Consumer Acceptance of Adaptive Cruise Control and Collision Avoidance Systems

THOMAS TURRENTINE, DANIEL SPERLING, AND DAVID HUNGERFORD

Consumer reactions to automated vehicle control technologies were studied. The motivating hypothesis was that current users of cruise control value the relaxation benefits they gain from its use and would therefore be early adopters of more automated controls. Four focus groups were conducted, two with avid users of cruise control and two with infrequent users. The hypothesis was not borne out: avid users valued cruise control as a driving aid more than as a means to relax and thus had little interest in more advanced automated controls. Less frequent users, in contrast, were more attracted to the automated controls because of the increased safety benefits they could provide in emergencies, although the users expressed concern about reliance on those automations in inappropriate circumstances. It is hypothesized that (a) avid cruise control users are not a special early market; (b) safety is the primary feature, both negatively and positively, in defining the early market; and (c) convenience is not likely to be a primary feature attracting early adopters of automated driving controls.

Saxton (*1*) refers to the transition between manual and automated control as a "fundamental evolutionary gap," suggesting a determined historical process rather than an open, market-driven process. Combining the concept of a linear development path with a market path, Johnston et al. (*2*) suggest that the implementation of intelligent vehicle-highway system (IVHS) freeways will take place as a five-stage process, whereas Chen and Ervin (*3*) envision a nine-step process. In both cases the first stage or stages would be voluntary, market-driven purchases of onboard navigation and route guidance systems. The second set of steps would be voluntary, market-driven purchases of automated acceleration and braking systems, which use radar-like sensing systems to warn drivers about possible collisions and to decelerate the car automatically. Other automatic vehicle control systems (AVCSs) also in development are automated steering systems and proximity sensors to warn of sideswipes and backup accidents (*4*).

Deploying IVHS technologies requires public investment in intelligent highways and private investment in intelligent vehicles (*5*). Public investment will require public approval, whereas private investment will require consumer interest.

The primary purported benefits to individual drivers from the IVHS and their motivation for purchasing IVHS technologies will be reductions in driving stress due to better information on travel conditions from advanced vehicle information systems (ADISs), increased safety from advanced vehicle control systems (AVCSs), and shorter travel times due to congestion reduction (*6*). However, the majority of these benefits will accrue to users only when the IVHS is fully deployed. Therefore, early consumer demand for ADIS and AVCS components is less certain.

Early demand faces a number of perceptual and human factor barriers, such as fears of invasion of privacy through centralized vehicle-highway interfacing, demonstrated reliability and safety, willingness to release control to a computer, uncertain benefits, and high initial cost (*7*). Credibility is especially an issue with the AVCS. Elias et al. (*8*) believe that an automated freeway system must be 20 times more safe than the current system to be acceptable to the public because of the driver's loss of direct control over the vehicle. Johnston et al. (*2*) note that commercial air travel is about 10 times as safe as automobile travel but that the public is more concerned about deaths from air travel than about deaths from automobile travel because of the large accidents and involuntary risk in air travel.

There are currently no public studies of consumer willingness to purchase driving automation. However, planners will need an advanced understanding of consumer responses. Because most AVCS technologies are still in development, consumer studies are in the exploratory stage, investigating potential early adopters and those with driving experiences related to proposed technologies (*9*).

METHOD AND RESEARCH DESIGN

This study was designed to investigate consumer responses to two AVCSs in advanced stages of development: (a) adaptive cruise control (ACC) and (b) the collision avoidance system (CAS). ACC is a radar-controlled system for adapting the throttle speed of a vehicle to that of a vehicle in its path. The CAS is a radar-controlled braking device that assumes control of braking when objects are detected in a car's pathway and the driver does not respond.

It was hypothesized that avid users of cruise control are potential early adopters of ACC and CAS technologies, with the assumption that these drivers are more willing to adopt automated driving technologies for their convenience. This hypothesis was formulated from innovation theories that suggest that early adopters of a technology are likely to be early adopters of subsequent related technologies.

The choice to use focus groups was based on the need to probe consumer responses to a radical shift in technology without the benefits of actual product testing. Four focus group interviews were conducted, each with 11 participants. Two groups were composed of avid users, and the other two of infrequent users. Infrequent users of cruise control were

Institute of Transportation Studies, University of California, Davis, Calif. 95616.

the control group. Ownership of cruise control could not be used as an identifying characteristic because consumers must often purchase a bundle of power options to get only one of the options. At least 3 participants confirmed this hunch, stating that they had purchased the power options bundle to get power mirrors and were not interested in cruise control.

Participants were recruited from an automotive market research data base that contained 8,000 households in Santa Clara, California—a congested urban area just south of San Francisco. Participants were recruited through phone interviews in which they were asked whether they owned a recent-vintage car with cruise control and how frequently they used that feature. Avid users were defined as respondents who liked using cruise control and used it every week. Infrequent users owned but generally disliked cruise control and used it less than weekly. Participants were paid $40 to participate.

The selection process resulted in a mixture of middle-class professionals, homemakers, and retired persons, with a high number of engineers (three to four per group)—the result of Santa Clara's computer manufacturing economy. Two-thirds of the avid group were males, and two-thirds of the infrequent users were females. Avid users reported higher annual miles traveled than infrequent users.

Cruise controls owned by the participants were of several types. The controls are located on a lever extending from the steering column, on the dashboard, or on the front surface of the steering wheel. In addition, speed controls varied from those that have only an on-off function, to those with a step function. Several participants expressed greater satisfaction with the steering-wheel type of cruise control, which also included accelerator and decelerator buttons. They liked the convenient location and often used cruise control instead of the foot pedal for acceleration.

The group interviews were divided into three parts: a discussion of current cruise control, the concept of ACC, and the concept of the CAS.

USES OF CRUISE CONTROL

The most cited advantage of cruise control was the ability to relax from the task of controlling speed on long journeys (cited by 23 of 44 participants). The second most cited advantage was using cruise control to control speeding on long stretches, where it is possible to lose track of speed, and in urban situations with well-known speed traps. The third most cited advantage was fuel savings. Several other advantages were cited by one or two participants, including one person whose college friends had used cruise control to control speed after drinking.

The most cited disadvantage of cruise control was that it was difficult to use in local urban driving conditions and, therefore, of limited practicality (cited by 11 of 44 participants). The second most cited disadvantage of cruise control was that the driver might relax too much when the cruise control is in operation, not be alert to danger, or not have the foot in position to brake. Although seemingly inconsistent with the already stated benefits of being able to relax, discussion centered around the idea that cruise control should be used carefully and when appropriate. Whether the driver is relaxing too much was considered to be a matter of individual judgment. Several participants reported having seen other drivers resting their feet on the seat, dashboard, and even out the window while driving sections of open freeway and thought that was too relaxed. Several infrequent users were afraid to use cruise control for fear it would malfunction, or because it required them to look down to set it.

The participants revealed that cruise control can be used as a convenience and as a tool; as a convenience it allows them to relax from work, whereas as a tool it increases work efficiency. Although infrequent users stated that they generally dislike using cruise control as a tool in traffic, avid users reported using cruise control often as a tool in what they described as congested situations. All avid users and several infrequent users said they used cruise control to keep up with the flow of traffic on multilane freeways where traffic flows at a steady speed.

Several avid users said they often use cruise control to travel in groups of vehicles moving in the same lane at or above the speed limit on long stretches of open freeways. Caravans (platoon-like groups) are unspoken agreements among drivers to travel together at a speed set by a lead driver. Participants believed cruise control owners group this way on long highways, coordinating their speeds. Some drivers say they reduce headway by concentrating on the brakelights of the lead car instead of the one directly in front, thereby anticipating speed changes as many as 10 cars in advance. Only one participant in the avid users group said he avoids these caravans because the close headways seem risky.

Several avid users said they attempted to use cruise control in local urban driving whenever possible. These drivers were willing to reset more often and to switch lanes to avoid resetting; a few admitted to waiting until the last moment to avoid resetting. Owners of variable speed cruise control use their accelerate and coast buttons to adapt to cars in front. One described using his cruise control in this context as though it were a video game, the goal being not to reset. A special use of cruise control among avid users was to control speed on expressways with timed intersections. The final major occasion for use of cruise control was to control speed for known speed traps.

The convenience benefits of cruise control generated much less enthusiasm because of a sense that relaxed driving is not compatible with safe driving. All participants thought that the convenience use of cruise control should be restricted to open stretches of highway; avid users were adament that drivers should not use cruise control to relax in other driving contexts. What determined when and where a driver used cruise control depended on the judgment and skills of the driver. Although cruise control has no decision-making components to its design, two future products addressed in the remaining paragraphs respond to traffic conditions and vehicle interactions.

RESPONSES TO ACC CONCEPT

After discussing cruise control, the groups were presented with the ACC concept. ACC was described as a radar-based speed control system, which the consumer could set for a desired speed, with the radar system adjusting vehicle speed to match that of vehicles directly in front. Once the front car moves into another lane, the consumer's car would resume

its set speed. In addition, the system uses an audible signal to warn the driver of upcoming vehicles in its path.

The primary response among avid and infrequent users of cruise control was questioning whether the system would malfunction. In particular, several respondents were concerned that radar was not a reliable technology. One respondent mentioned a story about police using radar and clocking a tree at 70 mph. Several participants thought radar would be less responsive to nonmetallic objects. Another thought the radar would have to "see way out there." Several wondered how well the beam could focus on what was in front without getting confused about things on the side. In the final two interviews, the word "sensor" was substituted for radar, raising less negative responses. In addition, respondents were concerned about dependence on the technology.

Parents in the groups had a mixed reaction to the device, fearing on the one hand that their teenage children would not have the proper judgment to know when to use the device and on the other hand thinking that the warning system would be a good device to teach children not to tailgate.

The warning system was seen in a favorable light as a safety supplement—to keep drivers from tailgating and to catch them when not alert—and as a way to instruct new drivers of safe driving habits. In fact, many of the infrequent users thought the warning system was worthwhile but that the ACC would not be of much use. Among avid users there was some interest in the warning system, but the adaptive mechanism was not seen as a major improvement over existing cruise control. Those who owned cruise controls with accelerator buttons noted that their use of cruise control was much like ACC. They recognized the utility of ACC but did not see any great advantages over the system they already possessed.

Among avid users there was a humorous but telling suggestion that what was really needed was a device to control the speed of the driver in front; the problem is seen as that of getting around the car ahead to maintain speed. These avid users were not enthusiastic about putting speed control in the hands of the slowest driver in a lane. In all groups there was a mostly accurate perception that such a technology might improve traffic flow but, to be effective, would have to be on all cars, and would therefore be standard rather than optional.

Participants were asked to estimate, by secret ballot, the price of an ACC system and what they were willing to pay. Participants were not happy to make such an estimate, because many had no idea what their current cruise control had cost. Price estimates for the ACC ranged from $300 to $2,800, with an average of $900. Twenty-three said they would not purchase ACC technology at all, whereas 21 indicated they would be willing to pay between $100 and $1,400. Drivers consistently exhibited a willingness to pay estimates that were half of their price estimates. These figures can be interpreted in two ways. On the one hand, they reflect relative disinterest, because even those that were interested said they would be willing to pay only about half of what they think ACC will cost. On the other hand, many were willing to pay significant amounts.

RESPONSE TO CAS CONCEPT

The CAS was described as a sensor-based system that warns drivers of collisions and applies brakes automatically if a collision is imminent and the driver is not taking corrective action. Response to the CAS was more emotional and engaged than that for ACC. The immediate response of participants in all groups was a concern about technical reliability. Respondents asked many questions about how the device would respond in normal and extreme conditions. There was a general perception that the device would not distinguish between dangerous and nondangerous objects in the road and objects coming from the side.

A further response was a concern that collision avoidance was a complex decision, that complex technology would be subject to failure under many circumstances, and therefore that CAS technology could not be relied on. Avid users dwelled on comparing their own skills with the machine. Several comments suggest that avid users thought the CAS would interfere directly with their own good habits. It was thought that the device would be particularly suited for avoiding rear-end collisions in bumper-to-bumper traffic. Participants cited their own lapse of attention under those conditions. Two participants had been rear-ended in freeway traffic by someone who did not see them. They both said it would have been great if the other driver had a CAS. Avid users (who tended to be most confident of their own skills) and a few nonusers who feared losing control to the technology were most opinionated about machine failure.

As with cruise control and ACC, participants debated the compatibility of relaxation and good driving goals. Several participants were concerned that drivers would learn to rely on the system instead of on their own instincts, leading to less than vigilant driving. Other participants debated the previous concerns, stating that the CAS could be an aid to new drivers, a safety edge in poor driving conditions, and a backup when attention is averted. The groups were interested in the safety and tool benefits of the CAS but were uneasy with the intended and possibly unintended use of the CAS as a convenience.

Participants estimated that the price of CAS products would be $500 to $3,000, with the average being $1,500. Fourteen participants said they would not purchase it, whereas 30 stated they would be willing to pay $150 to $1,800.

SUMMARY

Given the conditions under which they do most of their driving, participants in the focus groups placed more value and importance on the tool uses of vehicle control technologies than on convenience uses. They especially valued safety benefits, although they doubted the reliability of these technologies (especially when based on radar) and their ability to respond to different types of dangers and obstacles.

As a result of this greater interest in safety, more drivers indicated an interest in purchasing CAS products than ACC, although the amount that drivers were willing to pay, of those interested, was about the same for both technologies.

These findings are tentative and need to be confirmed in larger studies, but they suggest that the designers and marketers of IVHS technology would be advised to focus more on safety benefits than on convenience benefits and to be highly sensitive to drivers' reluctance to defer control to machines.

Moreover, it appears that avid cruise control users, because they are more interested in driving efficiency than safety or even convenience and believe their driving abilities to be superior to machine decisions, are not an attractive early market for ACC and CAS products. Infrequent users are a better market because of their belief in their own fallibility and therefore greater interest in the emergency assistance offered by warning signals and the CAS. Because convenience was considered to be an inappropriate use under current highway conditions, it is suggested that the earliest market for vehicle control technologies will be sensor-based information, such as audible collision warnings, to assist drivers. The second market will likely be for backup or shadow CAS devices, possibly becoming standard safety equipment. Only then, and with the development of exclusive access lanes for smart vehicles, are large numbers of consumers likely to purchase automated control for vehicles.

ACKNOWLEDGMENTS

This work was funded by the Program on Advanced Technology for the Highway (PATH) of the University of California, in cooperation with the State of California Business Transportation and Housing Agency, Department of Transportation. Appreciation is also extended to the participants in the focus groups.

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Publication of this paper sponsored by Committee on Vehicle User Characteristics.