Evaluating Older Drivers' Reaction to Forward Collision Warning (FCW) and Automated Emergency Braking (AEB) Under Conditions of Distraction Using a Driving Simulation

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16. Abstract

This research aims to evaluate older drivers' responses to Forward Collision Warning (FCW) and Automatic Emergency Braking (AEB) systems under visual distraction, with the goal of enhancing road safety and supporting broader adoption of driver assistance technologies among aging populations. The primary objective is to assess how these systems affect the driving performance of individuals aged 65 and older when distracted, using a high-fidelity driving simulator. In addition, the study explores older drivers' perceptions, trust, and attitudes toward FCW and AEB technologies to identify barriers and opportunities for increased user acceptance. The project is divided into two phases. Phase 1, documented in this report, involved a literature review, development of experimental protocols, questionnaire design, Institutional Review Board (IRB) approval, and creation of simulator scenarios. The findings and materials developed in Phase 1 provide the foundation for Phase 2, which will involve participant recruitment, data collection, and behavioral analysis.

17. Key Words
Forward Collision warning (FCW), Older drivers, Advanced Driver Assistance Systems (ADAS), Automatic Emergency Breaking (AEB), Distraction, Driving Simulator

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About NEUTC

The New England Regional University Transportation Center (NEUTC) is a multidisciplinary consortium committed to addressing the pressing issue of traffic safety. Our objective, in line with the Infrastructure Investment and Jobs Act (IIJA), is to drive transformative research, education, and technology transfer to address critical traffic safety needs in a time when roadway fatalities are distressingly high.

Our research and educational activities at NEUTC are guided by four principal safety themes, each addressing a critical challenge in transportation safety. These themes capture the various integral components of the transportation system, focusing on technology, infrastructure, vehicles, and users with a commitment to safety and public engagement. Our overarching theme is promoting safety, with the common underlying science being the study of behavioral, systemic, roadway environment, and mobility-driven factors on safety.

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MOTIVATION

Motor vehicle crashes continue to represent one of the leading causes of injury and death in the United States, with substantial implications for public health, transportation policy, and roadway design. In 2022, the U.S. recorded 42,795 traffic-related fatalities, figures that reflect a troubling rise in roadway deaths over the past decade (NHTSA, 2023). A significant proportion of these fatalities are attributable not to infrastructure failures or vehicle malfunctions, but to human factors specifically, driver inattention, distraction, cognitive overload, and delayed hazard recognition. These behavioral contributors compromise situational awareness and reaction times, particularly in complex or dynamic driving environments.

To address these risks, vehicle manufacturers and transportation safety agencies have accelerated the development and deployment of Advanced Driver Assistance Systems (ADAS), including Forward Collision Warning (FCW), Automatic Emergency Braking (AEB), and real-time driver monitoring systems. These technologies aim to reduce crash occurrences by providing early alerts or automated interventions during safety-critical situations. However, most evaluations of these systems focus on aggregate crash data or technical performance, with limited emphasis on driver-specific factors such as cognitive workload, or age-related functional decline.

Older drivers, defined as individuals aged 65 and above, are a rapidly growing segment of the licensed driving population and a key demographic of concern. As of 2023, they make up over 18% of Connecticut's population (U.S. Census, 2023), with projections indicating continued growth in this age cohort nationwide. Research consistently shows that older adults experience age-related declines in attentional control, visual processing, and cognitive flexibility, all of which are essential for safe driving, especially when engaging in multitasking or responding to unexpected hazards. These impairments are exacerbated in high-demand situations, such as navigating intersections, merging, or responding to sudden braking events scenarios where systems like FCW and AEB are designed to assist.

Despite their potential to benefit most from ADAS technologies, older drivers remain underrepresented in simulation-based evaluations and are often hesitant to adopt new safety systems due to concerns about usability, complexity, and loss of control. Furthermore, many existing studies rely on retrospective crash data, which fail to capture real-time driver interaction with system alerts, particularly under conditions of cognitive load or distraction. This gap limits our understanding of how these systems function in practice and how driver behavior, perception, and response vary across age groups.

This project seeks to address that gap by investigating how older drivers interact with FCW and AEB systems in safety-critical scenarios using a high-fidelity driving simulator. By evaluating driver responses under both distracted and non-distracted conditions, the study will provide evidence on the behavioral effectiveness of these technologies and inform design and deployment strategies that account for age-related differences in cognition, trust, and user experience. Ultimately, this work aims to support the development of inclusive safety technologies that enhance mobility and reduce crash risk for older adults—aligning with national goals such as the U.S. DOT's Safe System Approach and the UN Sustainable Development Goal (SDG) 3.6, which targets a 50% reduction in road traffic deaths and injuries by 2030.

EXECUTIVE SUMMARY

Methods

This project established the foundation for investigating how older drivers interact with FCW and AEB systems, particularly under conditions of cognitive distraction. The goal was to prepare the study for full execution by conducting a literature review, designing data collection instruments, obtaining ethical approval, and creating experimental driving scenarios.

This phase was structured around four key preparatory tasks:

1. A comprehensive literature review to identify gaps related to older adults and ADAS technologies.
2. Development of pre- and post-experiment questionnaires using Qualtrics.
3. Submission and approval of an IRB protocol covering all research procedures.
4. Design and programming of interactive driving scenarios using a high-fidelity driving simulator.

Together, these activities prepared the research infrastructure for participant recruitment and experimental data collection in Phase 2.

PROJECT ACTIVITIES AND MILESTONES

Task 1: Literature Review

The literature review conducted provided a comprehensive foundation for understanding the intersection of aging, driving safety, and the potential role of ADAS particularly FCW and AEB in enhancing mobility and safety among older drivers. As the aging population grows, the number of licensed drivers aged 65 and older continues to rise, accompanied by increased crash severity and fatality rates per collision.

The review identified that physiological and cognitive declines include slower reaction times, diminished fine motor control, and sensory impairments (vision and hearing) substantially increase crash risks for older drivers, particularly in complex driving situations such as unprotected left turns, highway merging, and lane changes. These functional declines challenge older drivers' ability to process information quickly, respond to hazards, and execute coordinated vehicle maneuvers, making them ideal candidates for supportive technologies like FCW and AEB.

Studies reviewed show that FCW systems reduce front-to-rear crashes by up to 27%, while AEB can reduce injury crashes by as much as 45%. These technologies operate using radar and camera sensors to monitor time-to-collision (TTC) and intervene if a crash is imminent. However, adoption remains low among older adults due to a lack of awareness, distrust, complexity of interfaces, and limited training during vehicle purchase.

Barriers to adoption include perceived intrusiveness of systems, insufficient understanding of ADAS capabilities, and the stereotype that older adults are resistant to new technologies. Nonetheless, research also reveals that seniors are open to learning and appreciate features that enhance safety without undermining driver control. Preferences lean toward simple, intuitive designs with customizable alerts favoring visual and haptic feedback over loud auditory warnings.

The literature strongly supports the hypothesis that FCW and AEB technologies, if properly designed and implemented with user-centered strategies, can significantly improve the driving safety and confidence of older adults. Furthermore, the need for improved education, clearer dealer demonstrations, and inclusive design emerged as crucial recommendations to support technology uptake among senior drivers.

This review not only provided information for the experimental design creation and participant considerations for the study but also emphasized the urgent need for tailored interventions that ensure the mobility, independence, and safety of the aging driver population.

A review paper from this task was submitted and presented at the 2025 Transportation Research Board (TRB) annual meeting.

Task 2: Designing Experiment Questionnaire

For task 2, the research team developed and programmed pre- and post-experiment questionnaires using the UConn Qualtrics platform. These instruments are essential for collecting participant data and evaluating user interaction with FCW and AEB systems. The full versions of both questionnaires are provided in the Appendix.

The pre-experiment questionnaire captures demographic information, including age, gender, race/ethnicity, and years of driving experience. It also assesses participants' baseline knowledge and attitudes toward ADAS, with a specific focus on FCW and AEB technologies. This allows the research team to understand prior exposure, comfort level, and expectations before engaging in the driving simulation.

The post-experiment questionnaire is designed to gather reflections on participants' experiences during the simulator session. It evaluates user perceptions of FCW and AEB performance, trust in system alerts, ease of use, and any self-reported behavioral changes or anticipated impact on future driving. The instrument also includes open-ended questions to capture qualitative feedback on usability and stress levels experienced during the simulation.

Together, these questionnaires provide critical data on both the cognitive dimensions of older drivers' interaction with ADAS, informing later phases of analysis and design improvements.

Task 3: Drafting and submitting the IRB Protocol

To ensure ethical integrity and compliance with human subject research standards, the research team developed and submitted a detailed Institutional Review Board (IRB) protocol to the University of Connecticut IRB. This protocol outlined the full scope of study activities planned for the study.

The protocol addressed a wide range of components, beginning with a clear statement of purpose, objectives, and significance. It identified older adults (65+) with valid driver's licenses and in good health as the study population and outlined plans for recruiting a demographically balanced sample. Specific attention was paid to inclusionary criteria, the absence of exclusionary factors related to race or ethnicity, and the recruitment methods such as community outreach via listservs, social media, and flyers in public locations to ensure a wide variety of participants.

Informed consent procedures were thoroughly documented, including how participants would be briefed on the study purpose, data collection, and their rights to privacy and withdrawal. Importantly, the protocol highlighted that consent would also cover video and audio recording during simulation sessions, with secure data storage protocols in place. These included password-protected servers, restricted lab access, and non-networked simulation equipment, ensuring the integrity and confidentiality of participant data.

The IRB submission also included detailed descriptions of the experimental design. Risk assessments and mitigation strategies were thoroughly discussed. Although simulator sickness was acknowledged as a minimal risk, protocols were outlined for early termination of sessions and participant support. Compensation was also addressed; participants would receive $70 via a reloadable ClinCard upon study completion.

The protocol further outlined plans for storing de-identified Qualtrics survey data, synchronizing sensor and video data using specialized software (Data Distillery), and conducting statistical analysis using mixed-model ANOVA to evaluate driver responses. A robust data management and security plan ensured encryption at rest, restricted access, and no personally identifiable information linked to performance outcomes.

Finally, the IRB protocol included dissemination plans for sharing results via peer-reviewed publications, TRB meta-analysis submissions, and conference presentations. It is also committed to ongoing safety monitoring, deviation reporting, and documentation of any unanticipated problems in compliance with IRB policy.

The UConn team has received IRB approval to continue with phase 2 of this study and start data collection with human subjects.

Task 4: Creating Scenarios in Driving Simulator

As a core component of Phase 1, the research team created immersive and interactive driving scenarios using the SimCreatorDX® software, tailored specifically to evaluate older drivers' responses to FCW and AEB systems under distraction conditions. These scenarios were implemented within the Realtime Technologies RDS-2000 Full Cab Driving Simulator located at the Connecticut Transportation Institute, offering a high-fidelity, controlled environment for experimental testing.

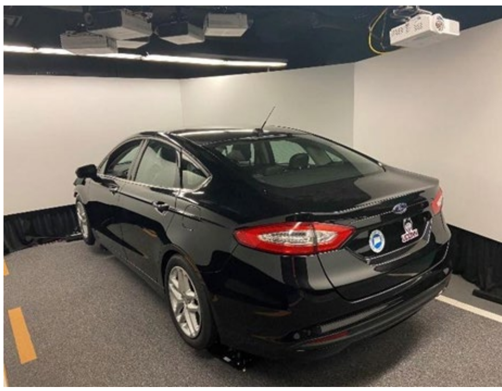
Each scenario was carefully programmed to simulate realistic urban driving conditions involving potential forward collisions. Critical variables such as pedestrian presence, vehicle interactions, roadway geometry, and traffic density were modeled to test drivers' reflexes and decision-making capabilities. Participants were exposed to randomized configurations: FCW only, AEB only and both systems combined, across both distracted and non-distracted groups.

The programming architecture allowed for:

- **Real-time vehicle dynamics monitoring**, including speed, lane positioning, and braking behavior.
- **Precise event timing** for FCW/AEB triggers based on time-to-collision calculations.

- **Full data integration** with video capture, and other behavioral monitoring systems.

This task laid the technical groundwork for reproducible and scientifically valid assessments of ADAS performance and user interaction. The scenarios will be central to collecting performance metrics and video data in Phase 2.




KEY OUTCOMES

- A comprehensive knowledge base to inform experiment design.
- A validated experiment questionnaire ready for deployment.
- IRB protocol approval received.
- Functional driving simulation scenarios ready for use by the participants.

NEXT STEPS (PHASE 2 PREVIEW)

- Recruit and onboard participants (65+ adult drivers).
- Conduct pilot testing of simulator scenarios and questionnaires.
- Begin data collection and monitoring using the approved IRB protocol.
- Analyze initial behavioral data for safety response metrics.

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APPENDIX

CTI Distracted Driving - Pre Drive

Q1. What is your current age?

- ○ 65-70 (1)
- ○ 71-75 (2)
- ○ 76-80 (3)
- ○ 81-85 (4)
- ○ 86+ (5)

Q2. What is your gender?

- ○ Male (1)
- ○ Female (2)
- ○ Non-binary / third gender (3)
- ○ Prefer not to say (4)

Q3. What is your race/ethnicity?

- ○ White (1)
- ○ Black or African American (2)
- ○ Hispanic (3)
- ○ Asian (4)
- ○ American Indian or Alaska Native (5)
- ○ Native Hawaiian or Pacific Islander (6)
- ○ Other (7)

Q4. How many years have you been driving?

- ○ Less than 5 years (1)
- ○ 5-10 years (2)
- ○ 10-20 years (3)
- ○ More than 20 years (4)

Q5. Please indicate your experience with the following driver assistance systems:

	I have used this technology (1)	I have not used this technology (2)
Forward Collision Warning (FCW) (1)	○	○
Automated Emergency Braking (AEB) (2)	○	○
Lane-Keeping Assist (LKA) (3)	○	○
Blind Spot Monitoring (BSM) (4)	○	○
Adaptive Cruise Control (ACC) (5)	○	○
Parking Assistance (6)	○	○
Other (7)	○	○

Display this question:

If Q5. Please indicate your experience with the following driver assistance systems: = Other [I have used this technology]

Q5.1. What other driver assistance systems do you have experience with?

____

____

____

____

____

Q6. How often do you use driver assistance technologies in your vehicle?

- ◯ Never (1)
- ◯ Sometimes (2)
- ◯ About half the time (3)
- ◯ Most of the time (4)
- ◯ Always (5)
- ◯ Not applicable (I do not have driver assistance technologies in my car) (6)

Q7. Do you believe that driver assistance technologies can help improve driving safety?

- ○ Strongly disagree (1)
- ○ Somewhat disagree (2)
- ○ Neither agree nor disagree (3)
- ○ Somewhat agree (4)
- ○ Strongly agree (5)

Q8. How confident are you that driver assistance technologies enhance your driving safety?

- ○ Not at all confident (1)
- ○ Not confident (2)
- ○ Slightly confident (3)
- ○ Moderately confident (4)
- ○ Extremely confident (5)

CTI Distracted Driving - PD

Q1. Which technology(ies) did you experience today?

◯ FCW (1)

◯ AEB (2)

◯ FCW and AEB (3)

---

1. Display this question:

2. If Q1. Which technology(ies) did you experience today? = FCW

Q2. How effective did you find the Forward Collision Warning (FCW) system in helping you avoid collisions during the drive?

◯ Not effective at all (1)

◯ Slightly effective (2)

◯ Moderately effective (3)

◯ Very effective (4)

◯ Extremely effective (5)

---

3. Display this question:

4. If Q1. Which technology(ies) did you experience today? = AEB

Q3. How effective did you find the Automated Emergency Braking (AEB) system in helping you avoid collisions during the drive?

◯ Not effective at all (1)

◯ Slightly effective (2)

◯ Moderately effective (3)

◯ Very effective (4)

◯ Extremely effective (5)

5. Display this question:

6. If Q1. Which technology(ies) did you experience today? = FCW and AEB

Q4. How effective did you find the Forward Collision Warning (FCW) and Automated Emergency Braking (AEB) system in helping you avoid collisions during the drive?

- ○ Not effective at all (1)
- ○ Slightly effective (2)
- ○ Moderately effective (3)
- ○ Very effective (4)
- ○ Extremely effective (5)

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7. Display this question:

8. If Q1. Which technology(ies) did you experience today? = FCW

9. Or Q1. Which technology(ies) did you experience today? = FCW and AEB

Q5. How effective did you find the audio alert in helping you avoid collisions during the drive?

- ○ Not effective at all (1)
- ○ Slightly effective (2)
- ○ Moderately effective (3)
- ○ Very effective (4)
- ○ Extremely effective (5)

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10. Display this question:

11. If Q1. Which technology(ies) did you experience today? = FCW

Q6. Do you feel that the Forward Collision Warning (FCW) system improved your reaction time to sudden hazards during the drive?

- Not effective at all (1)
- Slightly effective (2)
- Moderately effective (3)
- Very effective (4)
- Extremely effective (5)

---

12. Display this question:

13. If Q1. Which technology(ies) did you experience today? = AEB

Q7. Do you feel that the Automated Emergency Braking (AEB) system improved your reaction time to sudden hazards during the drive?

- Not effective at all (1)
- Slightly effective (2)
- Moderately effective (3)
- Very effective (4)
- Extremely effective (5)

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14. Display this question:

15. If Q1. Which technology(ies) did you experience today? = FCW and AEB

Q8. Do you feel that the Forward Collision Warning (FCW) and Automated Emergency Braking (AEB) system improved your reaction time to sudden hazards during the drive?

- Not effective at all (1)
- Slightly effective (2)
- Moderately effective (3)
- Very effective (4)
- Extremely effective (5)

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16. Display this question:

17. If Q1. Which technology(ies) did you experience today? = FCW

Q9. How comfortable do you feel with the Forward Collision Warning (FCW) system after the drive?

- Extremely uncomfortable (1)
- Somewhat uncomfortable (2)
- Neither comfortable nor uncomfortable (3)
- Somewhat comfortable (4)
- Extremely comfortable (5)

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18. Display this question:

19. If Q1. Which technology(ies) did you experience today? = AEB

Q10. How comfortable do you feel with the Automated Emergency Braking (AEB) system after the drive?

- Extremely uncomfortable (1)
- Somewhat uncomfortable (2)
- Neither comfortable nor uncomfortable (3)
- Somewhat comfortable (4)
- Extremely comfortable (5)

---

20. Display this question:

21. If Q1. Which technology(ies) did you experience today? = FCW and AEB

Q11. How comfortable do you feel with the Forward Collision Warning (FCW) and Automated Emergency Braking (AEB) system after the drive?

- Extremely uncomfortable (1)
- Somewhat uncomfortable (2)
- Neither comfortable nor uncomfortable (3)
- Somewhat comfortable (4)
- Extremely comfortable (5)

---

22. Display this question:

23. If Q1. Which technology(ies) did you experience today? = FCW

Q12. How reliable do you believe the Forward Collision Warning (FCW) system is after using it during the drive?

- Extremely unreliable (1)
- Somewhat unreliablle (2)
- Neither reliable nor unreliable (3)
- Somewhat reliable (4)
- Extremely reliable (5)

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24. Display this question:

25. If Q1. Which technology(ies) did you experience today? = AEB

Q13. How reliable do you believe the Automated Emergency Braking (AEB) system is after using it during the drive?

- Extremely unreliable (1)
- Somewhat unreliablle (2)
- Neither reliable nor unreliable (3)
- Somewhat reliable (4)
- Extremely reliable (5)

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26. Display this question:

27. If Q1. Which technology(ies) did you experience today? = FCW and AEB

Q14. How reliable do you believe the Forward Collision Warning (FCW) and Automated Emergency Braking (AEB) system is after using it during the drive?

- ◯ Extremely unreliable (1)
- ◯ Somewhat unreliablle (2)
- ◯ Neither reliable nor unreliable (3)
- ◯ Somewhat reliable (4)
- ◯ Extremely reliable (5)

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28. Display this question:

29. If Q1. Which technology(ies) did you experience today? = FCW

Q15. Based on your experience, how likely are you to use the Foward Collision Warning (FCW) system in your own vehicle?

- ◯ Extremely unlikely (1)
- ◯ Somewhat unlikely (2)
- ◯ Neither likely nor unlikely (3)
- ◯ Somewhat likely (4)
- ◯ Extremely likely (5)

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30. Display this question:

31. If Q1. Which technology(ies) did you experience today? = AEB

Q16. Based on your experience, how likely are you to use the Automated Emergency Braking (AEB) system in your own vehicle?

- ◯ Extremely unlikely (1)
- ◯ Somewhat unlikely (2)
- ◯ Neither likely nor unlikely (3)
- ◯ Somewhat likely (4)
- ◯ Extremely likely (5)

---

32. Display this question:

33. If Q1. Which technology(ies) did you experience today? = FCW and AEB

Q17. Based on your experience, how likely are you to use the Foward Collision Warning (FCW) and Automated Emergency Braking (AEB) system in your own vehicle?

- ◯ Extremely unlikely (1)
- ◯ Somewhat unlikely (2)
- ◯ Neither likely nor unlikely (3)
- ◯ Somewhat likely (4)
- ◯ Extremely likely (5)
