car. **If your car is equipped with one (or more) of these systems, you qualify to participate in this study**. Although some of these devices are sold as aftermarket systems, we are currently **only interested in factory installed systems** (those that came as original equipment when you bought your vehicle from the dealer). Some car manufacturers market these under different names, so we have provided some specific brand names as a reference.

- Night Vision Systems (Night View, Night Vision)
- Advanced Cruise Control (Active Cruise, Adaptive Cruise, Intelligent Cruise, Distronic, Dynamic Cruise, Dynamic Laser Cruise Control)
- Park Aid (Park Distance Control, Reverse Park Aid, Parktronic, Reverse Warning)
- Navigation and Route Guidance Systems (sometimes called a GPS system)

How Do I Participate?

If you are interested in participating and your car has one or more of the systems listed above, please contact Westat, toll-free at **1-888-825-4711**. You will be asked to provide some basic information, and we will call you back at a date and time you specify to administer the survey. **We encourage you to call at your earliest convenience to set-up a time for conducting the survey.**

Thank you for your time,

Eddy Llaneras

Eddy Llaneras, Ph.D.
Senior Research Scientist, Westat

APPENDIX G SAMPLES EXCERPTS FROM ACC SYSTEM OWNER'S MANUALS

⚠ CAUTION

Under certain conditions where the vehicle in front slows drastically, or is stopped, the dynamic laser cruise control will neither warn you nor decelerate. The driver must depress the brake pedal to slow down, ensuring collision avoidance or that sufficient vehicle- to- vehicle distance is maintained.

⚠ Always remember that the range and ability of the system does have physical limitations. It will not apply the brakes or decelerate your vehicle when there is a slow-moving vehicle, stopped vehicle or stationary object ahead of you, as for example, at a traffic light or a parked vehicle. Also, the system does not react to oncoming traffic, pedestrians or other type of potential traffic such as a rider on horseback. It is also possible that the system may not detect smaller moving objects such as motorcycles or bicycles. Be especially alert when encountering any of these

Warning! ⚠

Close attention to road and traffic conditions is imperative at all times, regardless of whether or not Distronic is activated.

Use of Distronic can be dangerous on winding roads or in heavy traffic because conditions do not allow safe driving at a steady speed.

Distronic will not react to stationary objects in the roadway (e.g. a stopped vehicle in a traffic jam or a disabled vehicle). Distronic will also not respond to oncoming vehicles.

Switch off Distronic:

- when changing from the left to the right lane if vehicles are moving more slowly in the left lane
- when entering a turn lane or highway off ramp
- in complex driving situations, such as in highway construction zones

In these situations, Distronic will continue to maintain the set speed unless deactivated.

⚠ CAUTION

Do not rely excessively on dynamic laser cruise control. Observe the following precautions in order to avoid serious injury or death:

- **Under certain conditions where the vehicle in front slows drastically, or is stopped, the dynamic laser cruise control will neither warn you nor decelerate. You must depress the brake pedal to slow down, ensuring collision avoidance or that sufficient vehicle-to-vehicle distance is maintained.**
- **Do not use dynamic laser cruise control in the following conditions:**

  In bad weather (such as rain, fog, snow, sandstorms or direct sunlight, or when raindrops or snowflakes get on the laser radar sensor glass), the vehicle-to-vehicle distance will not be measured accurately.

  When using the windshield wipers at high or low speeds the dynamic laser radar cruise control turns off.

DOT HS 809 972
January 2006

U.S. Department
of Transportation
National Highway
Traffic Safety
Administration

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people saving people