Models of Driving: Simulator assessment of Adaptive Cruise Control conceptual understanding

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SAFETY RESEARCH USING SIMULATION

UNIVERSITY TRANSPORTATION CENTER

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A Report on Research Sponsored by
Safer-Sim: Safety Research Using Simulation
University Transportation Center

June 2018

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Abstract

Drivers have poor conceptual understanding of new adaptive driver safety systems (ADAS) such as adaptive cruise control (ACC). When using advanced safety systems, older drivers tend to be more open to learning through reading manuals, but also tend to struggle with learning the uses and limitations of a safety system. Different instructional formats can have different training effects for older learners. These can run counter to our intuitive expectation that older drivers will be more comfortable with, and therefore learn more from, traditional instructional formats such as books or manuals.

This study compared the efficacy of different forms of instruction (informational text, problem-based scenarios, interactive game scenarios) for older and younger drivers learning about ACC systems. The study used a repeated measures design to look at drivers' conceptual understanding of ACC before and after instruction and after simulator driving experience. We found that the participants performed the same on the test of conceptual understanding of ACC before they received any instruction; however, after receiving instruction and after using the driving simulator participants in the Text condition performed significantly better than those in the Interactive condition. We also saw differences in performance on one of the events in the driving simulator. In this event, drivers approach a truck pulling a low trailer and must brake (disengaging ACC) in order to avoid a collision. Younger drivers seem to show a greater benefit from the scenario-based instruction (braking earlier), while older drivers did not. Overall, drivers in the Text condition performed better than the other two instructional formats on this event.

1 Introduction

Drivers often have poor conceptual understandings of new adaptive driver safety systems (ADAS) (Jenness et al., 2008a; Jenness et al., 2008b) such as adaptive cruise control (ACC). In particular, drivers have difficulty understanding the limitations of driving safety systems, especially as novice users (Larsson, 2012). Although experience improves knowledge of the system, even older, more experienced users of ACC often develop poor understandings of limitations (Dickie & Boyd, 2009). In fact, a majority of ACC owners indicate that they are not aware of any manufacturer warnings or limitations of ACC, and many are confused about when their ACC system is actually operating (Jenness et al., 2008b). Drivers also develop trust levels that are inappropriate to the level of reliability of a system and their own understanding of system limitations (Kazi et al., 2007), with trust levels maintained regardless of system performance (Rudin-Brown, Parker, & Malisia, 2003; Beggiato & Krems, 2013). In fact, it appears that trust is often unrealistically high, especially among drivers with poor understanding of ACC limitations (Fancher et al., 1997; Dicke & Boyd, 2009). Further, although ACC systems may reduce workload and improve safety through reduced speed and increased time headway (the time between vehicles in transit), adaptation to the system results in more distracted driving (Stanton & Young, 2005) increased reaction time (Rudin-Brown, Parker, & Malisia, 2003; Rudin-Brown & Parker, 2004) and later, harder breaking in safety-critical situations (Xiong et al., 2012).

There is little instruction available to learn about these systems aside from car manuals, and few drivers read manuals to completion (Mehlenbacher et al., 2002). In fact, many drivers report that experimenting with ACC on the road is one of the only, if not the only, places they learn about the system (Jenness et al., 2008b). Drivers learning to use ACC systems are at risk to develop dangerous incorrect conceptual models of ACC system functions, and therefore overtrust system performance (Kazi et al., 2007; Itoh, 2012). This is particularly true if users are presented with only limited information about ACC's limitations (Beggiatio & Krems, 2013). With a large majority of ACC owners and a third of non-owners interested in having the system in any future vehicles (Jenness et al., 2008b), appropriate instruction becomes increasingly important for traffic safety.

Older drivers may be more likely to have vehicles with advanced safety systems given that these systems are more prevalent in higher-end vehicles, which tend to be driven by older drivers. When using advanced safety systems, older drivers tend to be more open to learning through reading manuals, but also tend to struggle with learning the uses and limitations of a safety system (Jenness et al., 2008a; Jenness et al., 2008b). Older drivers also use ACC more than their younger counterparts (Fancher et al., 1997) and, as typically low sensation-seekers, tend to use longer time headways and react more consistently to critical events (Rudin-Brown & Parker, 2004).

1.1 Instructional format

Different instructional formats can have different training effects for older learners. These can run counter to our intuitive expectation that older drivers will be more comfortable with, and therefore learn more from, traditional instructional formats such as books or manuals. Learning with video instructions supported better knowledge acquisition for older learners than did textual manuals (Gramss & Struve, 2009), and learning with an instructional video rather than a user manual (a text guide with pictures) improved performance for older learners, but did not influence the performance of younger users (Mykityshyn, Fisk, & Rogers, 2002). Comparing the effect of static training materials (printed instructions and still pictures), animation (showing movement), and narration (narrated messages and animation), older individuals profited more from multiple channels of presentations (animated visuals and narrated speech) than from static visual material in learning a complex task (Lin & Hsieh, 2006). Other suggestions for older learners include using audio-plus-video instruction when learning spatial information may be important (McLaughlin, Rogers, & Fis, 2002), and that interactive or hands-on involvement may be crucial in facilitating the learning of older individuals (Mayhorn et al., 2004; Choi, Carranza & Fox, 2013).

Another body of research suggests that game- and simulation-based interactive media can be powerful tools that help learners build domain-specific knowledge and skills, because they a) use rewards to motivate players to use knowledge to accomplish goals; b) help players visualize and understand new concepts by linking information visualizations to concrete choices and experience; and c) force players to use those concepts to solve increasingly-difficult problems or make increasingly-difficult decisions (Gee, 2007). Games and simulations "are computational models of real or hypothesized situations or natural phenomena that allows users to explore the implications of manipulating or modifying parameters within them" (National Academies, Honey & Hilton, 2011, p. 9), which can help learners explore, visualize and devise explanations for phenomena that are difficult to manipulate or observe (Linn & Eylon, 2011). Little research, however, has comparatively investigated age-based effects of these forms of media on older and younger users.

This project investigated the comparative efficacy of different forms of instruction (informational text, text-based scenarios, interactive game) for older and younger drivers learning about ACC systems. We compared the impact of different types of instruction on participants' mental models of ACC, as well as on their driving performance in a driving simulator. This study is 2 X 3 X 3 repeated measures design, with Age (younger/older) and Instruction (text, scenario, interactive) as between subjects variables, and Assessment (pretest, post-instruction test, post-simulation test) as a within-subjects variable. This design allowed us to identify any interactions between age and instructional type, examining both their understanding of ACC, as well as their performance in the driving simulator using ACC.

2 Method

2.1 Participants

Sixty drivers ages 18 to 25 years old and 55 to 70 years old were recruited to participate in the study. Drivers were recruited via mass emails on the university email system, ads in the University of Iowa Health Care *Noons News*, and printed posters in the Johnson County community (City of Iowa City Senior Center, Coralville Public Library, St. Patrick's Catholic Church, Our Redeemer Lutheran Church, Zion Lutheran Church, Newman Catholic Student Center, and Parkview Church). Potential participants were screened to see if they had driven a car using ACC, to ensure they were an experienced driver, and that they would be able to drive comfortably in the simulator. If they passed the pre-screening, participants were then assigned to one of three instructional formats: Text-based instruction, Scenario-based instruction, or an Interactive game-like instruction. Thus there were 6 groups of participants: Older Text, Older Scenario, Older Interactive, Younger Text, Younger Scenario, and Younger Interactive. Participants were paid $75.00 to complete the study.

2.2 Procedure

Upon arrival at NADS, a researcher discussed the consent documents and explained the potential side effects of using the driving simulator, such as eye strain or nausea. After consenting, participants filled out a pre-questionnaire on their understanding of how ACC would work in a variety of situations. Participants sometimes asked questions seeking information on ACC. The researcher told participants to answer to the best of their knowledge and reminded them that “I don’t know” is an acceptable answer.

Participants then received instruction on how ACC works based on the instructional format to which they were assigned. In the Text condition, participants received a one-page handout with text and diagrams that explained how ACC works. This condition was similar to reading about ACC in an owner’s manual. In the Scenario condition, participants were presented with a description of a driving scenario on a laptop. The scenario included text and diagrams and described a driving situation that could occur while using ACC. The scenarios were created to represent the limitations of ACC. For each scenario, the participant responded by typing answers to written questions that asked them to predict how the ACC would respond in that situation and explain why. The Interactive condition involved an interactive, game-like system on a laptop in which the user's car had ACC and the user could manipulate parameters, including the driver's desired speed, the road's speed limit, and how much the road curves. Participants were presented with situations in which two of the three parameters were set and asked to set the third parameter so that their car (that was using ACC) would not crash into the car in front of it. Participants were then asked to type their settings into an online questionnaire. Upon completion of their instruction, participants once again filled out the questionnaire on their understanding of how ACC would work in a variety of situations.

Participants then entered the driving simulator. The researcher discussed how to use the driving simulator, including how to set and adjust the ACC. Participants then completed a 10-minute practice drive. Upon completion of the practice drive, participants engaged in a 30-minute drive in the simulator with a variety of scenarios designed to test the participants' understanding of how ACC works. During the drive, a researcher answered basic questions about how to use the driving simulator, and reminded the participant to use ACC as much as they felt comfortable doing so. The researcher did not offer advice on how ACC works. If for any reason the driver crashed during the simulation, the researcher stopped the drive and reset the driver at the most recent checkpoint. After completing the drive, participants filled out a brief form asking how they were feeling and offered a mint or water to help with possible nausea. They then completed the questionnaire on their understanding of how ACC works a third time.

2.3 Instructional materials

There are three instructional formats used: Text, Scenario and Interactive. The Text condition is similar to reading a car manual, with text and still pictures and/or diagrams. The Scenario condition involves a series of text and diagram descriptions of situations that could occur when driving with ACC. The learner was asked to predict how the ACC would respond in a situation and explain why. The scenarios are designed to represent most of the limitations of ACC. The Interactive condition involve an interactive game-like system in which the user can manipulate parameters such as speed, terrain (e.g., curves and hills), and weather. The users predict and explain what will happen, and then observe the outcome. They were given contexts in which parameters have been set and asked to predict and explain how the ACC will respond. None of the instructional materials discussed the effect of irregularly-shaped vehicles or vehicle-towed cargo carrying devices.

2.4 Driving Simulator

The NADS ¼ cab miniSim was used to collection driving performance data. This miniSim has three 42-inch 720p plasma displays, **Error! Reference source not found.**. The miniSim includes three screens (each 3.0 feet wide by 1.7 feet tall) placed 4 feet away from the driver's eye point. This configuration produces a horizontal field of view of 132 degrees and a vertical field of view of 24 degrees. Visual icons could be displayed within the visual field, for example on the A-pillars or in the rearview mirror, in the configurable instrument panel, or as additional equipment on the dash or other appropriate location relative to the driver's eye point. The audio system default included speakers mounted below the left and right displays. The driving performance data relating to lane position, speed, steering, throttle pedal, and brake pedal are all recorded at 60 Hz.

2.5 Simulator Drives

There were three drives used in this study; a practice drive and two main study drives. Each participant experienced the practice drive and one main study drive. The practice drive was approximately 5 minutes in length, depending on the chosen speed of the driver. The drive was on a freeway in daytime, with clear and dry environmental conditions, and a posted speed limit of 55 mph. It was designed to allow participants to acclimate to the simulator and the ACC system, but did not include transitions between environments or merging onto or exiting the interstate. The main study drives included rural, interstate, and residential roadways with daytime, clear, and dry road conditions with posted speed limits of 55 mph, 65 mph, and 30 mph respectively. There were 14 events and an estimated drive time of 30 minutes with the ACC system engaged. Of the 14 events, 5 were designed to gather data in benign driving situations that would not prompt participants to disengage the ACC. The two main study drives differed in the order of some events while the order of the environments was the same for both.

2.6 Dependent measures

The dependent measure for the simulator drive events was adjusted minimum time to collision, which is defined as the lowest time headway in seconds from onset of the event between the driver's vehicle and a vehicle in front of the driver. The larger the number the less collision risk and a value of zero indicates a collision.

The dependent measure for conceptual understanding consisted of 34 Likert-type items adapted from Beggiato's (2014) instruments about mental models and trust in ACC systems. The items involved a 4-point Likert scale, "Totally agree," "Agree," "Disagree," "Totally disagree," as well as "Don't Know." The instrument asks participants about the function of ACC on roads with different physical characteristics, road conditions, kinds of traffic, and varieties of lighting. For example, one item is "ACC works on straight roads."

3 Results

3.1 Comparisons of conceptual understanding

A 2 x 3 x 3 mixed analysis of variance (ANOVA) was conducted with Age (Young and Old) and Format (Text, Scenario and Interactive) as between-subject variables and Time (Before Instruction, After Instruction, and After Simulator) as a within-subject variable. The three-way ANOVA showed the three-way interaction was not significant, F (4, 53) = 1.147, *p* = .339, nor was the two-way interaction between Time and Age, F (2, 53) = 3.055, *p* =. 051. However, the two-way interaction between Time and Format was significant, F (4, 53) = 71.506, *p* <. 01, displayed in Figure 3.1. Simple effect tests were then conducted to examine the effect of Format at each point of Time. There is no significant difference between drivers using the three formats before they received any instruction (Time 1), F(2, 56) = 1.356, *p* = .266. However, the difference was statistically significant after receiving instruction (Time 2), F(2, 56) = 3.983, *p* <.05, and after using the driving simulator (Time 3), F(2, 56) = 3.835, *p* <.05. The follow-up tests with Bonferroni correction revealed that after receiving instruction (Time 2), scores for drivers in the Text condition were significantly higher than drivers in the Interactive condition (*p* < .05), and this difference was still significant after using the driving simulator (Time 3) (*p* <.05).

3.2 Comparisons of driving performance

There was a significant difference between groups for one event during the simulator drive. During this event, the driver approaches a truck with narrow boom on a trailer traveling at 55 mph. The truck with trailer braked hard with sufficient force to slow to 20 mph in 5 seconds, requiring a response from the driver to avoid a collision as the ACC will not detect the trailer. The truck with trailer then accelerated to 70 mph. There is an interaction in minimum time to collision between Age and Format ($p = 0.0490$), displayed in Figure 3.2a, and an effect of instructional Format ($p = 0.0057$), displayed in Figure 3.2b. Keeping in mind that a larger time to collision is better, younger drivers and older drivers exhibited different performance in the scenario-based condition and similar performance in other conditions. Younger drivers seem to show a greater benefit from the scenario-based instruction (braking earlier), while older drivers did not. Overall, drivers in the Text condition performed better than the other two instructional formats on this event.

4 Discussion

The benefit from the text-based instruction that we see with both the truck-with-trailer driving simulator event, as well as in the Likert-type measurement, could be due to difficulties understanding the scenario and interactive problems without any prior knowledge of ACC. A future comparison of instructional format that might be informative would be to give all participants a brief text-based introduction to ACC, so all participants have a basic understanding of how ACC works, then differentiating instruction to learn about the limitations of ACC and variations in performance in different contexts. Thus, after a brief text-based introduction, the participants in the text-based condition would receive further information about ACC and its limitations via text, the scenario condition would learn about ACC through reasoning about situations that might arise when driving, and the interactive group would learn about ACC by changing parameters (i.e., road and car conditions) on a simulation. This might enable the participants to benefit more from the scenario and interactive types of instruction.

The significant difference of driver performance on the irregular vehicle event (by age in the scenario-based condition and by instructional format) is interesting because none of the instructional materials dealt explicitly with irregular vehicles or vehicle-towed cargo-carrying devices. Within the scenario format, it appears that younger drivers were able to benefit more from this format of instruction than the older drivers. It could be that the younger drivers were more familiar with this type of problem-based instruction or had experienced it more recently than the older drivers, thus being able to learn more during instruction and demonstrate it during the simulator drive. However, this does not explain why we see this effect only for the event involving the truck pulling a trailer, and not for other events that require disengaging the ACC in order to avoid a collision. It could also be that young drivers were better able to develop a model from the scenario materials, which featured problems that explored the vertical limitations of some ACC systems on hills.

5 References

Beggiato, M. & Krems, J.F. (2013). The evolution of mental model, trust, and acceptance of adaptive cruise control in relation to initial information. *Transportation Research Part F: Traffic Psychology and Behavior*, 18, 47-57.

Choi, W., Carranza, J., & Fox, M. (2013). Guidelines for older-adult-friendly online tutorial for Facebook: Content, design, and training principles. *Proceedings of the American Society for Information Science and Technology*, *50*(1), 1-4.

Dickie, D.A. & Boyle, L.N. (2009). Drivers' understanding of adaptive cruise control limitations. *Proceedings of the Human Factors and Ergonomics Society,* 53, 1806-1810.

Ericsson, K., & Simon, H. (1984). *Protocol Analysis: Verbal Reports as Data.* Cambridge, MA: MIT Press.

Fancher, P.S., et al. *Intelligent cruise control field operational test.* Report No. UMTRI-97-4. The University of Michigan Transportation Research Institute, Ann Arbor, MI., 1997

Gee, J. (2007). Learning and Games. In K. Salen (Ed.), *The Ecology of Games* (pp. 21–40). Cambridge: MIT Press.

Gramss, D., & Struve, D. (2009). Instructional videos for supporting older adults who use interactive systems. *Educational Gerontology*, *35*(2), 164-176.

Lin, D. Y., & Hsieh, C. T. (2006). The role of multimedia in training the elderly to acquire operational skills of a digital camera. *Gerontechnology*, *5*(2), 68-77.

Jenness, J. W., Lerner, N. D., Mazor, S., Osberg, J. S., & Tefft, B. C. (2007). *Use of Advanced In-vehicle Technology by Young and Older Early Adopters: Results on sensor-based backing systems and rear-view video cameras* (No. DOT HS 810 828). Springfield, VA: Department of Transportation: National Transportation Highway Administration.

Jourdenais, R., Ota, M., Stauffer, S., Boyson, B., & Doughty, C. (1995). Does textual enhancement promote noticing? A think-aloud protocol analysis. In R. Schmidt (Ed.), *Attention and awareness in foreign language learning* (pp. 183–216). Honolulu, HI: National Foreign Language Research Center.

Kazi, T. A., Stanton, N. A., Walker, G. H., & Young, M. S. (2007). Designer driving: Drivers' conceptual models and level of trust in adaptive cruise control. *International Journal of Vehicle Design*, *45*(3), 339–360.

Larsson, A. F. (2012). Driver usage and understanding of adaptive cruise control. *Applied Ergonomics*, *43*(3), 501–506.

Linn, M. C., & Eylon, B.-S. (2011). *Science learning and instruction: Taking advantage of technology to promote knowledge integration*. New York: Routledge.

Mayhorn, C. B., Stronge, A. J., McLaughlin, A. C., & Rogers, W. A. (2004). Older adults, computer training, and the systems approach: A formula for success. *Educational gerontology*, *30*(3), 185-203.

McLaughlin, A. C., Rogers, W. A., & Fisk, A. D. (2002, September). Effectiveness of audio and visual training presentation modes for glucometer calibration. In *Proceedings of the Human Factors and Ergonomics Society Annual Meeting* (Vol. 46, No. 25, pp. 2059-2063). SAGE Publications.

Mehlenbacher, B., Wogalter, M. S., & Laughery, K. R. (2002). On the reading of product owner's manuals: Perceptions and product complexity (Vol. 46, pp. 730–734). Presented at the *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, SAGE Publications.

Mykityshyn, A. L., Fisk, A. D., & Rogers, W. A. (2002). Learning to use a home medical device: mediating age-related differences with training. *Human Factors: The Journal of the Human Factors and Ergonomics Society*, *44*(3), 354-364.

National Academies Committee on Science Learning, National Research Council, Honey, M., A., & Hilton, M. (2011). *Learning Science Through Computer Games and Simulations.* Washington, D.C.: National Academies Press.

Norman, D. A. (1983). Some observations on mental models. In D. Gentner & A. Stevens (Eds.), *Mental models* (1st ed., pp. 7–14). Hillsdale, NJ: Lawrence Erlbaum.

Rudin-Brown, C.M., & Parker, H.A. (2004). Behavioral adaptation to adaptive cruise control (acc): implications for preventive strategies. *Transportation ResearchPart F: Traffic Psychology and Behavior*, 7(2), 59-76.

Rudin-Brown, C.M., Parker, H.A., & Malisia, A.R. (2003). Behavioral adaptation to adaptive cruise control. *Proceedings of the Human Factors and Ergonomics Society*m 47(16), 1850-1854.

Stanton, N. A., Walker, G. H., Young, M. S., Kazi, T., & Salmon, P. M. (2007). Changing drivers' minds: The evaluation of an advanced driver coaching system. *Ergonomics*, *50*(8), 1209–1234.

Stanton, N.A. & Young, M.S. (2005). Driver behaviour with adaptive cruise control, *Ergonomics*, 48 (10), 1294-1313.

Xiong, H., et al. (2012). Use Patterns Among Early Adopters of Adaptive Cruise Control. *Human Factors: The Journal of the Human Factors and Ergonomics Society*, 54 (5), 722-733.

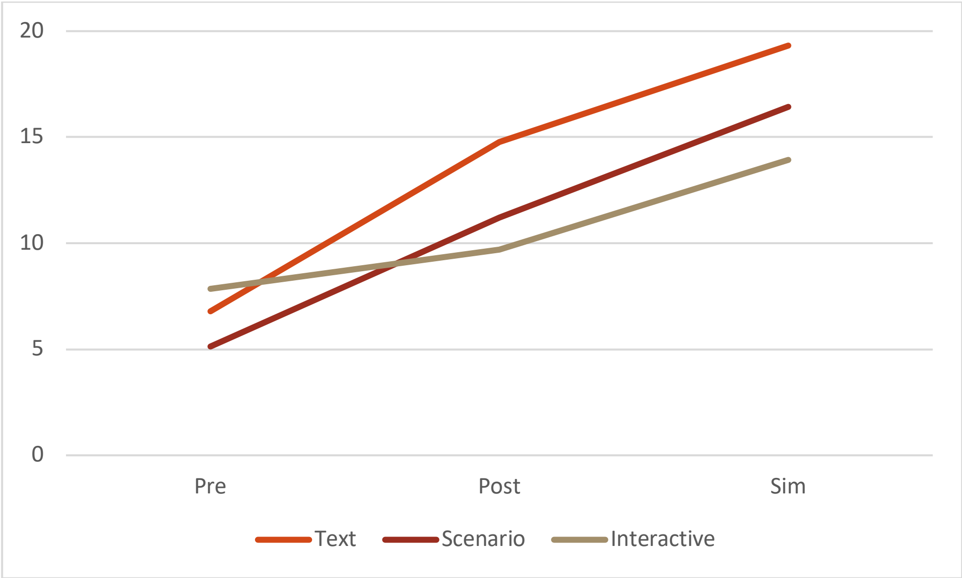


Figure 3.1. Mean scores on the conceptual understanding test for the Text, Scenario, and Interactive groups before instruction, after instruction, and after using the driving simulator.

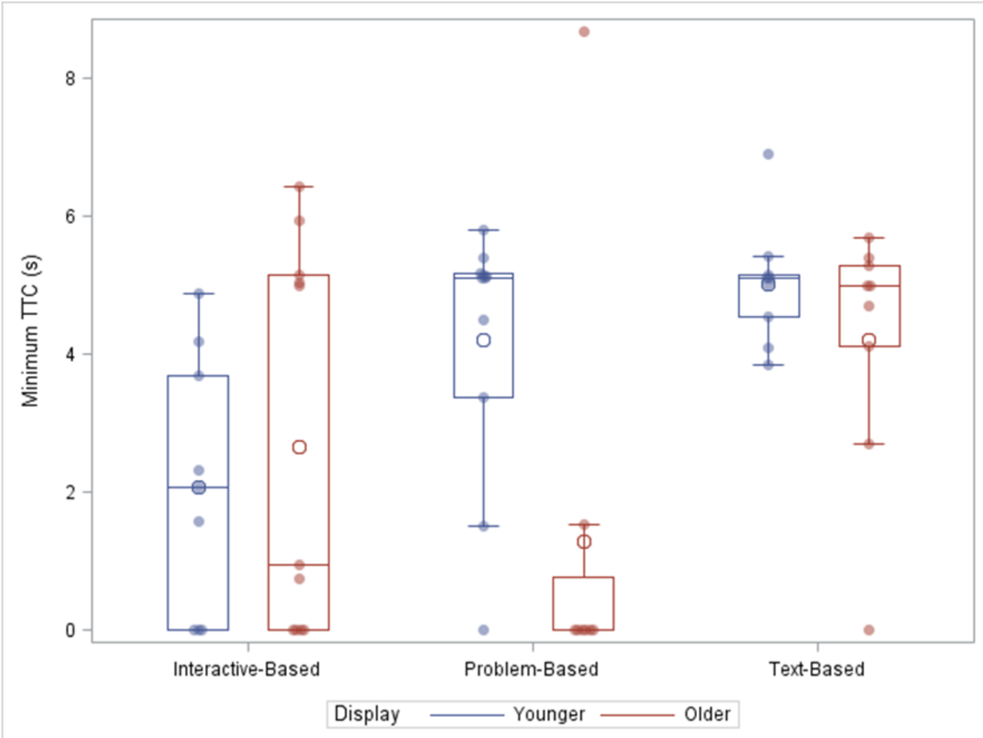


Figure 3.2a. Age and Format interaction for Minimum Time to Completion on the simulator event involving a truck towing a trailer.

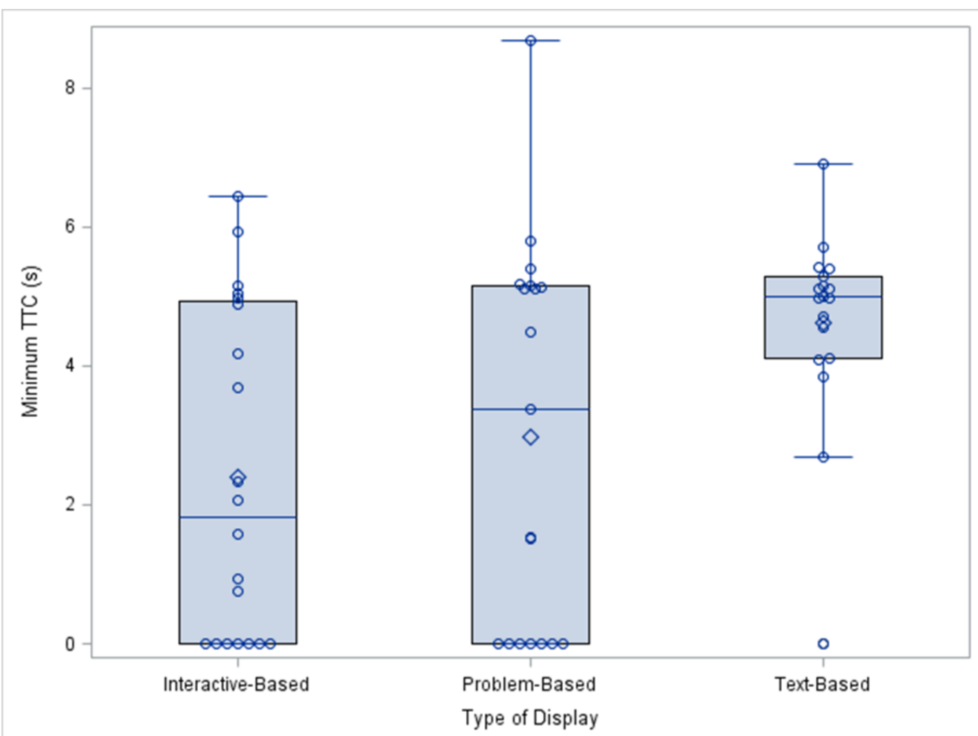


Figure 3.2b. The effect of instructional format on Minimum Time to Collision for the driving simulator event involving a truck towing a trailer.

Appendix A: Text-based instruction

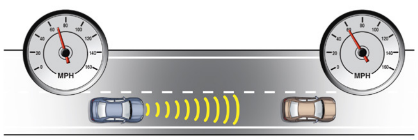
MyCarDoesWhat.org
Deeper Learning

ADAPTIVE CRUISE CONTROL

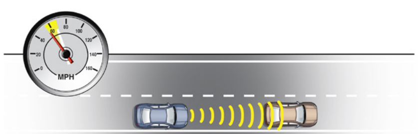
Understand

WHAT IS IT?

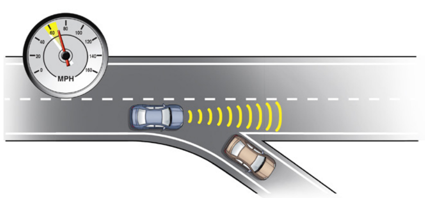
Conventional cruise control can maintain a steady speed that you set. Adaptive cruise control (ACC) is an enhancement of conventional cruise control. ACC automatically adjusts the speed of your car to match the speed of the car in front of you. If the car ahead slows down, ACC can automatically match it. Once the car ahead moves out of your lane or accelerates beyond your car's set speed, your ACC allows your car to return to the speed that you have set. Other than setting your speed, you only need to turn on the system and select your preferred following distance.



Car with ACC approaching a slower vehicle when travelling at a constant speed set by cruise control



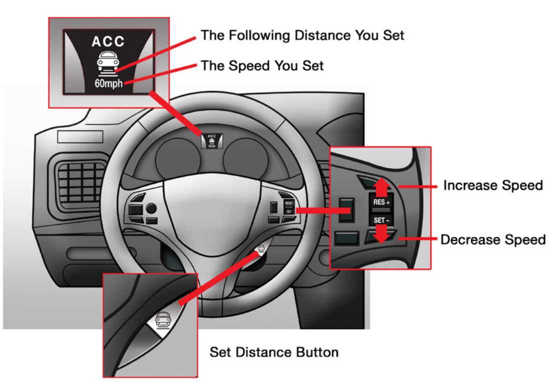
Car with ACC reduces speed to match speed of slower vehicle in front



With no vehicle in front, ACC accelerates back to the set speed

HOW TO USE IT?

The specific controls will be different depending on your particular car type, but usually you will have to start by setting a cruising speed and a following distance to the car ahead.



Activation/Deactivation

Most systems are operated by controls on the steering wheel. You can also intervene at any time by use of the brake or accelerator pedal.

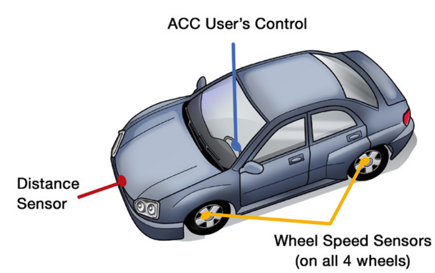
Setting the speed

You can set the speed using the +/- speed button. You can also accelerate as normal until the desired speed is reached. Then you press a button to have the ACC "remember" the speed. Most ACC systems will work down to about 25 MPH.

Setting the distance

ACC systems allow you to set a following distance, or time interval, between your car and the car ahead. ACC systems provide various car-to-car distance options, such as: short, medium, or long distance. You can change the setting at any time as traffic conditions change. A longer setting is recommended for most driving.

HOW DOES IT WORK?



Like standard cruise control systems, ACC keeps your car at the speed you set, as long as there is nothing in front of you. A sensor unit is added to determine the distance between your car and other cars in front you.

Speed and distance sensors.

ACC uses information from two sensors: a distance sensor that monitors the gap to the car ahead and a speed sensor that automatically accelerates and decelerates your car. ACC uses information from these sensors to adjust your speed and maintain the set distance from the car in front of you.

Looking under the hood: Radar-based systems.

Let's take a look at one ACC technology: radar-based ACC. Some ACC systems send radar waves that reflect off objects in front of your car. Based on the radar reflection, ACC uses distance, direction and relative speed to detect if the car is within the distance you set. ACC predicts the path of your car and then decides whether any of the vehicles ahead are within your set distance.

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Appendix B: Scenario-based instruction

Introduction

The next set of questions involve using images to solve scenario problems about adaptive cruise control (ACC).

Please enter your subject ID.

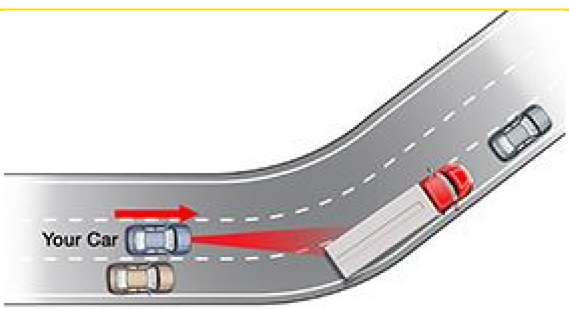
Subject ID

Challenge: Curving Roads

Challenge 1: Curving Roads

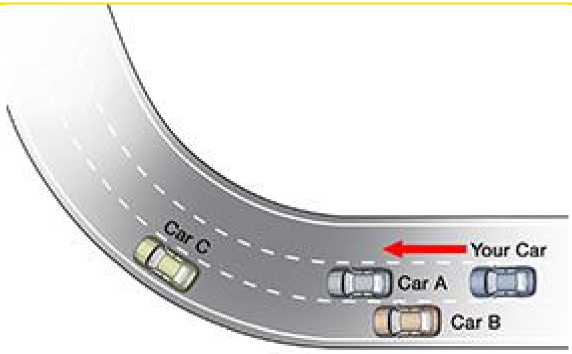
Your ACC system looks directly in front of you for other vehicles. Because it only looks forward, your ACC system may have trouble detecting traffic on curving roads.

In the image below, see how ACC's field of view works when the road curves. Its view may include traffic in another lane. It may also miss vehicles in your own lane. In situations like this, your ACC system may not react appropriately to the traffic around you. In the example, your ACC system may unexpectedly slow down if it detects the semi in the other lane.



Curving Roads: What Would You Do?

Look at scenario in the image below. Imagine yourself driving the blue vehicle. Think about the questions shown below.



As you approach the curve, how might your ACC system respond?

How should you respond?

Challenge: Hills

Challenge 2: Hills

Just as your ACC system may struggle with curving roads, it may also have trouble on hilly roads. ACC looks straight in front of the vehicle, and can't bend its view up or down hills (or around curves). The image shows how the system's field of view may not see everything when on a hilly road, and may respond incorrectly. In the example, your car's ACC system may not detect Car B, and could unexpectedly speed up.

Hills: What Would You Do?

Look at scenario in the image below. Imagine yourself driving the blue vehicle. Think about the questions shown below.

As you approach the top of the hill, how might your ACC system respond?

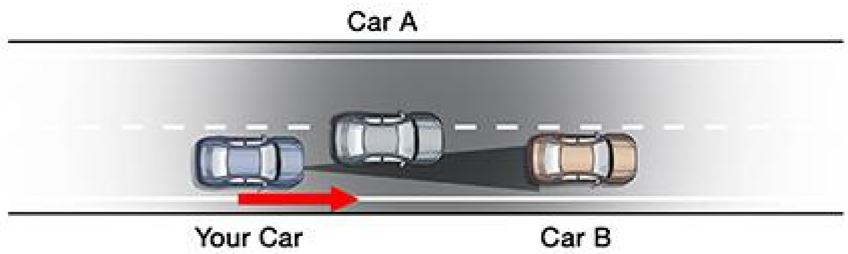
How should you respond?

Challenge: Merging Traffic

Challenge 3: Merging Traffic

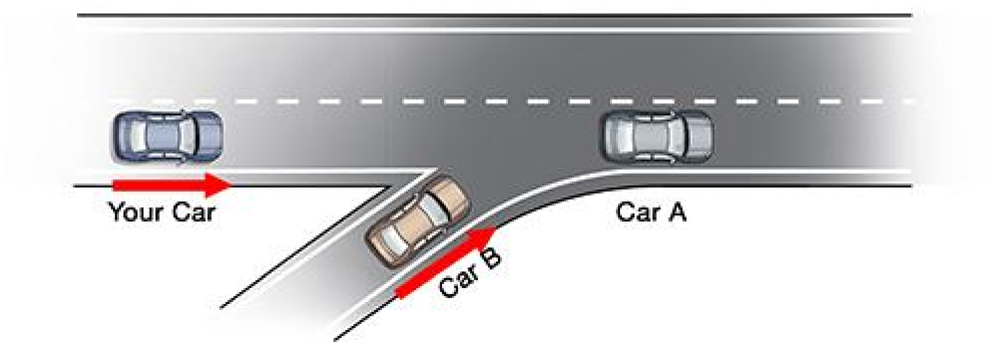
ACC systems detect other vehicles directly in front of you. Because of the system's field of view, ACC may not detect a vehicle that is in your lane but not directly ahead of your car. This can include vehicles that are merging into or out of your lane. In the example, Car A may be

outside of your ACC's field of view and yet still in front of you.



Merging Traffic: What Would You Do?

Look at the scenario in the image below. Imagine yourself driving the blue vehicle. Think about the questions shown below.



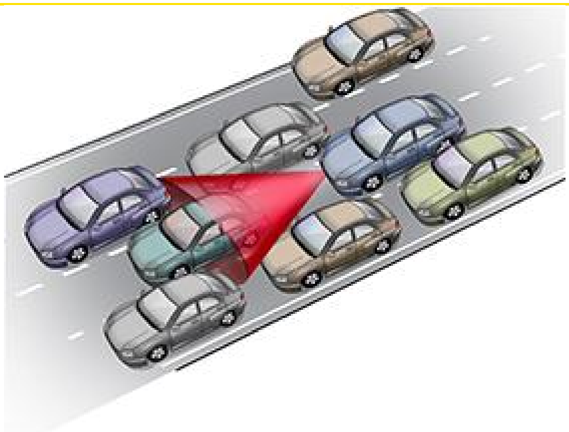
How might your ACC system respond?

How should you respond?

Challenge: Slow and Heavy Traffic

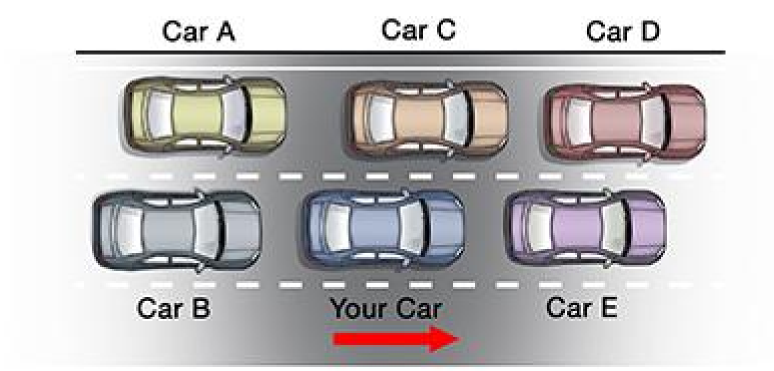
Challenge 4: Slow and Heavy Traffic

ACC systems can help regulate speed in traffic, but they may struggle in heavy, stop-and-go traffic. Your ACC system has to detect a vehicle and also judge its distance and speed. Quick lane changes and braking in heavy traffic situations may cause the system to struggle. In slow traffic, many systems will disengage below a certain speed.



Slow and Heavy Traffic: What Would You Do?

Look at the scenario in the image below. Imagine yourself driving the blue vehicle. Think about the questions shown below.



How might your ACC system respond?

How should you respond?

Appendix C: Interactive game-based instruction

Introduction

The following questions involve using the PIAyCC toy to solve problems about adaptive cruise control (ACC).

Please enter your subject ID.

Subject ID

Problem Situation 1 (Road Curve)

Introduction: **You are a road designer working with the Iowa Department of Transportation. You are working on an existing highway which has a speed limit of 55mph and contains a lot of tight curves. While most drivers stay near the speed limit of 55mph, some drivers go as high as 70mph on this road, leading to dangerous situations when systems like Adaptive Cruise Control (ACC) are used.**

Your task: **Redesign the road to fit the demands of traffic without changing the road's state-mandated speed limit. In redesigning the road, you are only able to make changes to the curviness of the road. What is the smallest change you can make to the road's curviness in order to eliminate dangerous situations (red ACC detection cone) involving cars exceeding the speed limit?**

PIAyCC settings: https://d1mb3o0baqfche.cloudfront.net/?cs=70&ts=55&rc=7&ss=10

What should the new road curve be for this highway?

	0	1	2	3	4	5	6	7
Road Curve								

Problem Situation 2 (Average Traffic Speed)

Introduction: **You and your team did so well with the highway that the DOT have assigned you to another problematic road. The speed limit here is 35mph, with some tight curves. Some drivers go as quickly as**

55mph with ACC active, and this creates similarly dangerous situations.

Your task: **Unfortunately, the state has no funds available to make any changes to the road. Instead, they have given you permission to adjust the road's speed limit. What is the smallest change you can make to the speed limit in order to eliminate dangerous situations (red ACC detection cone) involving cars exceeding the speed limit?**

PlAyCC settings: https://d1mb3o0baqfche.cloudfront.net/?cs=55&ts=35&rc=5&ss=10

What should the new average traffic speed be for this highway?

	15	20	25	30	35	40	45	50	55	60	65	70
Average Traffic Speed												

Problem Situation 3 (Road Curve and Traffic Speed)

Intro**: You have been brought in to consult on adjustments to one final highway. The road has a lot of tight bends and a speed limit of 45 mph. However, some drivers create dangerous situations by driving at up to 65mph with their ACC active.**

Task: **In creating a safer situation, you are able to adjust the speed limit as well as the curve of the road. Unfortunately, the state has limited funds to pay for the changes. Your team has $100 to spend on the changes. The tables below summarize the costs associated with the changes you can make.**
What cost-effective changes can you make that will make the road safe? Choose the new average traffic speed and/or the road curve.

New speed limit	Total cost
46-49 mph	15
50-54 mph	30
55-59 mph	60
60+ mph	105

Decrease road curve to	Total cost
6	30
5	70
4	120

PIAyCC settings: https://d1mb3o0baqfche.cloudfront.net/?cs=65&ts=45&rc=7&ss=10

What should the new road curve be for this highway?

	0	1	2	3	4	5	6	7
Road Curve								

What should the new average traffic speed be for this highway?

	15	20	25	30	35	40	45	50	55	60	65	70
Average Traffic Speed												

Appendix D: Mental Model of ACC function Likert

	Totally Agree (1)	Agree (2)	Disagree (3)	Totally Disagree (4)	Don't Know (5)
maintains predetermined speed (1)	❍	❍	❍	❍	❍
steers automatically (2)	❍	❍	❍	❍	❍
works on freeways (3)	❍	❍	❍	❍	❍
keeps a 15 foot distance during standstill traffic (4)	❍	❍	❍	❍	❍
reacts to potholes in same lane (5)	❍	❍	❍	❍	❍
works when approaching a stationary object (6)	❍	❍	❍	❍	❍
reacts to pedestrians (7)	❍	❍	❍	❍	❍
is overruled by pressing brake pedal (8)	❍	❍	❍	❍	❍
works on roads with low speed limits (9)	❍	❍	❍	❍	❍
reacts to trucks in same lane (10)	❍	❍	❍	❍	❍
works on roads with low speed limits (11)	❍	❍	❍	❍	❍
detects right of way regulations (19)	❍	❍	❍	❍	❍
works during daytime (20)	❍	❍	❍	❍	❍

reacts when vehicles approach from behind (21)	❍	❍	❍	❍	❍
reacts to buses in same lane (22)	❍	❍	❍	❍	❍