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Intelligent Cruise Control System"

Driver Preferences and Usability of Adjustable Distance Controls for an Adaptive Cruise Control (ACC) System

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16 Abstract

This report describes an investigation of driver preferences and usability of adjustable distance controls for an adaptive cruise control (ACC) system. ACC is conceived as an enhancement to conventional cruise control that would accommodate a slower moving vehicle in the lane of travel by providing some moderate level of deceleration and distance maintenance behind the slower vehicle. While the ACC system is maintaining a distance behind a slower vehicle, there is the possibility for the driver to adjust the following distance according to his/her preferences. In this study, thirty-six participants (equal numbers of men and women grouped according to ages 25-39, 40-54, and 55 and over) were Introduced to the concept of ACC by using a computer prototype of an ACC system. Participants were asked to provide their preferences for labels for two types of adjustable distance controls: one type that adjusts both speed and distance (shared controls) and another that adjusts only distance (separate control). They also used the controls to get closer and farther away from a slower vehicle in front of them and provided their preferences for shared or separate controls for distance adjustment. Participants preferred shared controls to a separate control for distance adjustment. They preferred the labels ACC/DEC for shared controls over '+/-' and ACC/COAST. The labels preferred for the separate control were NEAR/FAR as opposed to symbols (arrows or chevrons). Because these preferences were obtained through the use of a computer prototype of ACC, usability tests should be conducted on the road to validate the data.

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TABLE OF CONTENTS

LIST OF FIGURES

INTRODUCTION

Conventional cruise control, a popular convenience feature on cars in the U.S., maintains a speed selected by the driver and thus, relieves the driver of the task of maintaining a constant speed. The use of cruise control on highways, however, is becoming less effective due to congestion that prevents driving at preselected speeds for extended periods of time. Adaptive cruise control (ACC) is conceived as a driver support system that would enhance the performance of conventional cruise control and allow the system to be used under a wider range of traffic conditions than conventional cruise control. With ACC, a sensor on the front of the vehicle senses a vehicle In the path of travel (lead vehicle) and. if that vehicle IS traveling at a slower speed than the ACC vehicle, the ACC system slows down the vehicle to maintain a time headway (based on speed) or distance behind the lead vehicle. (This enhanced feature of cruise control will be referred to as distance control in this paper.) While minimum and maximum following distances will be programmed in to the control logic of the system, there is the possibility for the dnver to adjust the following distance according to his/her preferences.

Objective of the Present Study

The objective of the present study was to evaluate how following distance for an ACC system should be adjusted by the dnver. Current cruise control systems allow the driver **to** adjust the set speed the system should maintain. In the design of an ACC system, there are two possible ways the driver could adjust the following distance: using the same controls that adjust speed (shared controls) or using separate controls. A second issue that arises with regard to buttons for distance control is the labels on the buttons.

A study was conducted to evaluate the usability of a prototype ACC system. Specifically, the followrng issues were addressed:

- For an ACC system, do drivers prefer shared controls that adjust both speed and distance or separate controls?
- How should the controls be labeled so that they are intuitive and meaningful?

METHODS AND PROCEDURES

Participants

Thirty-six drivers (18 men and 18 women) participated in the study. Participants were recruited so that an equal number of men and women could be placed in each of the following three age groups (25-39 years, 40-54 years, and 55 years and over). While a majority of the participants (30) were employees at Ford Motor Company, SIX were friends and family members of the experimenter and one member of the ACC development team.

All but two of the participants reported that they drive daily: two men in the younger age group repotted driving only 2-3 times a week. Thirty of the 36 participants repotted driving vehicles produced by Ford Motor Company and 29 of the 30 had cruise control systems in their vehicles. Only three drivers (one man and two women all in the older age group) had never used cruise control. Three participants stated that they use cruise control on a daily basis and nine use it 2-3 times a week, while fourteen only use it on long trips or highway driving. Others use it occasionally (4) or rarely (1). Approximately one-half of the participants (17) had heard of ACC before participating in this study.

Test Materials

Current Cruise Control System on Ford Production Vehicles

The current cruise control system on a majority of Ford production vehicles in the U.S. was the basis for the ACC system used in this study. The buttons the driver uses to operate this system, on the steering

wheel of the vehicle, are shown in the upper left picture in Figure 1. To enable the system, the driver presses the ON button. This puts the system in a ready or standby state and the driver is still in charge of maintaining his/her vehicle speed. Once the driver has accelerated to a speed at which he/she wants the system to maintain, the driver presses the SET/ACC button to engage the system. At this point, the system maintains the speed selected by the driver. While the system is maintaining this speed (speed control), the driver can use the SET/ACC and COAST buttons to increase and decrease set speed, respectively. The buttons increase and decrease speed at the rate of 1 mph per tap or until released. The SET/ACC and COAST buttons are laid out so that the button that increases set speed is above the button that decreases set speed. This above/below or up/down configuration is consistent with the button functions of move forward/backward. In addition to the configuration of the buttons, the surfaces of the buttons provide the driver with additional feedback (tactile) of the up/down functions; the SET/ACC button has a raised surface that can be associated with increase and the COAST button has a lowered surface that can be associated with decrease.

In order to engage the resume function using the RES button, the driver first needs to press the brake pedal to cancel system control. At this point, the driver is now regulating the speed of the vehicle. In order to resume to the set speed, the driver presses the RES button and the system accelerates the vehicle to the speed that had been previously set by the driver before he/she pressed the brake pedal. The OFF button disables the system and clears the set speed from the system memory. In order for any of the cruise control functions to operate once the OFF button is pressed, the driver must engage the system by pressing ON and must set the speed by pressing SET/ACC.

At any time during system control, the driver can take over speed control of the vehicle by pressing the pedals. Accelerator override allows the driver to increase vehicle speed using the accelerator pedal: when the pedal is released, the vehicle returns to the set speed and the system resumes control of vehicle speed. As mentioned above, pressing on the brake cancels system control and the driver regains control of vehicle speed.

ACC System

With an ACC system, the basic functions of conventional cruise control are retained and the same buttons can be used to control these functions as described above when the system is operating in cruise control. With the capability of the ACC vehicle to slow down to accommodate a slower vehicle in the path of travel and maintain a following distance (distance control), the driver could adjust this distance using system controls. Given that there are already controls that increase (SET/ACC) and decrease (COAST) speed, it may be a natural extension of the functions of these controls to increase and decrease following distance. Thus, the SET/ACC button could be used to get closer to the vehicle ahead and the COAST button could be used to get farther away from the vehicle ahead.

Labels for Shared Controls

The labels on the shared controls for the ACC system that adjust both speed and distance must be unaerstandable for both parameters. In order to maintain consistency between the driver interface for conventional cruise control and that of the ACC system, labels with which the driver is familiar were used as the basis for test labels. The three sets of labels tested for the shared controls are shown in Figure 1 These include the current labels (SET/ACC and COAST) used on a majority of Ford production vehicles as well as SET/ACC and DEC, and SET/+ and '-.'

The current labels ACC and COAST make sense for distance adjustment as well as speed adjustment; the car has to accelerate to get closer to the vehicle ahead and to coast (decelerate) to get farther away from the vehicle ahead. An alternative label for COAST that may be more intuitive to the driver since it is an antonym (opposite) of accelerate, DEC (decelerate), was tested. Finally, rather than word abbreviations, the symbols '+' and '-' were used to indicate increase speed (move forward) or get closer and decrease speed (move backward or back off) or get farther away, respectively. The '+' and '-' symbols for increase and decrease, respectively, are in common use and should make sense to most

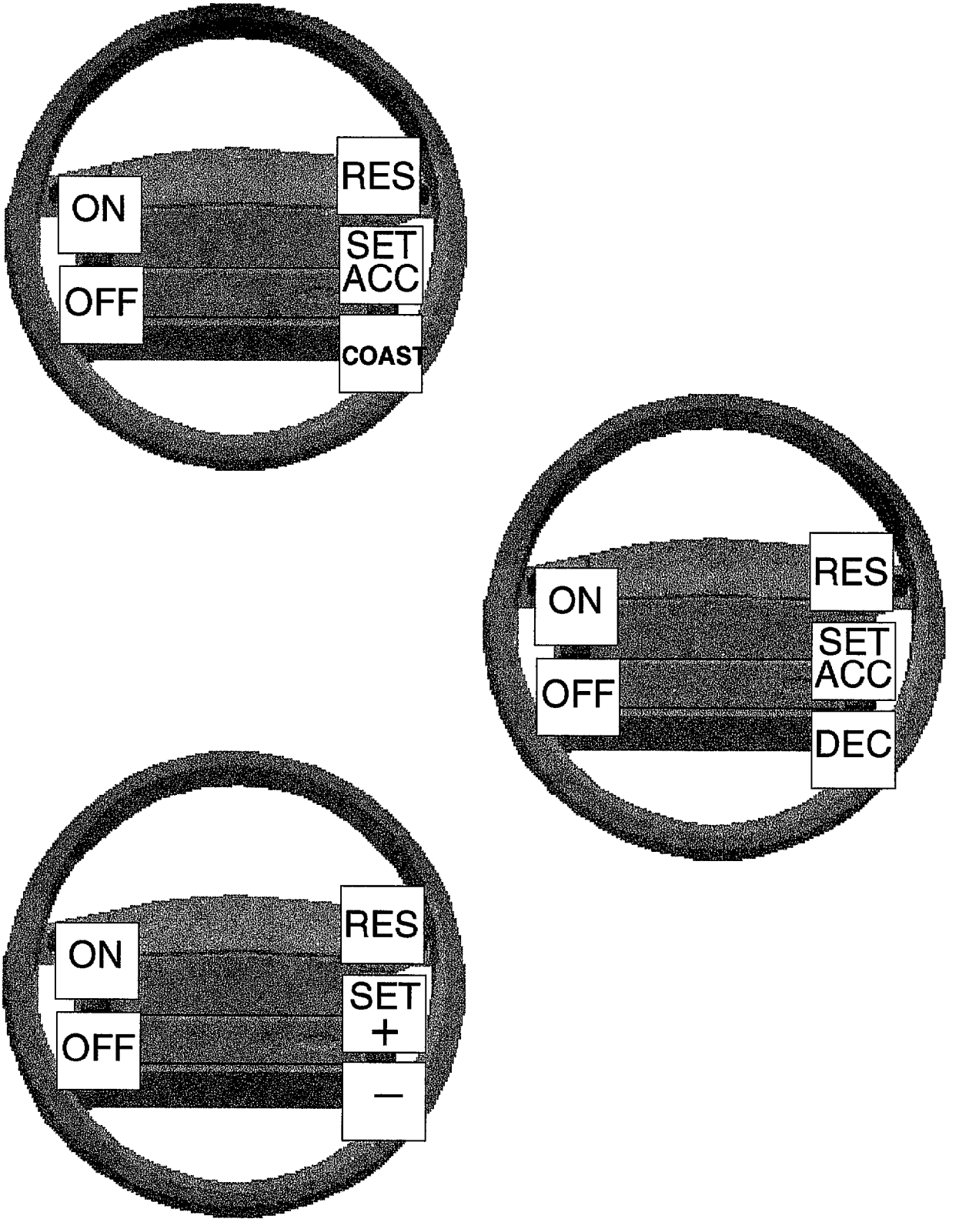


Figure 1. Labels tested for the shared controls

people. Thus, the labels tested for the shared controls included the current button labels on a majority of Ford productjon vehicles as well as labels that may be more intuitive to the user than the current labels.

The possibility for confusion exists with the '+/' labels for the shared controls. With regard to pressing the SET/ACC or SET/+ button, the ACC system's response of increasing speed, moving forward, and getting closer all are conveyed appropriately through the labels ACC and '+,' if the driver is thinking in terms of closing the *gap or space* between the ACC vehicle and the vehicle ahead. However, if the dnver is thinking in terms of increasing his/her distance to the vehicle ahead, the button labeled '+' that would be pressed to increase speed in speed control would provide the opposite than desired function when pressed to increase distance in distance control (it would actually decrease distance to the vehicle ahead by accelerating the vehicle). Thus, if the driver associates '+' with increasing distance rather than moving forward, the shared button label '+' for both speed and distance control will be confusing to the dnver. A similar argument can be made for the '-' label. The additional tactile feedback that is provided on the surface of the buttons (increase/decrease), however, may alleviate this confusion if it exists.

Labels for a Separate Distance Control

SIX sets of labels that were tested for a separate distance control are shown in Figure 2. These labels were chosen for testing after a review of proposed or recommended labels for adjustable distance controls (Adaptive Cruise Control Performance Specification, 1995; Richardson and Ashby, 1994: Ward, Humphreys, and Fairclough, 1995). Two of the sets of labels consist of word pairs, NEAR/FAR and MIN/MAX, and the other four consist of symbols (arrows and chevrons). All of the buttons are meant to be used in a similar manner; to get closer to the vehicle ahead the driver would press the top of the buttons and to get farther away from the vehicle ahead the driver would press the bottom of the buttons. The label sets, NEAR/FAR and MIN/MAX, clearly convey this: push the top to get near the vehicle ahead or to minimize the distance to the vehicle ahead and push the bottom to get farther away from the vehicle ahead or to maximize the distance.

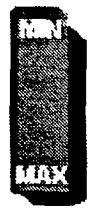
The possibility for confusion exists with the other labels, however. For the two buttons, arrows and button One (see Figure 2), the symbol on the top of the button (up arrow) typically conveys up or increase, so if the driver IS thinking of increasing closeness or closing the *gap* or *space,* he/she would press the top of the button. If the driver wants to increase distance, however, pressing the top of the button would have the opposite effect (move closer to the vehicle) than the one the driver intended (get farther away from the vehicle).

The chevrons on buttons Two and Three (see Figure 2) may be difficult to interpret. On button Two, the chevrons on the top of the button are meant to indicate close or little space and the chevrons on the bottom of the button are meant to indicate far or a lot of space by showing chevrons that are close togetner and far apart, respectively. The same close/far meaning is meant to be conveyed through the labels on button Three; one chevron indicates close (little space) and three chevrons indicate far (a lot of space).

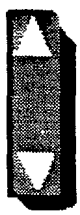
Computer Prototvoe of ACC

A computer prototype of ACC was developed using Altia(R) Design 2.0 software which allows for efficient design and development of user interfaces. The graphical interface of the prototype consists of the Instrument panel, steering wheel, and a view of a two-lane road through the windshield as seen from the driver' s perspective. (See Figure 3.) The accelerator and brake pedals are also present in the lower right corner of the prototype computer display. The five buttons used to operate conventional cruise control are present on the steering wheel.

NEAR/FAR



MIN/MAX



Arrows

One

Two

Three

Figure 2. Labels tested for the separate distance control

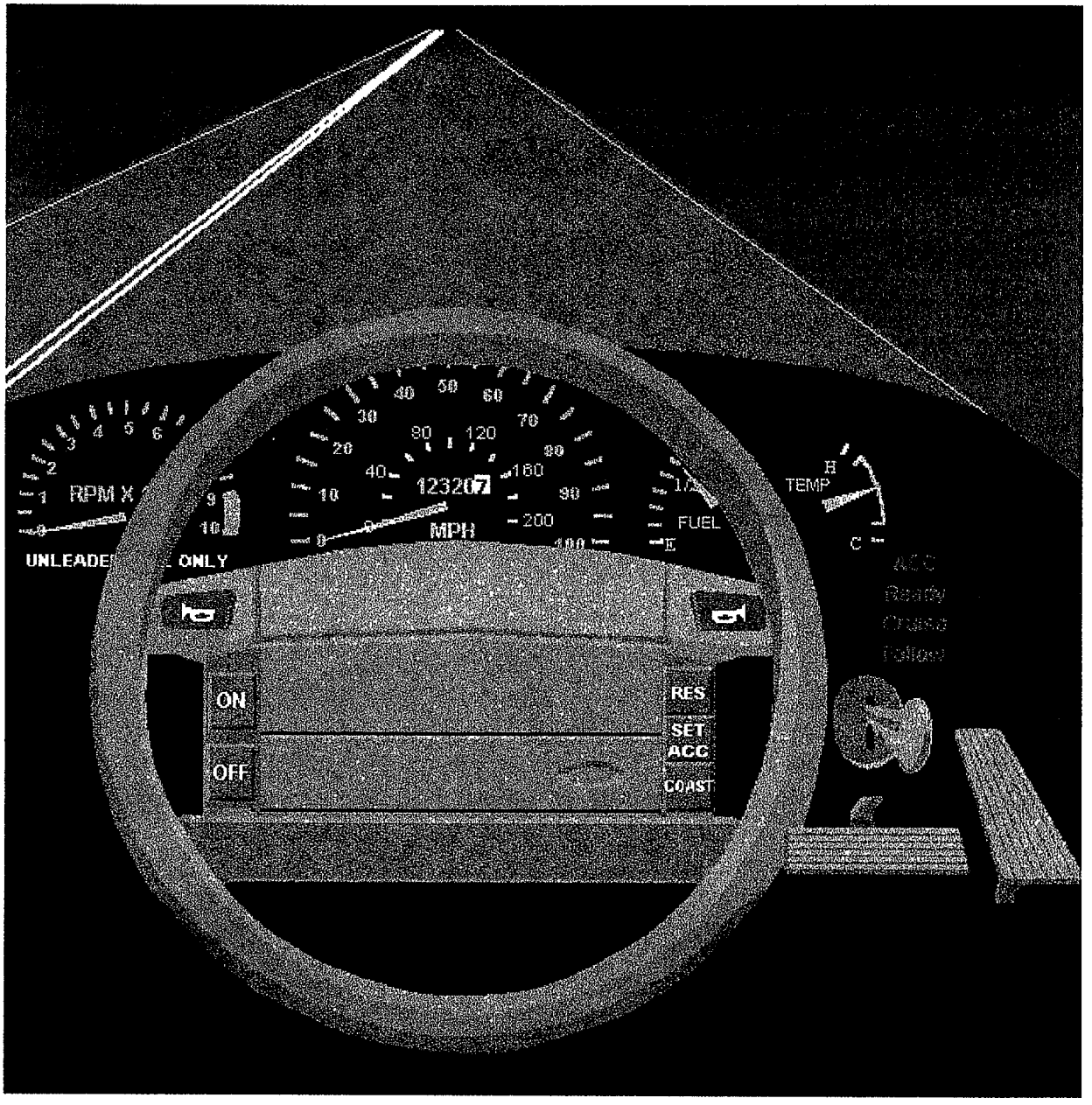


Figure 3. Interface of the ACC computer prototype

During the study, the prototype ran on an IBM™ ThinkPad™ laptop computer with 20 Megabytes of RAM and sound capabilities. Participants used the mouse to click on buttons and other objects that they wanted to operate such as the key in the ignition and the pedals. For example, holding down the mouse button and dragging it down simulated using the accelerator pedal, and the speedometer reading changed appropriately.

Sounds were associated with some objects as well. For example, when participants clicked on the key they heard the sound of a car engine starting. Some other sounds included a click associated with a button press and squealing brakes when the brake pedal was pressed.

The conventronal cruise control functions of the prototype were operational and functioned just as they would in a production cruise control system. Participants could turn the cruise control system on and off, set a cruise speed, increase and decrease the set cruise speed, and use the RES button to accelerate to the set speed given that they had pressed the brake pedal to cancel the system. Accelerator override was also operational so that drivers could increase their speed using the accelerator pedal and when they released it, the vehicle would return to the set speed.

In addition to conventional cruise control functions, the prototype also simulated ACC so that when there was a vehicle ahead in the same lane traveling at a slower speed than the participants' own vehicle. their vehicle appeared to slow down and maintain a set distance to that vehicle (lead vehicle). Participants could increase and decrease their distance to the lead vehicle using two buttons on the steennng wheel (SET/ACC and COAST, SET/ACC and DEC, or Set/+ and '-' depending on which labeling scheme they saw on the prototype). In a subsequent part of the study, participants used a separate button to increase and decrease their distance to the lead vehicle. This varying distance was simulated in the prototype by animation of the lead vehicle that made it get bigger and smaller.

Test Procedure

Because the ACC prototype was on a laptop computer, the experimenter was able to conduct the study at each participant's desk. Upon arrival at the designated location, the participant was greeted and told that the purpose of the study was to obtain his/her impressions of the driver interface of a new cruise control system. While the experimenter set up the computer, the participant read an information letter (Appendix A) describing the process of participating in the study and read and signed an informed consent form (Appendix B).

The study was divided into two parts: the first part consisted of drivers' understanding and usability of a conventronal cruise control (speed control) system and the second part consisted of their understanding and usability (distance adjustment) of an ACC system (distance control). Understanding and usability of conventional cruise control was examined first so that all of the participants started the ACC part of the study with a full understanding of the capabilities of conventional cruise control systems. Thus, those drivers who may not have fully understood or used all of the functions of the buttons prior to the beginning of the speed control part of the study were introduced to all of the functions by the end (as described in more detail in the following paragraphs).

In the first part of the study, speed control, participants initially described the function of each of the five buttons on the steering wheel while simply looking at the interface (they could not press buttons to see what they did). Specifically, participants were asked, "What does this button do?" and "What does the car do when you press it?" The order in which participants were asked to describe the button functions (ON, SET/ACC, COAST, RES, and OFF) is fairly representative of how the system might be used on the road. Only twelve participants were shown the aforementioned labels. The other two-thirds saw the buttons with either SET/ACC and DEC (12 participants) or SET/+ and '-' (12 participants).

After describing the functions of all of the buttons, participants were told, "...to use the system to make sure that it functions the way you think it should." While a protocol was not followed, the experimenter made sure that participants used all of the buttons on the steering wheel by prompting them if necessary. For example, if they stopped after setting a cruise speed, the experimenter prompted them with, "How would you increase your set speed?" If participants were unsure of how to use any of the buttons, the experimenter explained the function(s) to them and then the participants used the button(s) to do it(them).

Upon completion of using all of the buttons to operate the system, part two of the study, distance control, began. Given that speed control was currently set on the prototype, participants were asked to watch a scenario on the road and describe what they saw happening. Specifically, participants were told, "You are driving on the road with your cruise control system set at -- mph. Suppose there is a car ahead of you that is going slower than your vehicle. Watch what happens." At this point, the experimenter put a vehicle far down on the road using a hidden button on the screen. Participants watched as it appeared that they were getting closer to the vehicle ahead and at a certain distance, the speed of the participants' vehicle

decreased until a set distance was maintained behind the vehicle. After this, participants were asked a series of questions about varying the distance between their vehicle and the vehicle ahead of them which eventually led to the use of the SET/ACC and COAST buttons (or the other two sets of labels) on the steering wheel to get closer and farther away from the vehicle ahead, respectively. (See page 2 of the data collection form in Appendix C for the questions that each participant answered.) Once participants saw that the buttons on the steering wheel could vary both speed and distance, they ranked their preferences for the three sets of labels. Appendix D shows the ranking sheet for the shared control labels.

After ranking the three labeling schemes for the shared controls, participants were asked if they would like a separate button for varying the distance. Next, they were asked to rank their preferences for labels for a separate button that would vary distance. (See Appendix E.) Subsequently, the experimenter ran a new version of the ACC prototype that had a separate button with their preferred labels. (All participants saw the labels SET/ACC and COAST on the steering wheel buttons now.) Using this new button, participants got closer and farther away from the vehicle ahead of them. Next, they answered questions about their expectations of the system and the functions of other buttons, as well as display issues. Finally, in order to determine the population stereotypes for the button labels with regard to which labels are associated with getting closer and farther away from the lead vehicle, participants were asked to identify the end of the button they would press to get farther away from the vehicle ahead of them on the distance control ranking form (Appendix E).

Upon completion of both parts of the study, participants filled out a background questionnaire (Appendix F) which obtained information about their cruise control usage and driving habits.

RESULTS

Participant Descriptions and Use of Controls for Distance Control

Scenario Illustrating System Distance Control

All participants could describe the distance control scenario adequately; participants noticed that their vehicle slowed down as they approached the slower moving vehicle (lead vehicle) in their lane. When their vehicle had matched the speed of the lead vehicle and was maintaining a set distance, the participants were prompted with the question, “What is happening now?” if they had not already said something. All of the participants reported that their vehicle was matching the speed of the vehicle ahead of them. When asked if they knew how the vehicle could do this, all but one of the participants stated that it had a sensor or that it could sense the car ahead.

How would YOU vary the distance?

Participants were queried as to how they would vary the distance between their vehicle and the vehicle ahead of them. If they did not think they could vary the distance or were unsure as noted in the previous section, they were told that they could vary the distance and were asked how they would.

Almost one-half of the participants (16) said they would use the foot pedals to vary the distance between their vehicle and the vehicle ahead of them. (See Figure 4.) Only ten participants stated that they would use the buttons on the steering wheel to vary their distance (one-half of these participants saw the ‘ +/-' labels). Eight participants were not sure how to vary the distance and two would turn the system off and take over control of the vehicle.

If a participant responded that he/she would use the buttons to vary the distance to the vehicle ahead, he/she was asked to do so. All but one of the participants pressed the appropriate buttons; one participant who saw the label, ACC, pressed the RES button first and then ACC after they saw that they did not get closer to the vehicle ahead.

If a participant responded that he/she would vary the distance some other way than using the steering wheel controls (or was unsure), then he/she was prompted with the following, “Let’s say that you think that the gap between your car and the car ahead of you is just a little too big and you want to get a little closer to that car so that too many cars won’t cut in. Which button would you press on the steering wheel to get closer to the car ahead of you?" After demonstrating that they would press the ACC or ‘+’ button (only one participant who saw the label ACC pressed the RES button first), they were asked how they would get farther away from the car ahead of them. Everyone used the DEC, COAST, or '-' button to do this after the experimenter coached them through the use of the ACC or '+' buttons to get closer to the vehicle ahead.

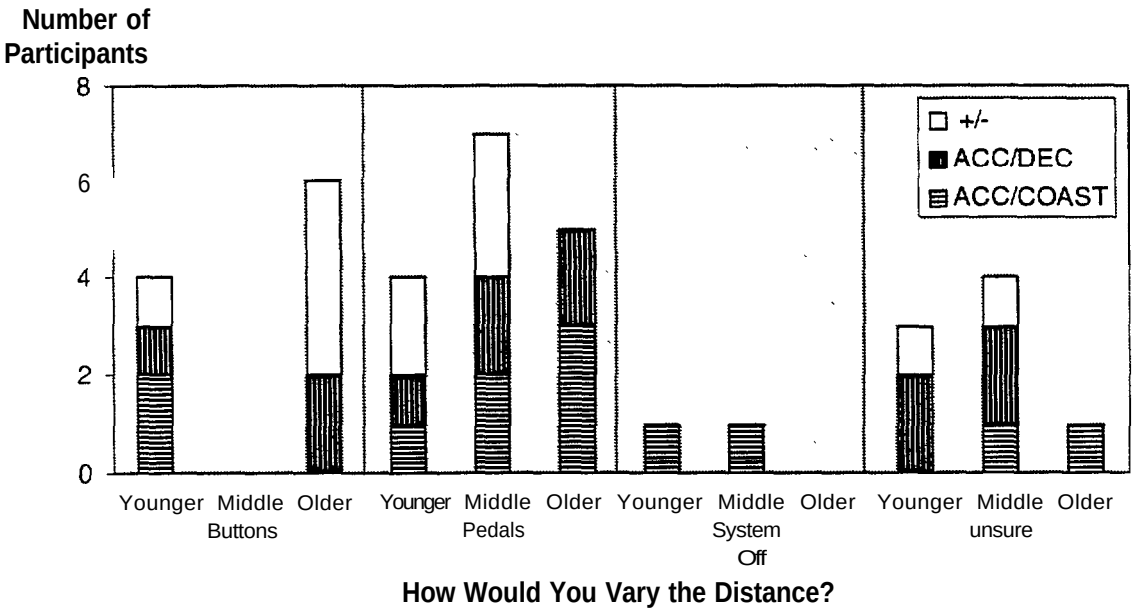


Figure 4. How would you vary the distance between your vehicle and the vehicle ahead of you? (12 participants per age group; 12 participants per button label set)

Label preferences for shared controls

After witnessing and demonstrating that the buttons that traditionally increase and decrease speed could also vary distance. participants ranked their preferences for the labels on these buttons. Figure 5 shows that slightly more participants preferred the labels ACC/DEC (16) over ‘ +/-' (12). The ACC/COAST labels were preterred by the fewest number of participants (8).

It is interesting to note that a majority of those participants who were shown the ACC/DEC and ‘ +/-' labels while using the prototype preferred these labels when ranking them. This is not true of those who were snown and used the current labels, ACC/COAST. A majority of these participants preferred the ACC/DEC labels.

Figure 6 shows the number of participants who ranked each of the labels as least preferred. Not surprising given the data for most preferred labels, the ACC/COAST labels were ranked last by the most participants (16) and the ACC/DEC labels by the least (4). The labels ‘ +/- were also ranked last by 16 participants.

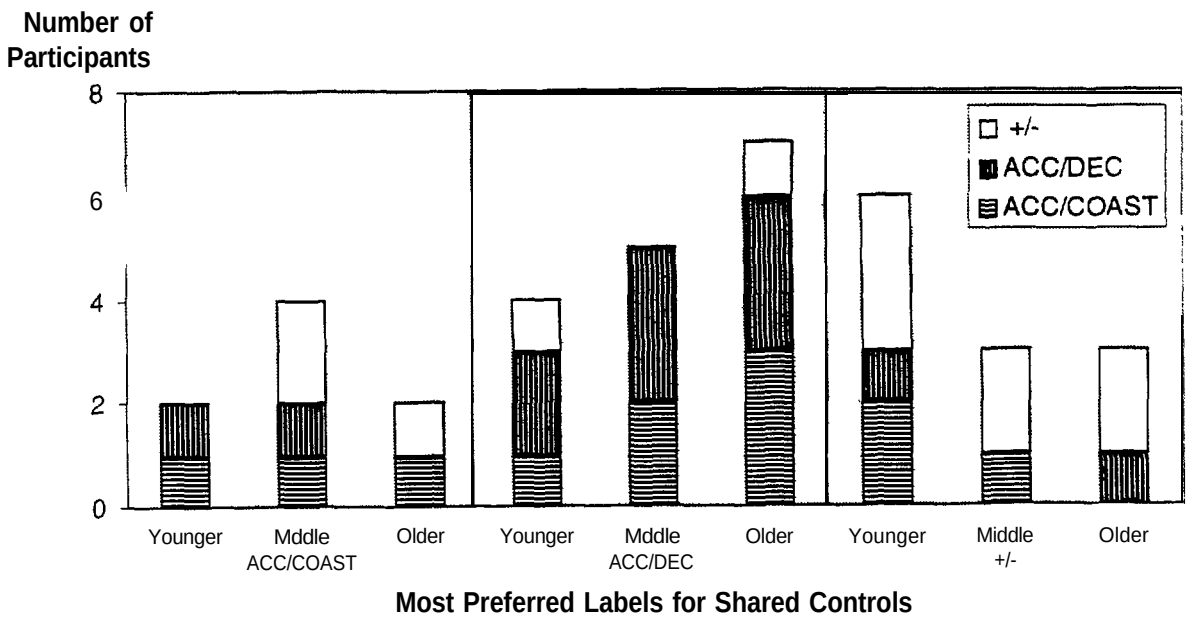


Figure 5. Most preferred labels for the shared controls
(12 participants per age group; 12 participants per button label set)
(The x-axis contains the labels participants preferred while the labels they saw on the steering wheel are coded on the bars.)

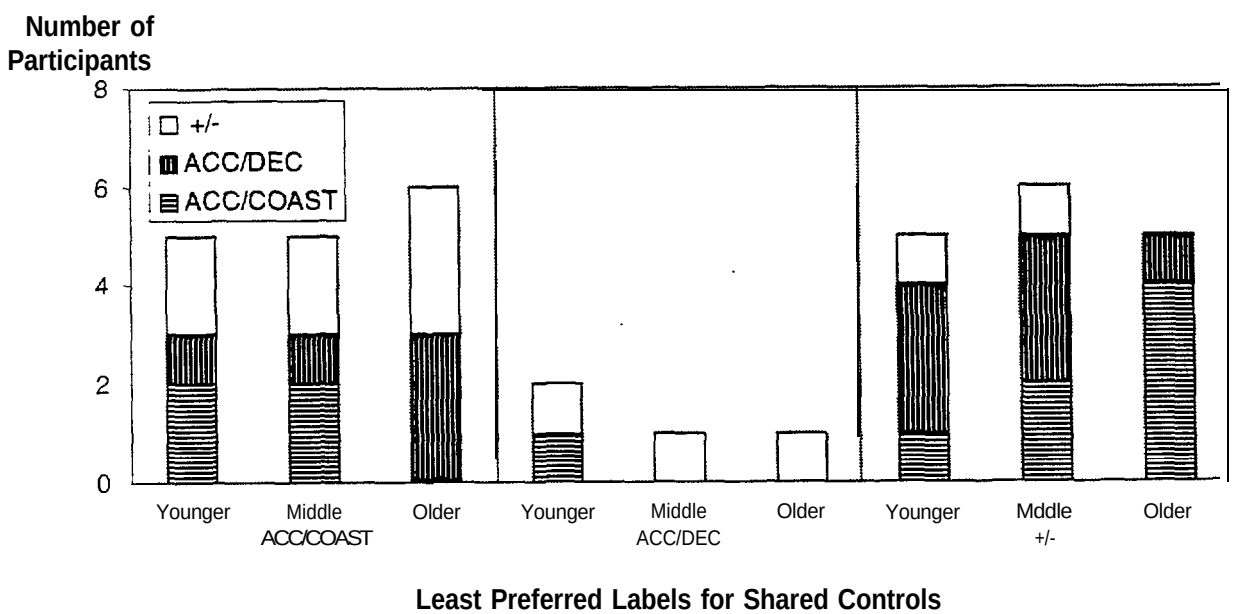


Figure 6. Least preferred labels for the shared controls
(12 participants per age group; 12 participants per button label set)
(The x-axis contains the labels participants preferred while the labels they saw on the steering wheel are coded on the bars.)

The scale values of the labels for the shared controls are shown in Figure 7. The scale values were computed by first obtaining a simple rank order of the data by analyzing the number of times a rank was assigned to each label and then assuming a comparative judgment method of reducing rank order data to a scale of equal intervals (Bartleson, 1984). These scale values show the rank order of the labels as well as their positions on the scale relative to each other.

The scale value data indicate that the ACC/DEC labels were ranked first and the ACC/COAST labels were ranked last. These data agree with the preference data in that the ACC/DEC labels were preferred over the other labels and the ACC/COAST labels were least preferred.

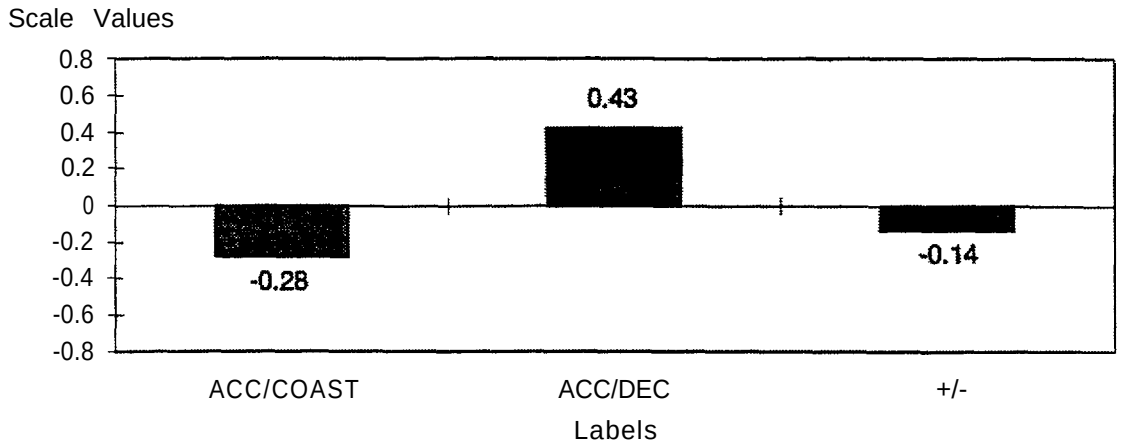


Figure 7. Scale values of the labels for the shared controls

Would you like a separate button to vary distance?

After using the shared controls and ranking their preferences for button labels, participants were asked if they would like a separate button to vary the distance between their vehicle and the vehicle ahead of them. Three-quarters of the participants (27) responded "no." (See Figure 8.) These participants thought that once they knew how the buttons functioned, they would not need a separate button to vary distance. It was generally felt that the fewer the buttons, the better. Eight participants wanted a separate button to vary distance and one was unsure.

Label preferences for a separate distance control

All participants ranked their preferences for distance control labels, even those who responded that they did nor want a separate control or those who were unsure. Prior to this exercise, participants were told the following, "Suppose you just bought a new car with this system on it and you do have a separate control to vary your distance to the vehicle in front of you. You get to choose the labels for this control and I want you to rank your preferences for the labels."

Over one-half of the participants (22) preferred the labels NEAR/FAR. (See Figure 9.) The labels MIN/MAX and arrows were preferred by seven and four participants, respectively. The three sets of labels with the various configurations of chevrons (buttons One, Two, and Three in the Figure) were only preferred by three participants.

The least preferred labels for the separate control to vary distance are shown in Figure 10. Three-quarters of the participants (27) ranked the three position control (button Three in the Figure) last. The two controls with words for labels (NEAR/FAR and MIN/MAX) were ranked last by only four participants.

(It should be noted that one participant ranked two controls (buttons Two and Three in the Figure) last which accounts for the total of 13 older participants in Figure 10.)

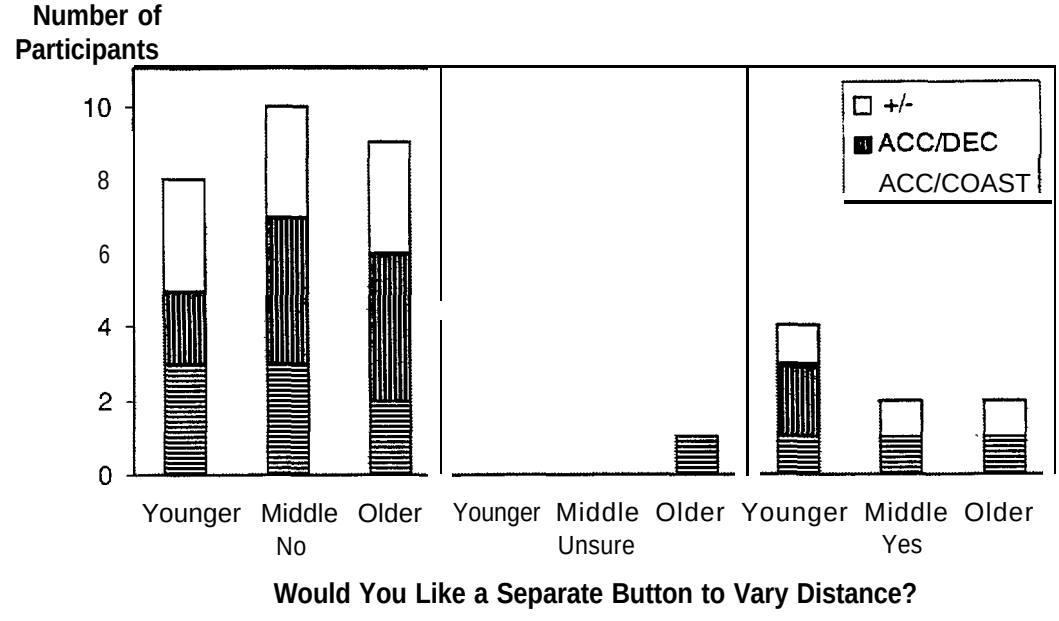


Figure 8. Would you like a separate button to vary the distance between your vehicle and the vehicle ahead of you?
(12 participants per age group; 12 participants per button label set)

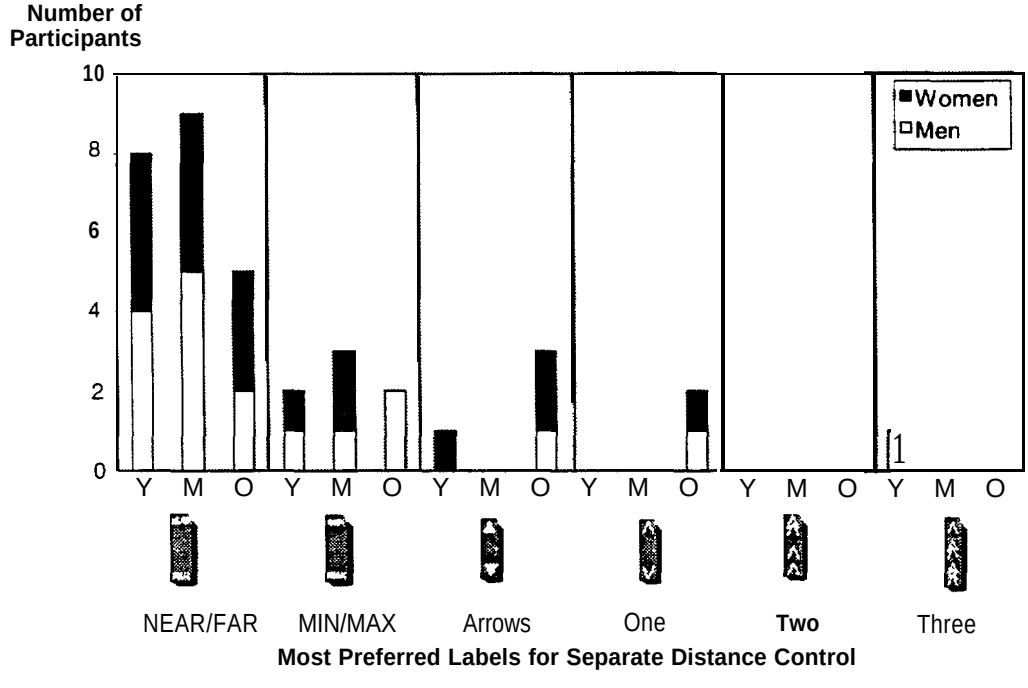


Figure 9. Most preferred labels for the separate distance control
(12 participants per age group; Y = younger, M = middle, and 0 = older)

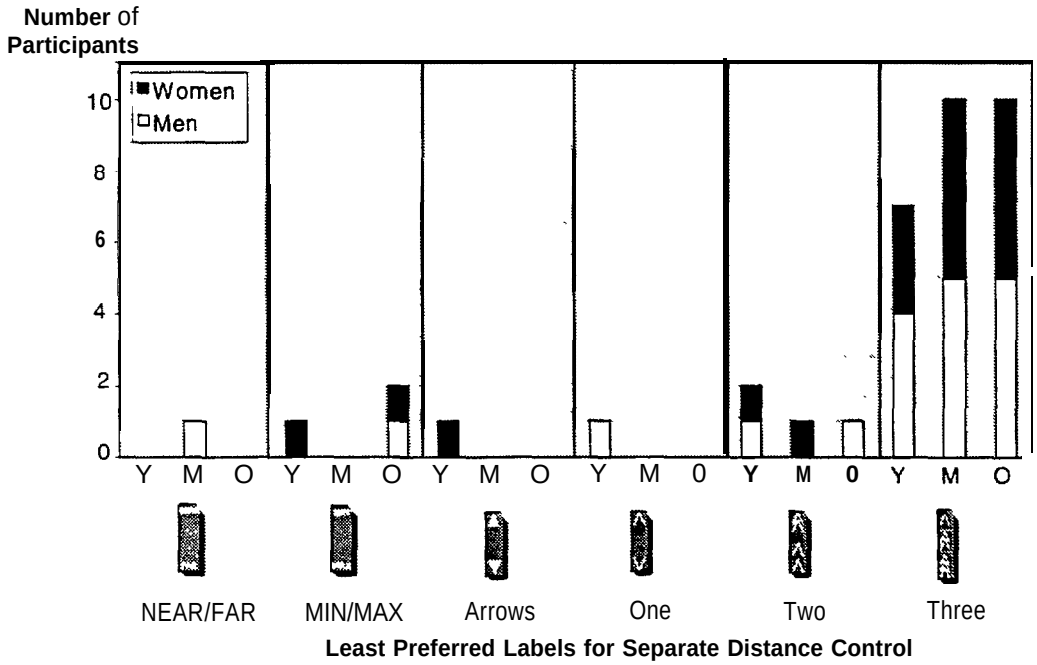


Figure 10. Least preferred labels for the separate distance control
(12 participants per age group; Y = younger, M = middle, and 0 = older)

The scale values of the labels for the separate control indicating the rank order for preferences are shown in Figure 11. As indicated by the data for the most preferred label, the labels NEAR/FAR, were ranked as number one (most preferred). The arrows, however, were ranked second followed by the MIN/MAX labels. Similar to the data from the least preferred label, the three position control (button Three in the Figure) was ranked last.

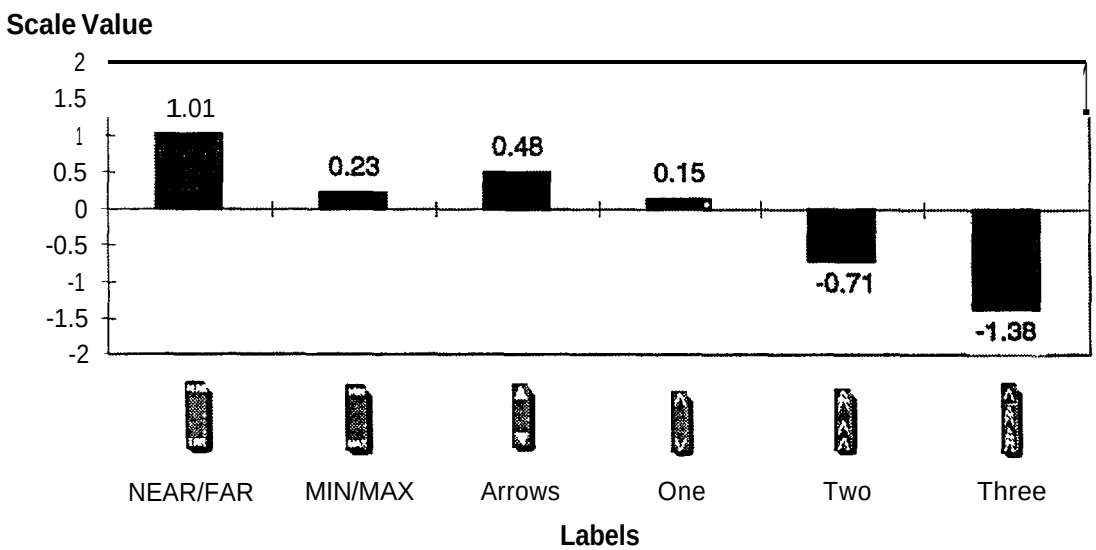


Figure 11. Scale values of the labels for the separate control

At the conclusion of the study, participants were asked, for each button, to place an 'X' at the end they would press to get farther away from the car ahead of them. In general, the labels on buttons Two and Three in the Figure were confusing to people. Nine participants placed question marks next to one or both of the buttons indicating that they did not know which end to press to get farther away. Five participants had the opposite understanding than the one intended for the labels on these buttons (button Two, 3 participants and button Three, 2 participants). Still others thought that either end would bring the car forward, accelerate the car slower, or were all maximum settings.

Usina the buttons with their Dreferred labels

After ranking their preferences for labels for a distance control, participants used the control with their preferred labels to get closer and farther away from the car in front of them. All the participants but one used the control with their preferred labels as anticipated. One person who chose the MIN/MAX labels pressed MIN to get farther away from and MAX to get closer to the vehicle in front of them.

Would you want a control with two or three settinas for distance?

Only six participants said they would like a control with two or three settings for distance. (See Figure 12.) Over three-quarters of the participants (29) said they would want more variability and liked the variable adjustment of the current control.

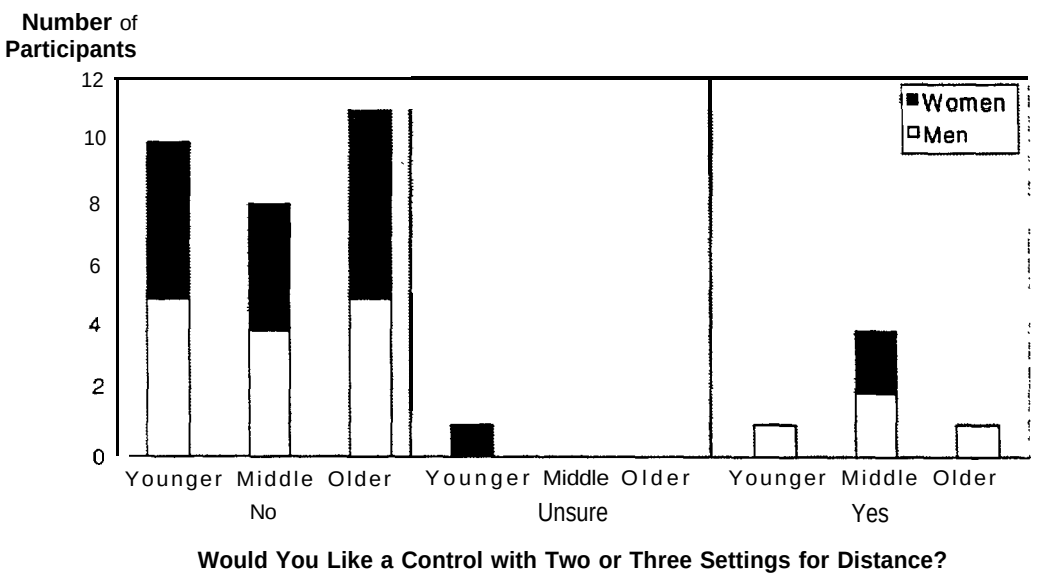


Figure 12. Would you like a control with two or three settings for distance?
(12 participants per age group)

Driver Expectations of the System

What should the car do if you press the SET/ACC button now?

Given the situation that the system is controlling headway and the driver has a separate control to vary distance, participants were asked what they expected their car to do if they pressed the SET/ACC button on the steerng wheel. A variety of responses were recorded for this situation and are shown in Figure 13.

One-half of the participants (18) expected the button to function for speed control: ten expected to set the current follow speed as the set speed and eight expected the vehicle to increase its current speed. Only one participant thought that the set speed would increase while the current follow speed remained unchanged. Three participants expected the system to decrease the distance to the vehicle ahead, a similar function to that of the distance control button. Thirteen participants did not expect the vehicle to do anything. Finally, one participant expected a warning light to be displayed.

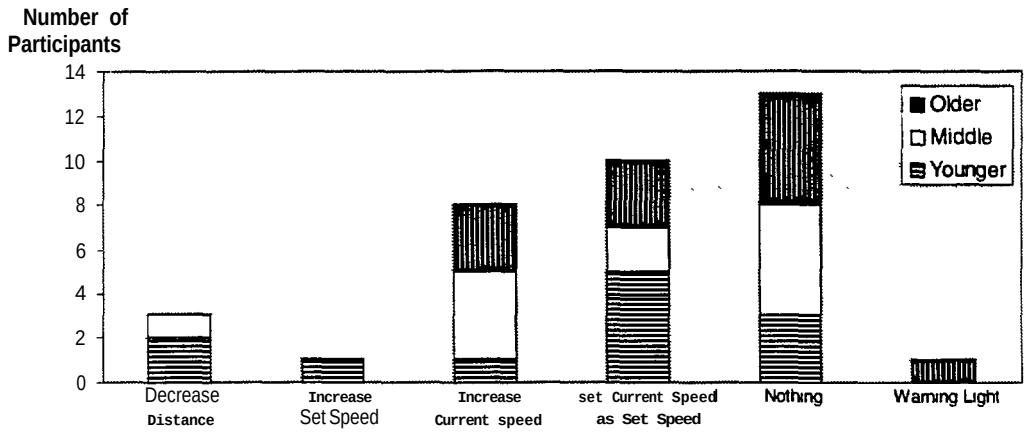


Figure 13. What should the car do when you press the control labeled SET/ACC? (12 participants per age group)

What should the car do if you press the COAST button now?

Given the same situation as posed above, participants were asked what their vehicle should do if they press the COAST button on the steering wheel while they are following a vehicle and there is a separate control to vary distance. Almost two-thirds of the participants (23) thought that the control should retain its speed control function of decreasing vehicle speed. (See Figure 14.) Five participants thought that they should get farther away from the car ahead (four said "increase distance,' one said 'back off'), a function similar to that of the distance control button. Five participants thought their vehicle should do nothing, one thought the system should go into a standby mode, and two were unsure.

If that car changed lanes. what would vou expect the svstem to do?

The following scenario was posed to the participants and they were asked what they expected their system to do: "Suppose that the car ahead of you changes lanes or exits the highway, what does your car do?"

A majority of the participants (30) expected the vehicle to resume to its set speed while the rest expected that the current speed at which the vehicle is following will become the set speed. Of those who expected the system to remain at its follow speed, some said that they did not expect the vehicle to increase its speed without input from the dnver.

It should be noted that this was the last question that was posed to participants. Prior to this question, participants were presented with the following description: ". ..your set speed was higher but your vehicle slowed down because the car ahead is going slower" (see the next section). This may have biased the responses to this question by inferring that the set speed is higher and is not the speed the system is currently maintaining.

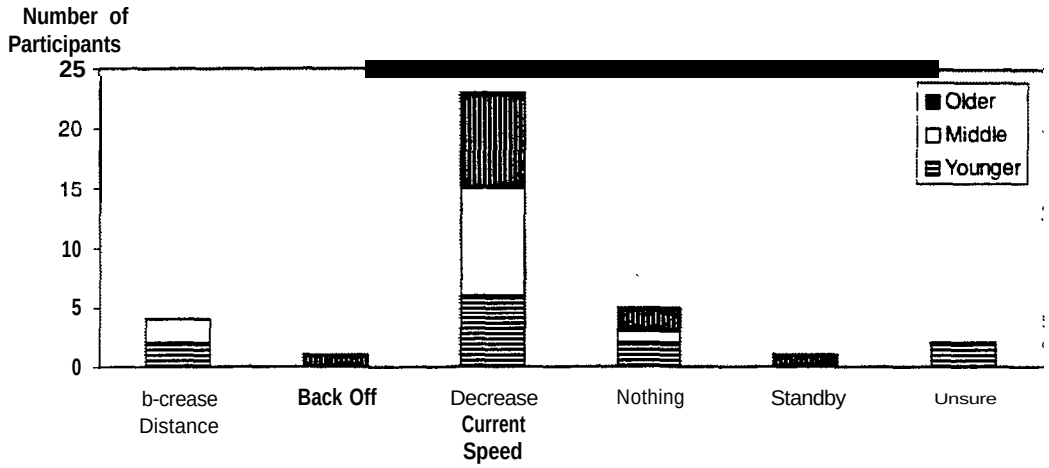


Figure 14. What should the car do when you press the control labeled COAST?
(12 participants per age group)

Display Issues

Do you want the set Speed displayed?

Participants were asked if they want a display or indication of their set speed after hearing the following description of system operation, "You originally set your speed at —— mph but your car slowed down because the car ahead of you is going slower. Your set speed is still —— mph."

Figure 15 shows that almost two-thirds of the participants (23) wanted some indication of their set speed when they are following a slower vehicle. A majority of the women (14 of 18) and participants in the middle and older age groups (18 of 24) tended to want their set speed displayed.

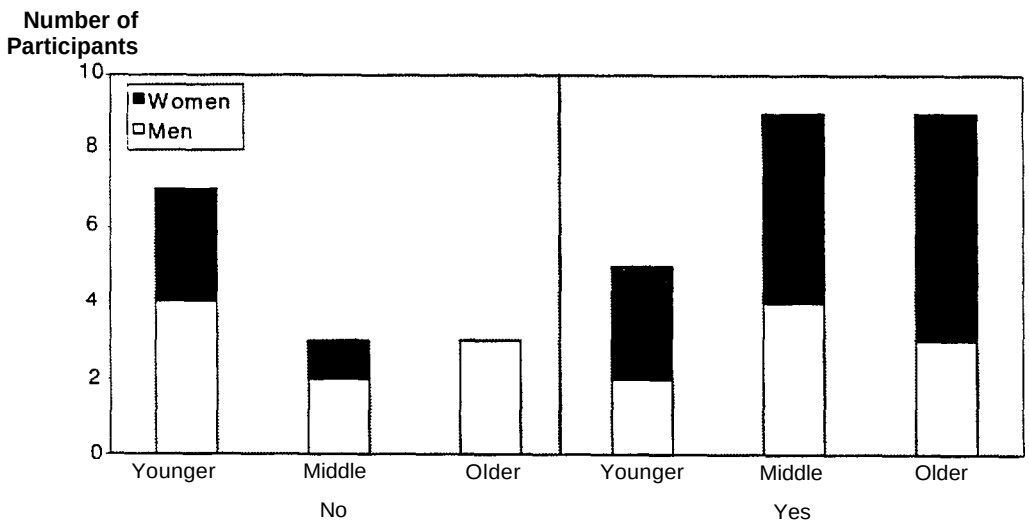


Figure 15. Would you like your set speed displayed or indicated?
(12 participants per age group)

Do you want the following distance displayed?

Participants were asked if they wanted some indication of their following distance (exact distance in meters or feet, distance setting with regards to operating range, etc.). The responses were split with regard to this; seventeen would like some type of display and sixteen said that it was not necessary. (See Figure 16.) Responses were also equally split between men and women and the middle and older age groups. Slightly more younger participants said they would like the following distance displayed (7) than not displayed (4). Two participants were unsure.

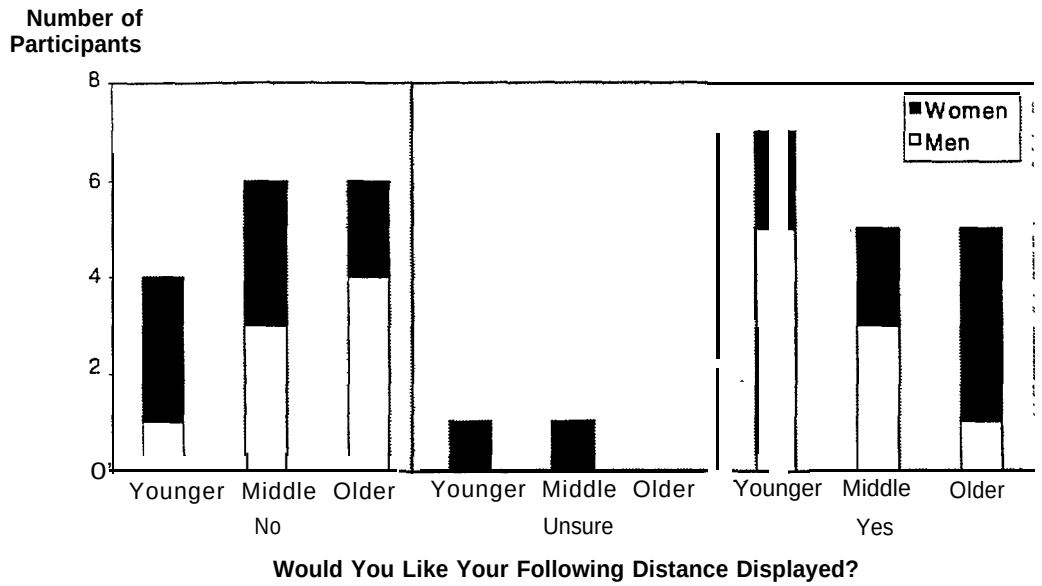


Figure 16. Would you like your following distance displayed?
(12 participants per age group)

SUMMARY AND RECOMMENDATIONS

Participant Descriptions and Use of Controls for Distance Control

Overall, participants could describe and understand the enhanced feature, namely, distance control. of the ACC system; when their vehicle operating under cruise control approached another vehicle, they recognized that they slowed down and maintained a certain distance behind that vehicle. Over one-half of the participants (20) thought that they could vary the distance between their vehicle and the vehicle ahead, but when asked to do so, only approximately one-quarter of the total participants (10) used the controls on the steering wheel. After participants realized that they could use the same buttons to vary their speed or distance to the vehicle ahead, a majority of them (75%) did not want a separate button to adjust their distance. Reasons stated were that it was not necessary and that they did not want more buttons than necessary on the instrument panel.

A majority of the participants (81%) also said that they preferred the continuous adjustment (fine Increments) of the distance control and would not want a control with only two or three distance settings. Participants said they wanted to be able to have control over the following distance and did not want to be forced into settings with which they may not feel comfortable.

Label Preferences for Shared Controls of Speed and Distance

If the same buttons are used to adjust speed and distance on an ACC system, as particrpants favored in this study, the labels ACC/DEC or ' +/-' are recommended. The labels ACC/DEC were ranked number one by the participants in this study followed by the ' +/-' labels. A majorii of the participants (44%) preferred the labels ACC/DEC for the buttons while the labels ' +/-' were preferred by 33% of the particrpants. Only 11% of the participants ranked the ACC/DEC labels as least preferred while the ' +/-' labels were least preferred by almost one-half of the participants (44%). The current labels, ACC/COAST, were preferred by only 22% of the participants.

Thus, it appears that for the shared functions of speed and distance control, the button labels ACC/DEC are preferred by drivers. The label ACC, however, in conjunction with SET (SET/ACC) could be Interpreted as the two word phrase, "set acceleration" or "set speed," rather than two individual words, "set" and "accelerate."

This misinterpretation may be lessened with the label SET/+ since '+' alone has the connotation of increase or add and the two-word phrase "set +" may not have an apparent meaning or have the same connotation as "set acceleration." Further, the ' +' and '-' symbols are more commonly used in foreign countries and may provide labels that are more meaningful to the international driving population.

Finally, cruise control systems with the enhanced feature of distance control may be called Adaptive Cruise Control (ACC) systems. The fact that the acronym, ACC, is the same as the abbreviation for accelerate, ACC, may lead to confusion, especially if drivers interpret the label SET/ACC to mean "set ACC system." Thus, if the control of speed and distance will be shared on buttons, additional investigations into appropriate labels, with the emphasis on international use (i.e., symbols), are recommended.

Label Preferences for a Separate Distance Control

If a separate distance control is provided to adjust the distance to the vehicle ahead, the labels NEAR/FAR are recommended. The symbols rank ordered from most preferred to least preferred were NEAR/FAR, arrows, MIN/MAX, One, Two, and Three. The word labels NEAR/FAR were preferred by 61% of the participants and least preferred by only 3%. While slightly more participants (19%) preferred the other word labels, MIN/MAX, over the arrows (11%) slightly more participants (8%) rated MIN/MAX as least preferred over the arrows (3%). In contrast, the buttons with the chevrons were preferred by 8% of the participants. In addition to preferring the button labeled NEAR/FAR, all of the participants who preferred this button used it as it was intended to be used.

Thus, it appears that for a separate distance control, the labels NEAR/FAR are preferred by drivers. These word labels, however, may be more familiar to the particrpants in this study, American drivers, than the labels with the symbols, especially the chevrons. While chevrons are not commonly used in the U.S., they are much more prevalent in other countries. Thus, drivers in other countries may prefer different labels for a separate distance control than those that were preferred in this study. It is recommended that studies be carried out in other countries to determine appropriate labels that can be used worldwide.

Driver Expectations of the System

When the system is controlling the following distance to a vehicle ahead and a separate distance control is provided, participants expected the buttons on the steering wheel (SET/ACC and COAST) to retain their speed control functions of setting/increasing the current speed of the system (50% of the participants) and decreasing the current speed (64%). When the slower vehicle ahead that the system is following changes lanes, participants (83%) expected their vehicle to resume to its higher set speed. However, it must be considered that this response may be biased based on a previous scenario in which the experimenter stated that although their vehicle slowed down, the set speed is still the higher speed at which they set the system.

Display Issues

Sixty-four percent of the participants would like some indication of their set speed when their vehicle is following another vehicle at a slower speed than at which the system was set. With regard to a display for following distance (exact distance in meters or feet, distance setting with regard to operating range, etc.). the responses were split; one-half of the participants wanted some indication of their following distance while one-half did not. Thus, if display space is limited on the instrument panel, a display for set speed should be given higher priority over a display for following distance.

CONCLUSIONS

In the design of ACC systems, driver preferences from using an ACC computer prototype suggest that the function of continuous distance adjustment be shared on buttons with speed control if drivers are given the opportunity to adjust their following distance to the vehicle ahead. While preferences for labels for these shared controls are SET/ACC and DEC, the possibility of misinterpretation of the SET/ACC label as well as ACC being the acronym for one popular name, adaptive cruise control, for this enhanced cruise control function suggest that additional investigations into shared control labels are necessary.

If a separate control for varying distance is provided, the labels NEAR/FAR are recommended. While word labels were favored by the participants in this study, American drivers, the chevrons that constituted the other labels that were tested may be preferred by drivers in other countries. Studies must be done to assure that drivers worldwide can understand the labels and operate the ACC system as intended.

Drivers want a display indicating their set speed but one indicating their following distance may not be necessary. While participants in this study expected to resume to their higher set speed when the vehicle ahead changed lanes, a bias may have been introduced by the experimenter. In terms of expectations of the system with a separate distance control, drivers expect the increase and decrease set speed functions to be operable when following a vehicle.

Finally, these recommendations are based on driver preferences using a computer prototype of an ACC system. Usability tests must be conducted on the road to confirm these recommendations.

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Bartleson, C.J. (1984). Measuring differences. In C.J. Bartleson and F. Grum (Eds), *Optical radiation measurements,* Volume 5, *Visual measurements* (pp. 441-489). New York: Academic Press.

Richardson, J., and Ashby, M. (1994). Driver *interface designs for an* ICC system (Technical report). HUSAT Consultancy Ltd. Leicestershire, England.

Ward, N.J., Humphreys, M.D., and Fairclough, S.H. (1995, April). The *emotional, cognitive and performance response of drivers to autonomous intelligent cruise* control *(A/CC)* (HUSAT Memo *867R).*

APPENDIX A

Subject Information Letter
Cruise Control Study

Dear Participant:

We would like to invite you to participate in a study of an advanced cruise control system. The purpose of the study is to obtain impressions of the driver interface as part of an evaluation of a new system. If you participate in this study, you will help us evaluate elements of the system design so that we can develop a system that is easy and enjoyable to use.

As a participant in this study, you will describe the function of each of the control buttons of the system. Subsequently, you will use a computer prototype of the system to engage the functions. If you have any questions during the study, the test observer can answer them for you.

This is a new system that is still under development and we are very interested in getting your input. We invite you to discuss the things you like and dislike about this system freely throughout the study.

Benefits: The results of this study will provide guidance for the development of cruise control systems that are easy and safe to use. By participating in this study, you will be lending your input to support research regarding the future development of cruise control systems.

Pavment: There will be no additional payment for your participation in this study. You will receive your regular hourly wage during the time you are involved with this study.

Confidentiality: We are gathering information on cruise control system use. **We** are not testing you. If you agree to participate in this study, your name will not be voluntarily released to anyone not working on this project. Your name will not appear in any reports or papers written about the project.

After the test observer has answered any questions that you may have, please let him/her know whether or not you are interested in participating in this study. If you are willing to participate, the test observer will ask you to read and sign a Subject lnformed Consent Form before you can participate in the study. Please note your participation in this study is voluntary. You may withdraw from this study at any time, and for any reason, without penalty or loss of benefits to which you are entitled.

Sincerely,

Steven J. Eckert
Program Manager, IVHS Controls
Advanced Electrical/Electronic Systems Engineering
Advanced Vehicle Technology

APPENDIX B

Subject Informed Consent Form
Cruise Control Study

I, _____, agree to participate in a study of the driver interface for an advanced cruise control system.

I understand that:

1) The purpose of this study is to obtain impressions of the driver interface as part of an evaluation of a new system.

2) As a participant, I will describe the function of each of the control buttons of the system. Subsequently, I will press appropriate button(s) based on functions the experimenter tells me to engage. I understand that the study will last about 30 minutes.

3) The results of this study will provide guidance for the development of future cruise control systems. By participating in this study, I am supporting research regarding the future development of such systems. I understand that I will not be informed as to the results of this study.

4) Ford is gathering information on controls for cruise control systems. Ford is not testing me. My name will not be voluntarily released to anyone not working on the project. My name will not appear in any reports or papers written about the project.

   The data gathered in this experiment will be treated with anonymity. Shortly after I have participated, my name will be separated from my data.

5) Ford employees will answer any questions that I may have about this study. The person in charge of this study is:

   Steven Eckert
   Program Manager, IVHS Controls
   Advanced Electrical/Electronic Systems Engineering
   Advanced Vehicle Technology
   tel: 32249, Profs: SECKERT

6) My participation in this study is voluntary and I understand that I may withdraw from this testing at any time, for any reason, without penalty or loss of benefits to which I am entitled.

   I certify that, to the best of my knowledge, I have no physical ailments or conditions which could either be further aggravated or adversely affected by participating in this study.

APPENDIX B Continued

I, _____, HAVE READ AND UNDERSTOOD THE TERMS OF THIS AGREEMENT. I VOLUNTARILY CONSENT TO PARTICIPATE IN THIS STUDY.

SIGNATURE _____

DATE _____

ADDRESS _____

_____

_____

TELEPHONE _____

APPENDIX C
DATA COLLECTION FORM

Cruise Control Study

Functions of Steering Wheel Controls

Ford is currently working on **new** features for cruise control and this is a prototype of the steering wheel controls. I'd like to know what you think each control button should do. Please answer based on your opinion of how this feature would operate, given that you just rented a car with this system.

Control	What does it do?	What does car do?
On		
Set/Accel		
Decel		
Resume		
Off		

Use of Steering Wheel Controls

Comments: _____

_____

_____

_____

_____

Lead Vehicle

Now, suppose there is a car ahead of you that is going slower than your vehicle. Watch what happens.

Particrpant's description of scenario: _____

_____

_____

How do you think this distance is maintained? _____

_____

Do you think you can vary this distance? _____

How? _____

Steering wheel controls ranking form

Would you want a separate button for varying the distance? _____

Headway controls ranking form

Now I'd like you to use the system with a vehicle in front of you. (Labels:)

How would you get closer to the vehicle? _____

_____

farther away? _____

_____

Would you want 2 or 3 settings for distance adjustment? _____

What would happen if you pressed the accel button now? _____

_____

coast button? _____

Do you want the set speed displayed? _____

Do you want the following distance displayed? _____

If that car changed lanes, what would you expect the system to do? _____

_____

Headway controls ranking form - For each button, place an X at the end that you would press to get farther away from the vehicle in front of you.

Both ranking forms - Other suggestions for labels

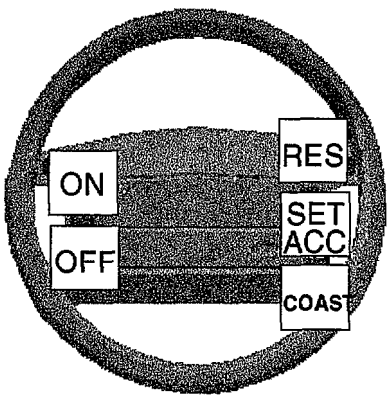
Background Form

APPENDIX D
RANKING FORM FOR SHARED CONTROLS

Subject N o.

Date _____

Please rank your preferences for adjustment button labels.
(1 = best, 3 = worst)



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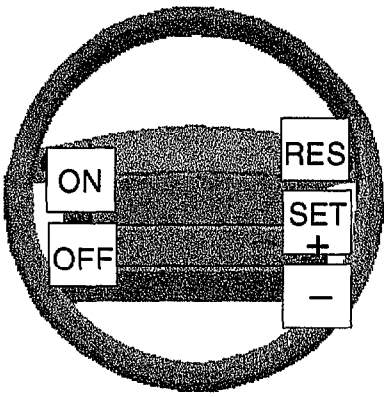

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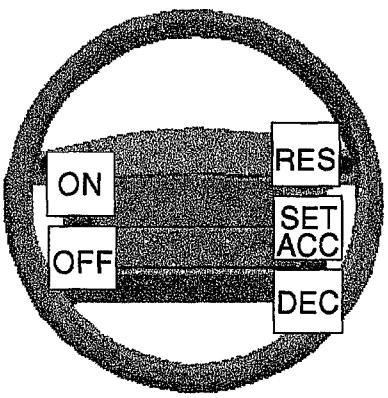

_____

Note: The original form that participants filled out was 100% larger than shown here and was laid out on the page in a landscape orientation.

APPENDIX E
RANKING FORM FOR SEPARATE CONTROL

Subject No _____

Date _____

Please rank your preferences for adjustment button labels.
(1 = best, 6 = worst)

 _____

 _____

 _____

 _____

 _____

_____

Note: The original form that participants filled out was 100% larger than shown here and was laid out on the page in a landscape orientation.

APPENDIX F

Subject No. _____

Date _____

Subject Background Form
Cruise Control Study

Name: _____ Profs: _____

Gender M F

Age Range 25-39 40-54 **55+**

Make and model year of vehicle(s) presently owned:

_____

Cruise control? N Y -> How often use it? _____

_____

Cruise control? N Y -> How often use it? _____

How often do you drive?

daily a few times a week a few times a month a few times a year

Have you ever heard of Intelligent Cruise Control (ICC) or Adaptive Cruise Control (ACC)?

N Y -> Where? _____

THANK YOU FOR YOUR PARTICIPATION AND INTEREST IN THIS STUDY!

Labels