CENTER FOR CONNECTED AND AUTOMATED TRANSPORTATION

Project Start Date: April 1, 2022
Project End Date: March 31, 2023

July 2023

Promoting Inclusive Design and Deployment of Connected and Automated Vehicles for Older Adults Through Education of Engineering Students

SUPPLEMENTAL DOCUMENT TO FINAL REPORT UMTRI-2023-10: Research Team Presentations to Students and Poster Presentations by Research Team and Students

by

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[1] Behavioral Sciences Group, University of Michigan Transportation Research Institute
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UMTRI | The University of Akron | Illinois Center for Transportation | Purdue University | Washtenaw Community College | Central State University

1. Research Team Presentations to Students

University of Michigan Transportation Research Institute

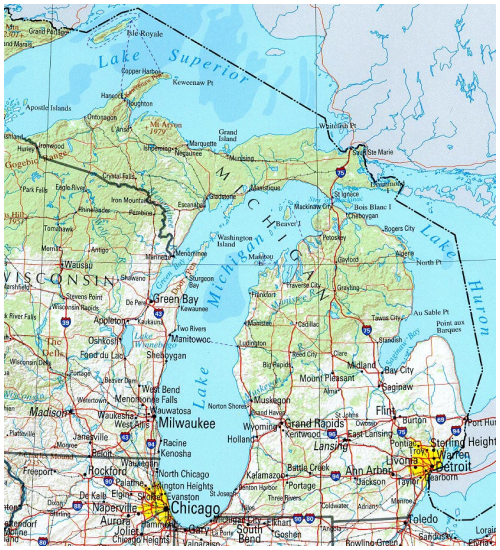
Lisa Molnar

September 7, 2022

Presentation Overview

- Personal and UMTRI Introduction
- Project Overview
  - Title
  - Team
  - Sponsor and Funding Period
  - Background
  - Objective
  - Tasks
- Questions/Discussion

Lisa J. Molnar: About Me



MICHIGAN STATE UNIVERSITY
Founded 1855

PUBLIC HEALTH

ANCORA IMPARO

MONASH University

- Current research interests: safe mobility across the lifespan, with special focus on aging drivers and other vulnerable populations; risky driving; Advanced Driving Assistance Systems & vehicle automation.
- Research methods used include surveys, naturalistic driving, research syntheses, program/guideline development, evaluation.

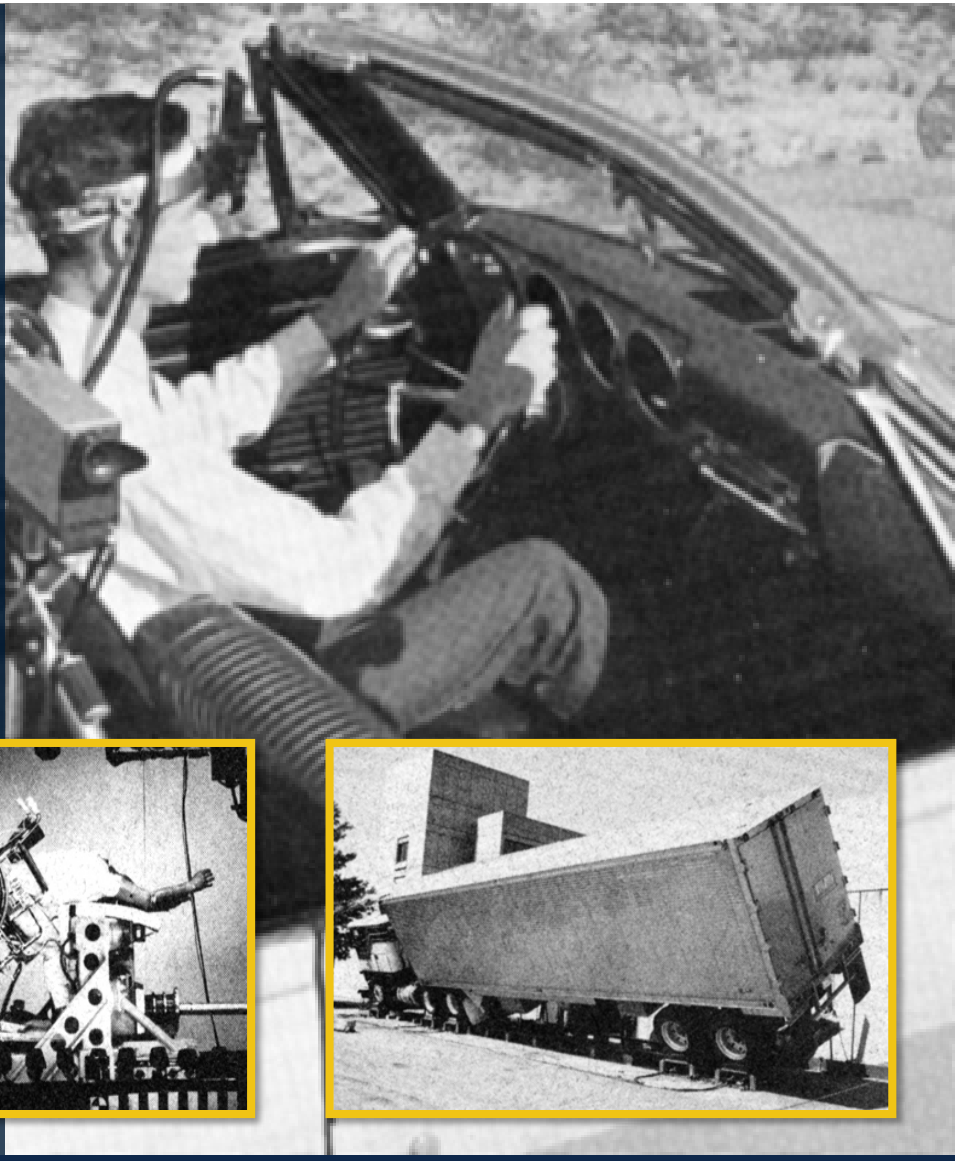
University of Michigan Transportation Research Institute

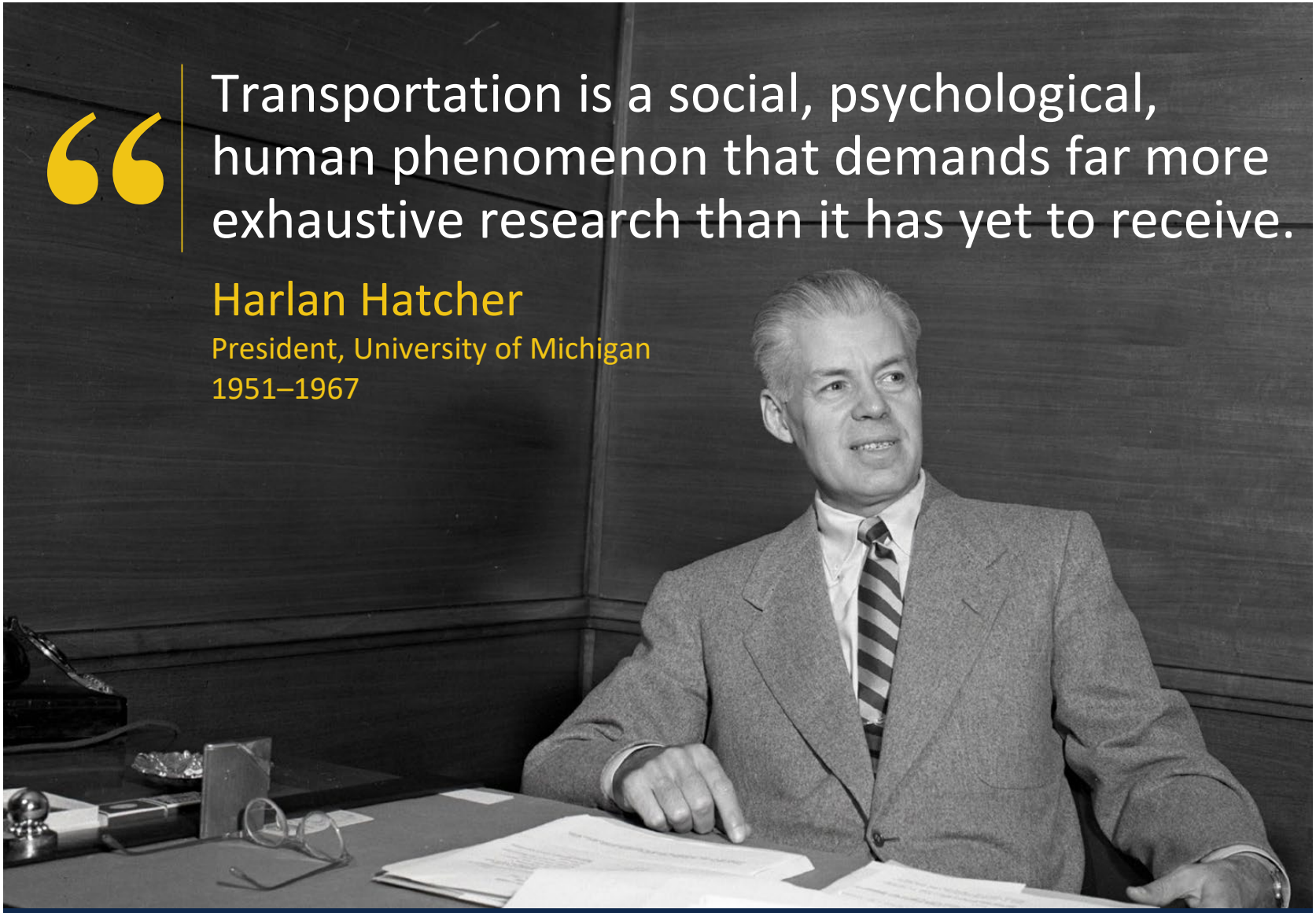
About UMTRI and the Behavioral Sciences Group

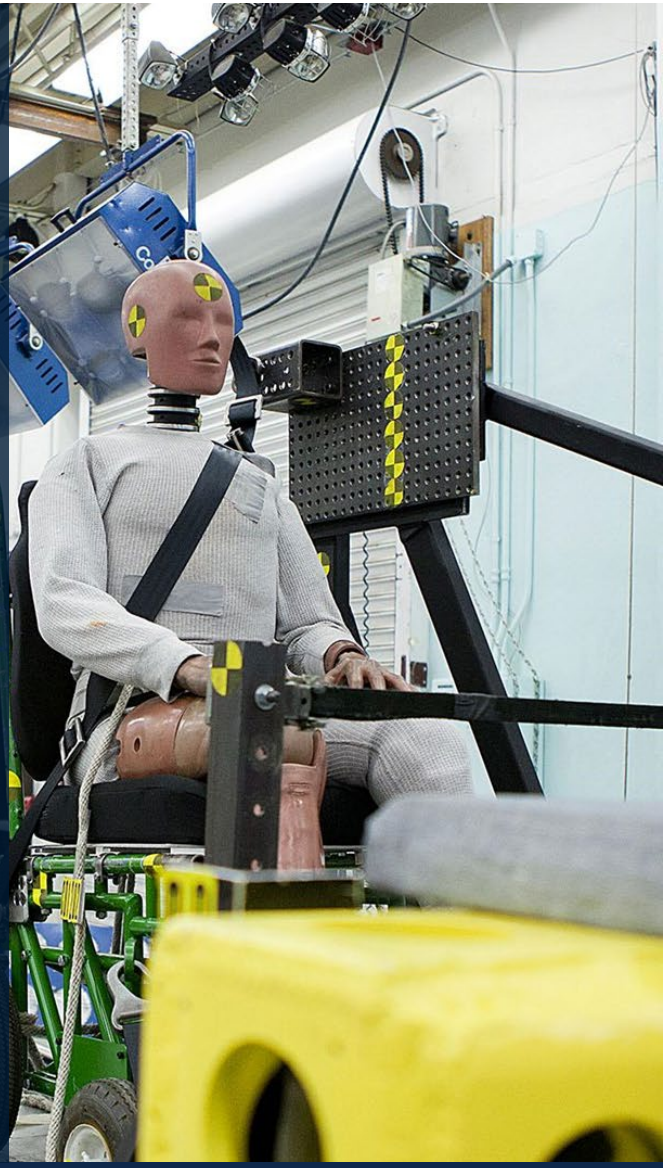
Founded in 1965

65k fatalities per year

$10M grant from Ford, GM, Automobile Manufacturing Assoc.

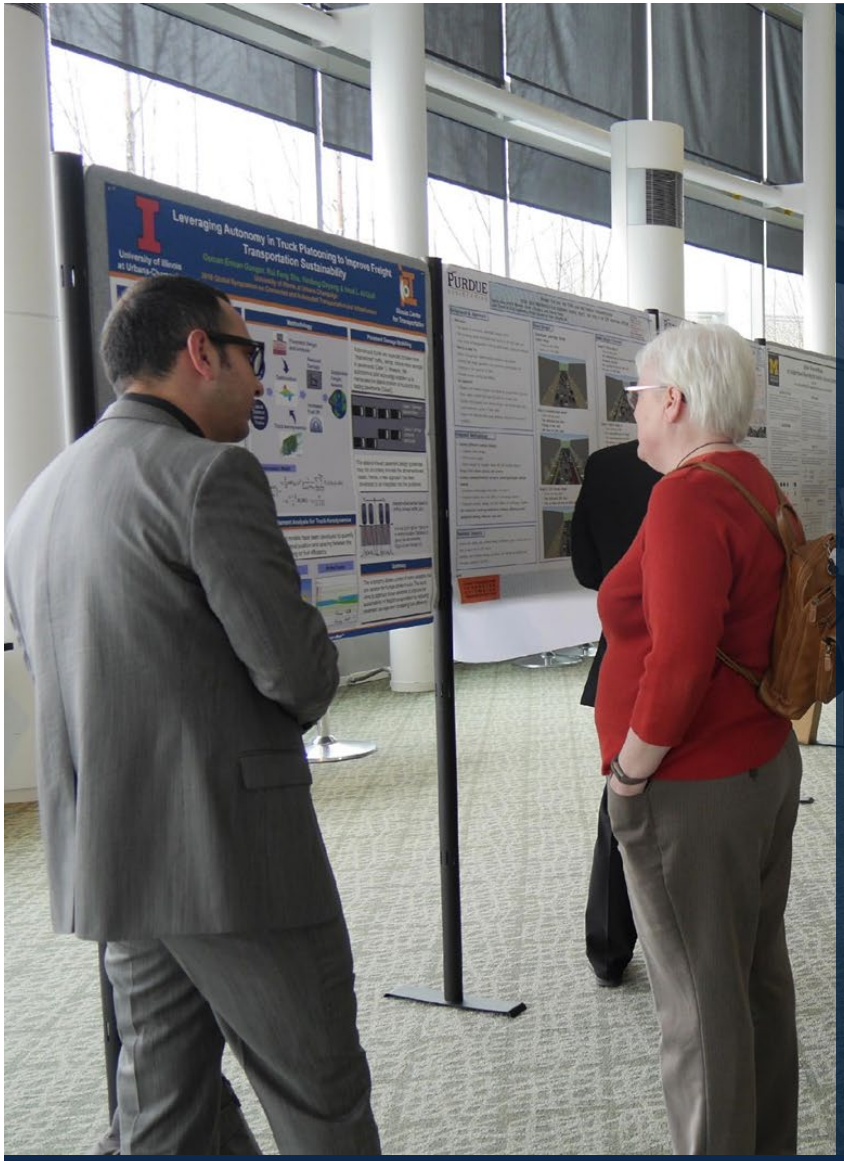



“
Transportation is a social, psychological, human phenomenon that demands far more exhaustive research than it has yet to receive.
Harlan Hatcher
President, University of Michigan
1951–1967



> The institute will coordinate the studies of highway transportation and undertake a broad systems approach to needed research in the field.

Harlan Hatcher



Globally recognized for our approach to research, the implementation of large-scale projects, and data

22 RESEARCH FACULTY

45 RESEARCH STAFF

$20M

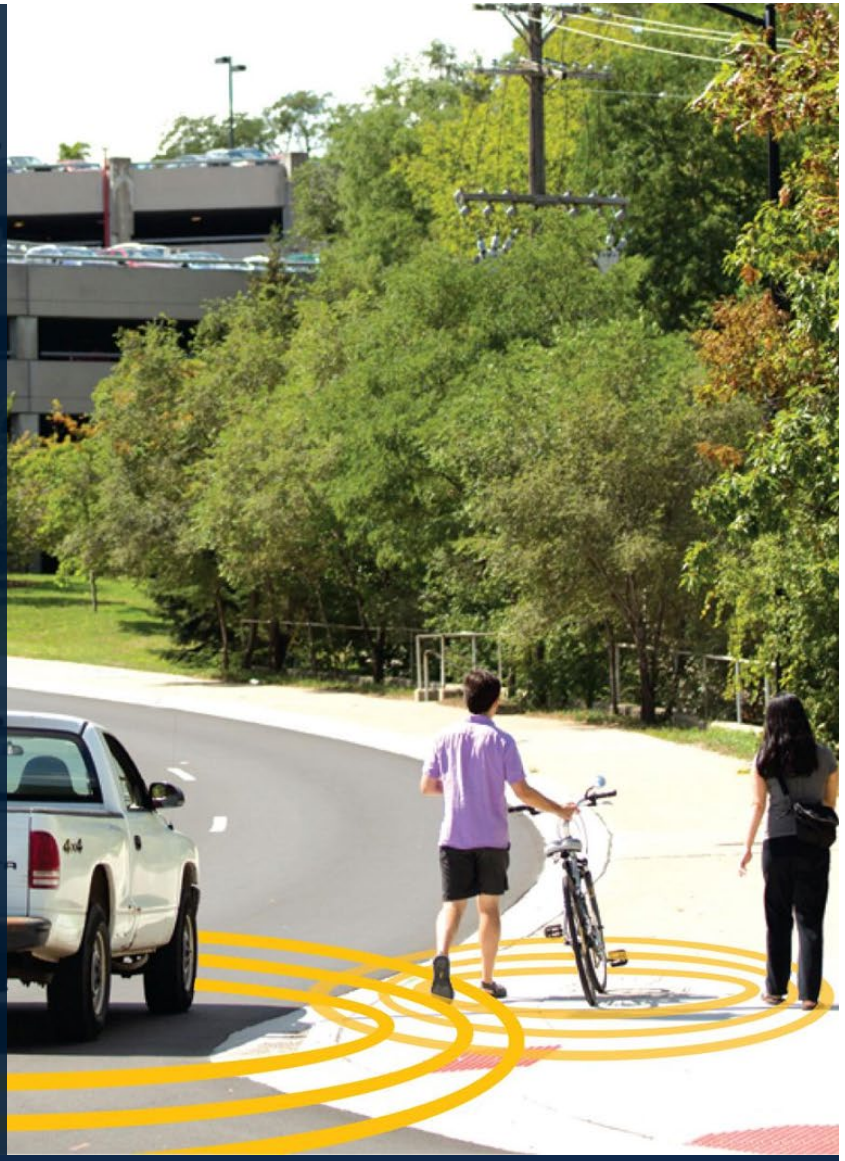
annual research expenditures:
6th largest on campus


“As we look to the future of mobility, we must think holistically about this complex problem. I am confident this change will help us do so to the great benefit of our faculty members, our students at both the undergraduate and graduate levels, and eventually society at large.”
Alec D. Gallimore, the Robert J. Vlasic Dean of Engineering, Richard F. and Eleanor A. Towner Professor, Arthur F. Thurnau Professor and professor of aerospace engineering.

Our Vision:

To be the foremost organization focusing on multidisciplinary transportation safety and mobility through our leadership, advanced research, education, resources, and partnerships.

Our Mission: ***To conduct and disseminate multidisciplinary transportation research to advance safe, equitable and efficient mobility.***



UMTRI

SAFE • EQUITABLE • EFFICIENT

UMTRI

SAFE • EQUITABLE • EFFICIENT

BEHAVIORAL SCIENCES

Enhance safe mobility for all ages by deepening our understanding of the social and behavioral issues important to mobility.

-Aging
-Use of vehicle technology
-Evaluation of policies, laws, and programs
-Impairment, risky driving
-Occupant protection

Project Title

Promoting Inclusive Design and Deployment of Connected and Automated Vehicles (CAVs) for Older Adults Through Education and Training of Engineering Students and Older Drivers

Project Team

- L.J. Molnar, UMTRI (PI)
- D.W. Eby, UMTRI (Co-I)
- P. Yi, University of Akron (Co-I)
- F. Zhou, U-M Dearborn (Co-I)
- H. Hada, Toyota North America (Industry Champion)

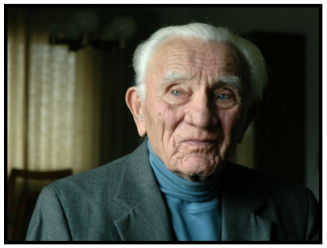
Sponsor and Funding Period

- Sponsor: Center for Connected and Automated Transportation

  - University Transportation Center funded by US Department of Transportation
  - Regional Center with multiple partners – UMTRI serves as lead
- Project period: 4/1/22 – 3/27/23

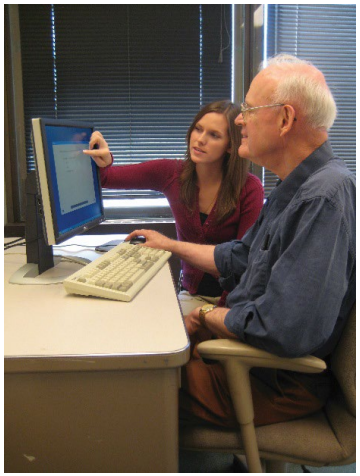
Project Background

- Development of CAVs holds promise for reducing crashes and enhancing mobility.
- However, challenges remain in ensuring that CAVs are accessible, acceptable, affordable, and otherwise inclusive for older adults.
- Challenges due in part to declines functional abilities, as well as mixed feeling about CAVs.
  - Lack of trust and acceptance.
  - Reluctance to give up control (lack of understanding of technologies).



Project Background

- There is an opportunity to:
  - Raise awareness of older adult challenges vis-à-vis CAVS among engineering professionals and students.
  - Improve CAV training for older adults.



Project Objective

- Increase students' awareness of and sensitivity to issues of older adult accessibility, acceptability, affordability, and other aspects of inclusion related to CAVs, using a framework of experiential learning.
  - Learning from experience or doing.
  - Exploring, engaging, reflecting, communicating.
  - Development/promotion of core competencies (e.g., creativity, teamwork, empathy, global and cultural awareness).
  - Building on and complementing class curriculum.

Main Project Tasks

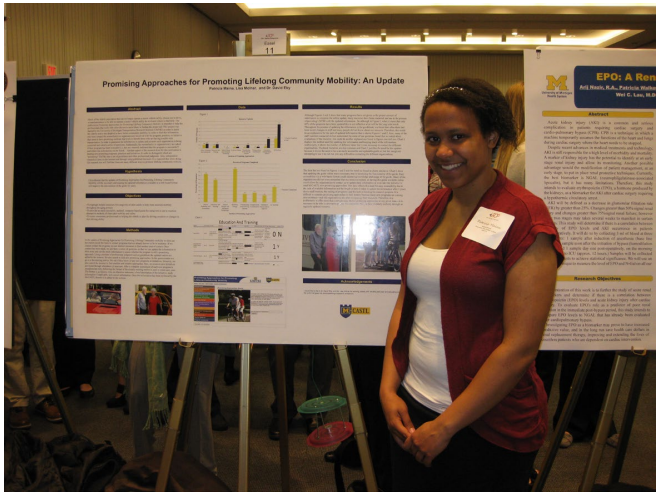
- Older adult needs assessment.
  - Literature review.
  - Community engagement - focus groups with older adults.
- Presentations/discussions with students.
  - Overview of project.
  - Results from needs assessment.
  - Industry perspective.
- Student reflection and communication through poster development/presentation.
- Final report and recommendations.

Classroom Presentations: Schedule and Format

- Dates:
  - September 7: Project overview.
  - October 12: Literature review findings.
  - November 9: Focus group findings.
  - November 30: Industry perspective.
- Format for data results presentations:
  - Research team presentations of findings.
  - Student discussions of corresponding or relevant classroom activities.
  - General discussion of convergence/divergence.

Poster Presentation

- Poster supplies/printing covered by study.
- Poster session held at UMTRI week of December 5 with reception/refreshments.
- Invitees: members of research team; CCAT members; University of Michigan faculty, staff, and students; industry representatives.
- Posters will be exhibited in Patricia F. Waller Gallery at UMTRI following session.



Questions?

Literature review: Methods and results

Renée M. St. Louis, PhD

October 12, 2022

Overview

- Introduction
- Recap of project and objective
- Literature review
  - Methods
  - Results
- Questions/Discussion

Renée M. St. Louis

- Assistant Research Scientist
- Behavioral Sciences Group
- BA, Psychology; MPH, PhD, Public Health
- rstloui@umich.edu

Research interests: psychosocial influences, behavior change models, older drivers, advanced driving systems, occupant protection, naturalistic driving behavior, decision-making

Promoting Inclusive Design and Deployment of Connected and Automated Vehicles (CAVs) for Older Adults Through Education and Training of Engineering Students and Older Drivers

Project background and objective

- CAVs hold promise for reducing crashes and enhancing mobility
- Need to ensure CAVs are accessible, acceptable, affordable, and otherwise inclusive for older adults
- Increase students' awareness of and sensitivity to these issues using a framework of experiential learning

Literature review

- Methods
- Population aging
- Declines in abilities
- Automated Driving Systems (ADSs)
- ADS design and deployment

Methods

- Purpose: gather background information from the literature to gain a better understanding of the issues surrounding older adults and CAVs
- Steps
  1. Develop selection criteria to guide the review
  2. Identify topics
  3. Develop search terms to capture topics
  4. Collect/store information in bibliographic management system
  5. Multiple-level review and synthesis of information

Methods

- Selection criteria
  - Type of document: journal articles, technical reports, industry documents, conference proceedings, book chapters, websites
  - Time period: 2010-present + seminal literature
  - Empirical evidence: no commentaries/opinion pieces
  - US or jurisdictions relevant to the US traffic context
  - Written in English
  - Meta-analyses and systematic reviews prioritized for inclusion

Methods

- Topics
  - Cognitive, psychomotor, and perceptual abilities that decline with age
  - Automated Driving Systems (ADSs) and vehicle technology issues
    - How older adults understand, learn about, and use such technologies
    - Attitudes related to trust and acceptance; barriers to use
  - Design of ADSs and ADS deployment demonstrations
    - Inclusion of older adults in ADS design
    - Challenges and successful strategies for deployment

- Search terms
  - Starting set of search terms, then iterative process
  - Permutations of each term (e.g., function* - function, functions, functioning, functional)
  - Search strings (e.g., AND, OR – driving AND aging)

Methods

- Databases searched: PubMed, PsychINFO, Transport Research International Documentation (TRID), ScienceDirect, Google Scholar
- Documents managed in Zotero
- Review and synthesize
  - All documents reviewed for inclusion by at least two members of the research team
  - Information synthesized and integrated

Population aging and older drivers

- Low fertility, increased life expectancy, and the aging of the post-WWII Baby Boomers (born 1946-1964)
- 10,000 Baby Boomers turn 65 years old each day in the US and will continue to do so until ~2030; will comprise 20% of population by 2050
- Mobility is often equated to driving
  - Urban sprawl
  - Dispersal of services
  - Aging in place
- Prefer to drive themselves

Declines in three areas of functioning

- Perception (seeing/hearing)
  - Declines make it difficult to: read street signs, interact with in-vehicle displays, see vulnerable road users, hear emergency vehicles
- Cognition (thinking/processing/deciding)
  - Complex and multifaceted process involving several aspects of mental functioning (e.g., attention, memory, reasoning)
  - Declines make it difficult to: drive in heavy traffic, negotiate intersections, attend to multiple tasks, respond quickly
- Psychomotor (moving)
  - Declines make it difficult to: check blind spots, change lanes, operate dashboard controls, get in/out of vehicle, buckle seatbelt

Prevalence of disability

	Age		
Disability	**All**	**65-74**	**75+**
Any Disability	12.7	24.2	47.1
Visual	2.3	4.1	8.8
Hearing	3.6	8.6	21.1
Ambulatory	6.8	14.8	30.9
Cognitive	5.2	5.1	12.7
Self-Care	2.6	4.2	12.3
Independent Living	5.7	7.4	23.0

Erickson et al., 2022

Declines in abilities

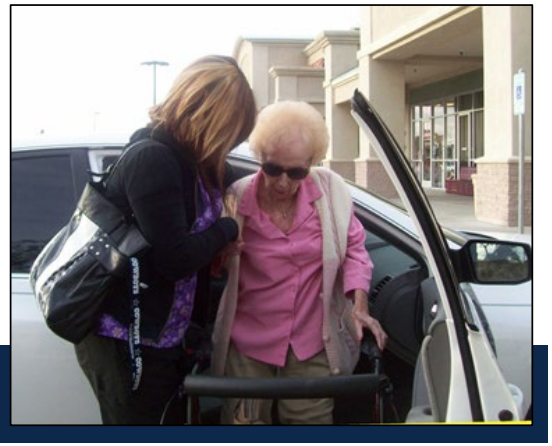
- Declines in abilities are due to:
  - The normal process of aging
  - Medical conditions that are more common in older adulthood
  - Effects of medications used to treat medical conditions

- Difficulties can be compounded when declines occur in multiple areas of functioning
  - 80% of older adults have comorbid medical conditions

- Significant variability within older adult population

Driving cessation and loss of mobility

- Negative psychosocial and health consequences
  - Loss of independence and lifestyle
  - Increased social isolation
  - Loss of self-esteem
  - Reduced access to healthcare and other essential services
  - Declines in physical health
  - Decreased quality of life
  - Increased depressive symptoms
  - Increased placement in long-term care facility
  - Increased stress on family caregivers



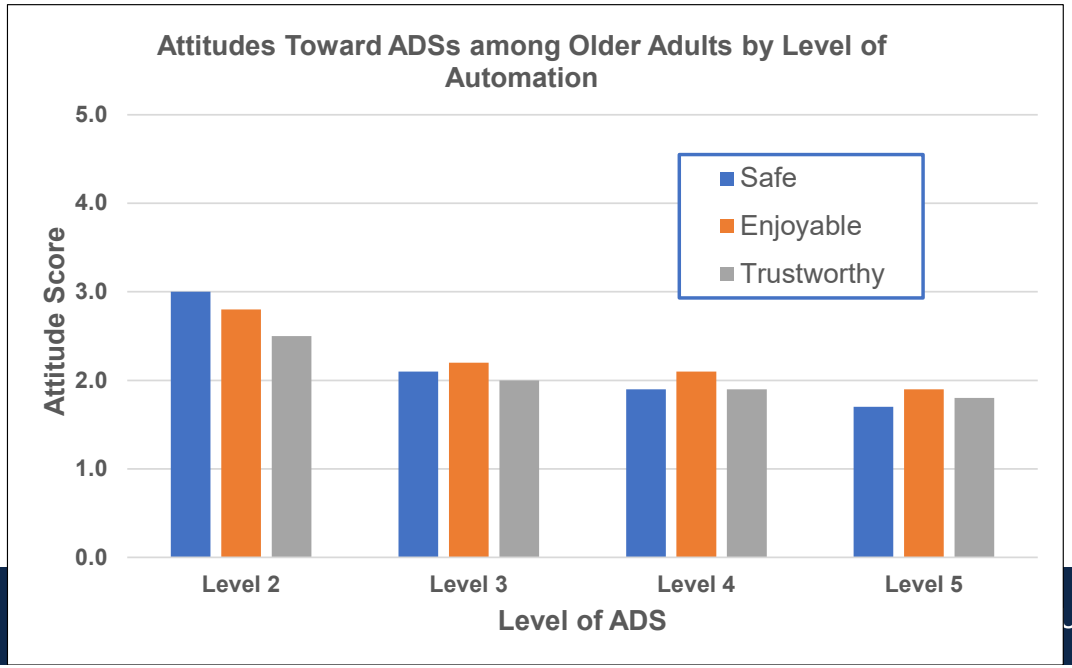
Advanced Driving Systems

Potential benefits of Advanced Driving Systems

- Safety
  - Assist/take over vehicle operations, reducing potential driver error
- Mobility and equity
  - Improve transportation options for underserved communities and people who can no longer drive
- Economic and societal
  - Reduce costs associate with crashes and vehicle ownership (if shared system); increase access to employment
- Efficiency and convenience
  - Optimal routes, avoid congestion
- Environmental
  - Decreasing air pollution, increasing use of shared vehicles thereby reducing fuel consumption and the need for parking spaces/associated land space

Perceptions of ADS technologies

- Older adults recognize the potential value of fully-automated vehicles for maintaining safe mobility as driving abilities decline
- Investigating attitudes is challenging
- As level of automation increases, positive attitudes decrease



Lajunen & Sullman, 2021

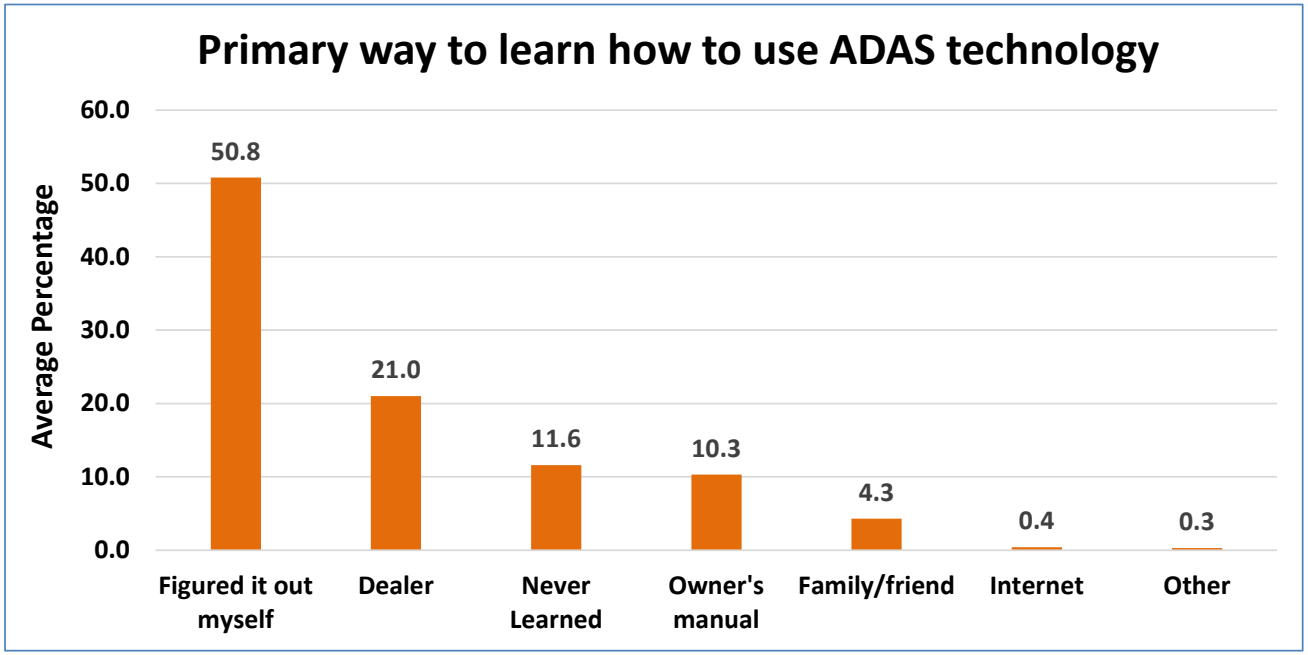
Concerns and factors that influence attitudes

- Key concerns
  - Safely managing transfer-of-control
  - Responsibility if technology fails
  - Technology will not perform in all road and weather conditions
  - Lack of sufficient testing
  - More expensive

- Gender
- Income and education
- Urban residence
- Level of functioning
- Experience with higher levels of automation

Advanced Driver Assistance Systems

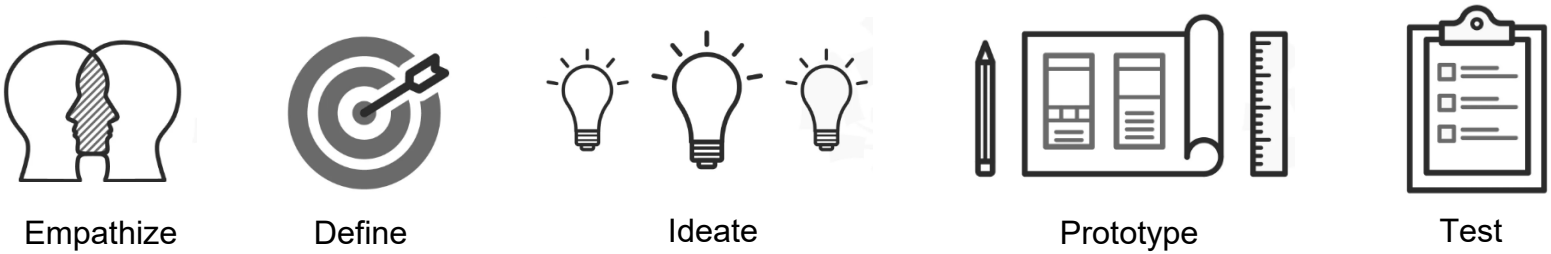
- Older adult will need to learn how the user interface works and how to communicate with the technology
- Technology adoption is influenced by ease of learning to use the technology



Eby et al., 2021

ADS design and deployment

- Design of advanced technology is informed by Human Machine Interface guidelines and testing protocols
  - 50th percentile male; limited guidance about perceptual, cognitive, or psychomotor impairments
- Importance of Human-Centered Design

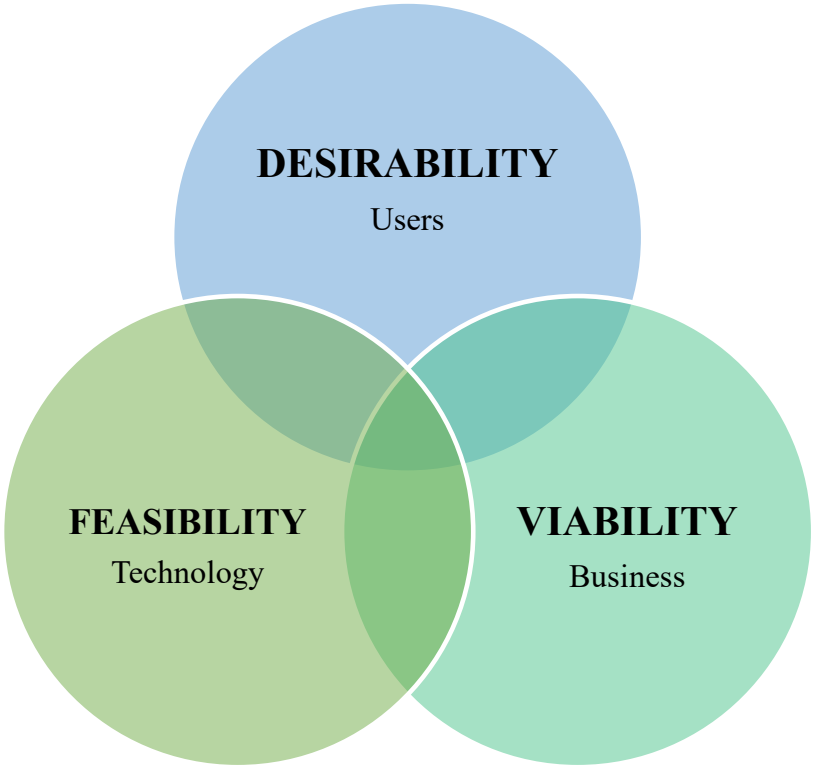


- Inclusion of older adults throughout process

ADS design and deployment considerations

- Physical layout
  - Step height
  - Deployable ramp
  - Width of seats
  - Space for personal items and mobility aids
  - Location of in-vehicle controls
  - Clarity of dashboard indicators
- Type of route
  - Door-to-door service preferred
  - Fixed-route must have shelters to protect passengers from exposure to the elements and provide seating
  - Route flexibility

Three Lenses of Human-Centered Design



Marketing

- Older adults tend to see themselves as younger than their chronological age by about 10-15 years
- Older adult consumer market should be segmented based on circumstances rather than age
  - Heterogeneity of older adult population
  - Universal design – helps older adults most, but also helps everyone
- Understand how current and future lifestyles can be best accommodated through vehicle design

Conclusions

- Population is aging
- Promise of ADS to enhance mobility
- Inclusion of older adults
  - Design can influence trust, acceptance, and accessibility
  - Need to address the concerns and expectations of older adults
  - Establish how older adults' capabilities and limitations can be supported with the vehicle design process
- Experience, training, and education to encourage adoption of new technologies

Thank you!

rstloui@umich.edu

Community Engagement: Methods and Results

Jennifer Zakrajsek, MS, MPH

November 9, 2022

Overview

- Introduction
- Recap of project objective and tasks
- Community engagement
  - Methods
  - Results
- Questions/Discussion

Jennifer S. Zakrajsek

- Lead Research Associate
- Behavioral Sciences Group
- BS, Movement Science; MS, Exercise Science; MPH, Health Behavior and Health Education
- jzak@umich.edu

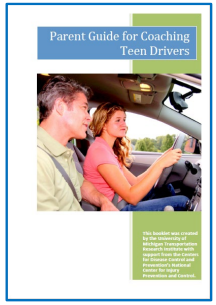
Research interests:

Teen driving and parent involvement, risky driving behavior, disparities in transportation access, enhancing safe mobility

Research Expertise:

Project coordination, focus/nominal groups, structured interviews, qualitative data analysis, naturalistic driving, survey research, driving and crash data management, intervention development

young DRIVER parenting .org



Promoting Inclusive Design and Deployment of Connected and Automated Vehicles (CAVs) for Older Adults Through Education and Training of Engineering Students and Older Drivers

Project Objective

Increase students' awareness of and sensitivity to issues of older adult accessibility, acceptability, affordability, and other aspects of inclusion related to CAVs, using a framework of experiential learning.

Main Project Tasks

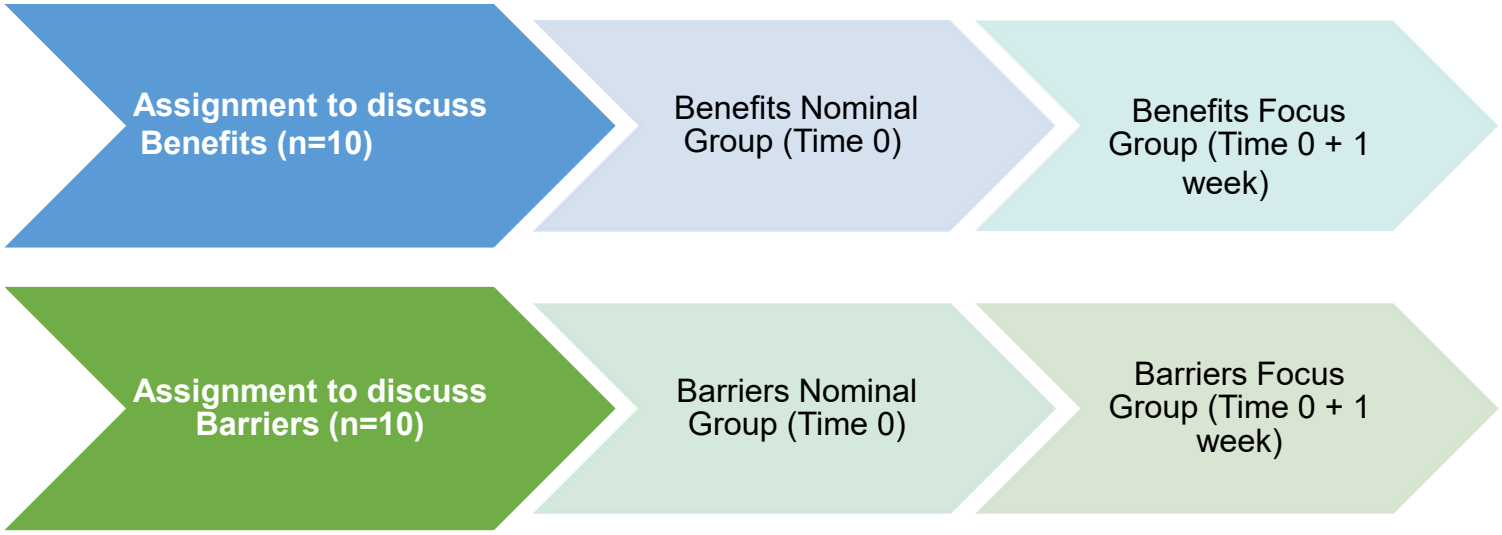
- Older adult needs assessment
  - Literature review
  - **Community engagement with older adults**
- Presentations/discussions with students
- Student reflection and communication through poster development/presentation
- Final report and recommendations

Community Engagement Objective

Learn more about potential benefits and barriers to using CAVs by talking with older adults themselves

Increase awareness of and sensitivity to issues surrounding older adults' CAV use

Community Engagement Design



Participant Recruitment

- Reviewed and exempted by IRB-HSBS
- Posting on *umhealthresearch.org*
- Eligibility criteria:
  - Age 65 and older
  - Able to attend two group sessions at UMTRI
- Telephone screening before scheduling
- Group assignment balanced by sex then randomized

Participants

- N=20 (10 per group)
- Mean age = 70 (range: 65-76)
- Range of medical conditions

Group Sessions

- 90 minutes with one break
- In-person at UMTRI
- 34-person capacity conference room
- One moderator and one note-taker
- Light refreshments
- Mandatory face masks
- Incentive payments: $40 nominal group + $60 focus group

Nominal Group Procedures

1. Informed consent
2. Welcome and introductions
3. Ground rules
4. Background information about CAVs
5. Individual list creation
6. Round-robin sharing of lists with group
7. Discussion: clarification of list items
8. Individual voting: select and rank top 5
9. Participant break
10. Presentation of results and items receiving votes
11. Discussion: clarification of remaining list items
12. Individual final voting: select and rank top 5

How could using CAVs help older adults?

Nominal group results:
Top benefits based on final vote

Item	Votes	Total
Accident prevention (e.g., obstacle detection)	4+5+5+5+2+4+5+3+3+5	41
Feel safe despite physical limitations (e.g., vision, hearing)	5+1+4+4+5+5+5+4+4	37
Can drive any time (weather, day/night, etc.)	3+1+2+4+3+4+3	20
Autonomous driving helps with fuel efficiency	2+2+3+1+4+1+1	14
Lower anxiety level	3+3+1+2+2	11

How could using CAVs be difficult or challenging for older adults?

Nominal group results:
Top barriers based on final vote

Item	Votes	Total
Learning how to use the technology	2+5+5+5+2+4+4+3	30
Makes the vehicles more expensive	5+4+3+5+1+4	22
Reluctance to give up driving/controlling the car	2+2+5+3+5+5	22
Concern that the technology is user-friendly enough to use independently	3+4+4+1+1	13
Intimidated by the technology	3+1+3+2+2	11

Focus Group Procedures

1. Welcome and introductions
2. Review background information about CAVs
3. Ground rules
4. Presentation of nominal group results
5. Group discussion (10-15 minutes per item with break)
6. Closing:
   a) clarification from note-taker
   b) Is there anything else we should be talking about…?

Data Analysis

- Data = nominal group voting, focus group transcripts, **field notes from notetaker**, notes from participants
- Systematic data analysis using open, focused coding process
- Identified emergent themes/concepts/categories
  - How often opinion was repeated
  - How many different participants stated opinion
  - How consistent participants were in their opinions
  - How much intensity was behind an opinion

Note: nominal/focus group results are not generalizable but are effective methods for obtaining valuable input from small groups.

Focus Group Themes: Benefits

- Accident prevention
  - Ways CAVs prevent accidents
  - Uncertainties related to accident prevention by CAVs
- Feel safe despite physical limitations
  - How CAVs impact limitations
  - Strategies to optimize how CAVs make older drivers feel safe
- Can drive any time
  - Situations older drivers might avoid without CAVs
  - Ways CAVs help older adults in those situations
- Autonomous driving helps with fuel efficiency
  - Ways CAVs impact fuel efficiency
  - How to promote this CAV benefit to older adults
- Lower anxiety level
  - Ways CAVs could lower older adults' anxiety
  - Strategies to optimize reduced anxiety from CAVs

Focus Group Themes: Barriers

- Learning how to use the technology
  - What older adults need to learn
  - How vehicle design could help older adults learn to use CAVs
- Makes the vehicles more expensive
  - Ways CAVs will make vehicles more expensive
  - Impact of cost on older adults
- Reluctance to give up driving/controlling the car
  - Things older adults have to give up to use CAVs
  - Strategies to overcome older adults' CAV reluctance
- Concern that technology is user-friendly enough to use independently
  - Things older adults may need help with to use CAVs
  - Where older adults feel comfortable getting CAV help from
- Intimidated by the technology
  - Things that intimidate older adults about CAVs
  - Getting older adults' buy-in for CAVs may be challenging

Common Themes from Benefits and Barriers Groups

- Many older adults will be resistant to using CAVs
- CAV training should be appropriately tailored to older adults' learning styles and stages of CAV acceptance, knowledge, and understanding
- Older adult CAV training should include opportunities for hands-on experience using CAVs
- CAV support and training for older adults should be ongoing and not a one-time administration
- Training that includes partnering older adults with peers and/or trusted mentors (e.g., kids/grandkids) for initial training and on-going support may be effective

Nominal/Focus Group Tips

1. Prepare and use a Field Guide
2. Present Ground Rules at start and use them
3. Create opportunities for all to share:
   a) Beware of discussion dominators
   b) Call on shy/hesitant people
   c) Encourage use of notepads
4. Do not try to attain consensus
5. Avoid yes/no questions or leading questions
6. Avoid inserting your opinion (manage the discussion flow not the responses)

Thank you!

Questions?

jzak@umich.edu

2. Poster Presentations by Research Team and Students

Promoting Inclusive Design and Deployment of Connected and Automated Vehicles (CAVs) for Older Adults Through Education of Engineering Students: Project Overview

UMTRI Group: Behavioral Sciences

Project Team

- Lisa J. Molnar, Research Associate Professor, UMTRI (PI).
- David W. Eby, Research Professor, UMTRI (Co-I).
- Ping Yi, Professor, Civil Engineering, University of Akron (Co-I).
- Feng Zhou, Assistant Professor, Industrial and Manufacturing Systems Engineering, University of Michigan – Dearborn (Co-I).
- Hideki Hada, Executive Engineer, Toyota Motor North America (Industry Champion).
- Renée M. St. Louis, Assistant Research Scientist, UMTRI.
- Jennifer Zakrajsek, Lead Research Area Specialist, UMTRI.
- Nicole Zanier, Research Area Specialist, UMTRI.

Project Sponsor

- Sponsor: Center for Connected and Automated Transportation (CCAT).
- CCAT is a University Transportation Center funded by United States Department of Transportation.
- CCAT is a Regional Center with multiple partners – led by UMTRI.

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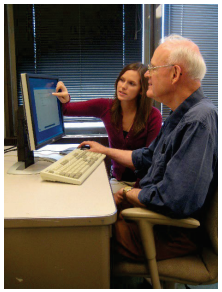
- However, challenges remain in ensuring that CAVs are accessible, acceptable, affordable, and otherwise inclusive for older adults.
- Challenges due in part to declines in functional abilities, as well as mixed feelings about CAVs - lack of trust and acceptance; reluctance to give up control (lack of understanding of technologies).
- There is an opportunity to raise awareness of older adult challenges vis-à-vis CAVs among engineering professionals and students.



Project Tasks

- Older adult needs assessment: literature review and community engagement (nominal and focus groups) with older adults.
- Presentations/discussions with students: overview of project; results from needs assessment; industry perspective.
- Student reflection and communication through poster development/presentation.
- Final report and recommendations.

Acknowledgement

Thank you to the Center for Connected and Automated Transportation (CCAT) for the financial support for this project, *Promoting Inclusive Design and Deployment of Connected and Automated Vehicles for Older Adults Through Education and Training of Engineering Students and Older Drivers*, and to the project's investigators Dr. Lisa J. Molnar (UMTRI), Dr. David W. Eby (UMTRI), Dr. Carol Flannagan (UMTRI), Dr. Feng Zhou (UM-Dearborn), and Dr. Ping Yi (The University of Akron). CCAT is the U.S. Department of Transportation's Region 5 University Transportation Center aimed at significantly impacting the evolution of the U.S. next-generation transportation system. Find out more at ccat.umtri.umich.edu.

Promoting Inclusive Design and Deployment of Connected and Automated Vehicles (CAVs) for Older Adults Through Education of Engineering Students: Older Driver Needs Assessment

UMTRI Group: Behavioral Sciences

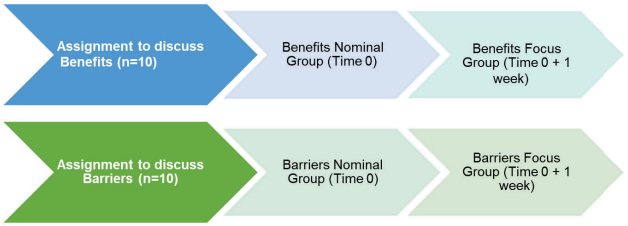
Background and Objective

- Part of project sponsored by the Center for Connected and Automated Transportation.
- Project objective is to increase students' awareness of and sensitivity to issues of older adult accessibility, acceptability, affordability, and other aspects of inclusion related to CAVs, using a framework of experiential learning.
- Project tasks include an older adult needs assessment consisting of a literature review and community engagement with older adults themselves (nominal and focus groups with older adults).

Methods: Literature Review

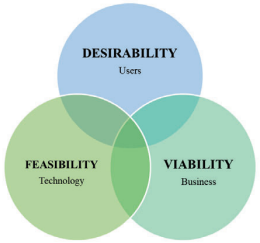
- Purpose: to gather background information from the literature to gain a better understanding of the issues surrounding older adults and CAVs.
- Steps:
  1. Develop selection criteria to guide the review.
  2. Identify topics.
  3. Develop search terms to capture topics.
  4. Collect/store information in bibliographic management system.
  5. Multiple-level review and synthesis of information.

Methods: Community Engagement



Results: Literature Review

- Population is aging; abilities decline with age.
- Promise of CAVs to enhance mobility.
- Inclusion of older adults.
  - Design can influence trust, acceptance, and accessibility.
  - Need to address the concerns and expectations of older adults.
  - Establish how older adults' capabilities and limitations can be supported with the vehicle design process.
- Experience, training, and education to encourage adoption of new technologies.
- Important of Human-Centered Design process.



Results: Focus Group Themes Related to Benefits of CAVs

- Accident prevention.
- Feel safe despite physical limitations.
- Can drive any time.
- Autonomous driving helps with fuel efficiency.
- Lower anxiety level.
- Ways CAVs could lower older adults' anxiety.

Results: Focus Group Themes Related to Barriers of CAVs

- Learning how to use the technology.
- Makes the vehicles more expensive.
- Reluctance to give up driving/controlling the car.
- Concern that technology is user-friendly enough to use independently.
- Intimidated by the technology.

Implications from Community Engagement

- Many older adults will be resistant to using CAVs.
- CAV training should be appropriately tailored to older adults' learning styles and stages of CAV acceptance, knowledge, and understanding.
- Older adult CAV training should include opportunities for hands-on experience using CAVs.
- CAV support and training for older adults should be ongoing and not a one-time administration.
- Training that includes partnering older adults with peers and/or trusted mentors (e.g., kids/grandkids) for initial training and on-going support may be effective.

Acknowledgement

Thank you to the Center for Connected and Automated Transportation (CCAT) for the financial support for this project, *Promoting Inclusive Design and Deployment of Connected and Automated Vehicles for Older Adults Through Education and Training of Engineering Students and Older Drivers*, and to the project's investigators Dr. Lisa J. Molnar (UMTRI), Dr. David W. Eby (UMTRI), Dr. Carol Flannagan (UMTRI), Dr. Feng Zhou (UM-Dearborn), and Dr. Ping Yi (The University of Akron). CCAT is the U.S. Department of Transportation's Region 5 University Transportation Center aimed at significantly impacting the evolution of the U.S. next-generation transportation system. Find out more at ccat.umtri.umich.edu.

How might we design a GPS tracking companion app to assist caregivers in monitoring the location of seniors with cognitive impairment while riding in autonomous vehicles?

Melissa Clive, Molouk Harp, Abigail Lorincz, Josh Brown, Seye Olabanji, Dasol Han, Swarna Pandu, and Seungju Choi
HCDE 510 taught by Dr. Feng Zhou, UMTRI Group: Behavioral Sciences

INTRODUCTION

Retaining independence is an important factor for seniors (65+) who still drive. Many seniors voice concerns for driving safety for themselves and their partners and/or senior friends, especially if a senior has a cognitive impairment. Based on the themes and feedback from our initial interview, we chose to target caregivers of seniors as the primary user and seniors with mild cognitive impairment as the secondary user who would be riding in the AV. Drawing inspiration from our focus group and their affinity for the app called Life360, we decided to create an app called CompaniON.

OBJECTIVES

CompaniON is an app meant to be used by both caregivers and senior adults. The app enables:

1. The caregiver of the senior adult to track their GPS location
2. The senior adult to cue the AV and act in a behavior that makes the AV more easier to locate
3. The caregiver and senior adult to communicate with each other if concerns arise and assistance is needed

METHODS-EMPATHIZE

FIRST ROUND

- Based on our initial literature review, we framed our design problem as follows: "**How might we design a GPS-tracking companion app to build trust among seniors in autonomous vehicles?"** to help seniors retain their independence, build trust through open communication with the AV, and to clearly communicate to the users' AV location & information.
- We set our target users as **"Seniors 65 or Older."** To conduct the focus group interview, we limited ourselves to people with previous driving experience and open to remote interviews.

SECOND ROUND

- Based on a second literature review and the user feedback after the focus group interview, we reframed our design problem as follows: **"How might we design a GPS tracking app to assist caregivers in monitoring the location of seniors with cognitive impairment in AVs?"**
- We refined our target users as **"Seniors with Mild Cognitive Impairment and their caregivers."**

METHODS-DEFINE PERSONA

FIRST ROUND PERSONA

- Based on our focus group interview, we analyzed the gained data and created our initial persona highlighting features of 'reliability' (AV battery status), understanding (AV information), and safety (location of friends and family).

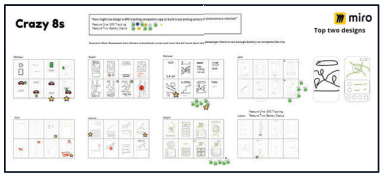
SECOND ROUND PERSONA

- After reframing our design statement, we recreated two personas–caregivers and cognitively impaired seniors–representing people who need transportation assistance and people who want to know where their loved ones are located.

METHODS-IDEATION

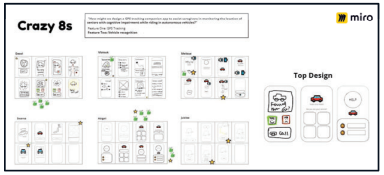
As a part of ideation, the **Crazy 8s method** was used to generate ideas. It was conducted online on **Miro** and members of the team simultaneously sketched out 8 ideas in 8 minutes. Each member selected 2 of their best ideas and further explained it to the team. Out of these shortlisted designs, the team voted for the best idea and low fidelity wireframes were developed subsequently.

FIRST ROUND OF IDEATION



Scenario Used: The passenger has chosen a suboptimal route and now the AV must alert the senior that there is not enough battery to complete the trip.

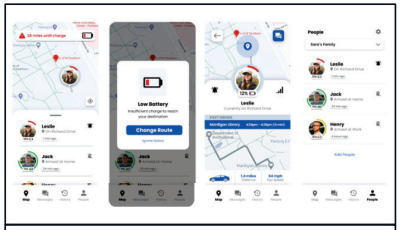
SECOND ROUND OF IDEATION: On revision of the design statement, the team conducted another round of crazy 8s.



Scenario used: Following a doctor's appointment, the senior forgets where she has parked and seeks help from the caregiver. The caregiver provides assistance through the CompaniON app in locating the AV.

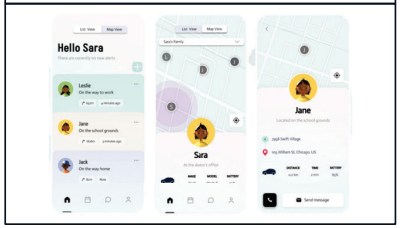
METHODS-PROTOTYPING: ROUND 1

DESIGN ONE



DESIGN TWO

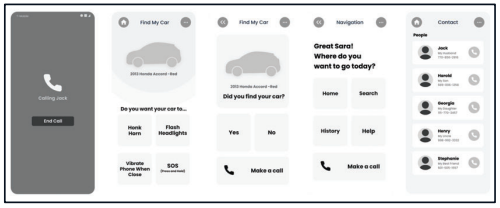
Our solutions focused on GPS tracking and AV battery status



METHODS-PROTOTYPING: ROUND 2

CAREGIVER'S INTERFACE

SENIOR'S INTERFACE



Our solutions focused on GPS tracking (for the caregiver) and AV location assistance (for the senior with mild cognitive impairment)

How might we design a GPS tracking companion app to assist caregivers in monitoring the location of seniors with cognitive impairment while riding in autonomous vehicles?

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TARGET AUDIENCE

PRIMARY USERS

Caregivers of seniors with mild cognitive impairments

SECONDARY USERS

Seniors aged 65+ with mild cognitive impairments

We have targeted our primary users—caregivers caring for senior adults (65+) with mild cognitive impairments—to test our prototypes and provide feedback. Our primary users will not only be monitoring the actions and whereabouts on the CompaniON application, but will also most likely be there to physically assist the senior adult for any initial questions or concerns in the setup of the app.

We would like to learn more about their experience as a caregiver to understand how we can improve their ways of virtually caring for the senior adult using our application. With additional time, another round of interviews with our secondary users would help in empathizing and bettering the user experience of the senior adults.

INTERVIEWEE DEMOGRAPHICS

Maureen; 54 years old; Ann Arbor, MI
Caring for someone who is 83 years old

Zeenat; 51 years old; Dearborn, MI
Caring for someone who is 77 years old

Renee; 65 years old; Belleville, MI
Caring for someone who is 89 years old

Robert; 68 years old; Belleville, MI
Caring for someone who is 89 years old

METHODS - TESTING

We presented our prototype to our target audience accompanied by follow-up interview questions to ascertain the functionality and usability of the overall design, as well as identify areas where improvements could be made.

We asked the participants the following usability questions:

- **If they (or the person they are caring for) found the app helpful**
- **What features they found most helpful, if any**
- **What features they found least helpful, if any**
- **If there was anything that they would add to make the design features more helpful to them**
- **A rating on a 10-point like scale to collect feedback on participants' understanding of the design layout, with 1 representing 'very confusing" and 10 representing 'very easy to understand.'**

RESULTS

MOST HELPFUL FEATURES FOR CAREGIVERS

- Option to track more than one senior and view their history feature as a timeline
- Ability to watch the senior on the move and review their call history
- Similarities to the 'Find My', 'Life360', and 'Google Maps' apps
- Option to call the senior from the caregiver's phone lock screen to save time

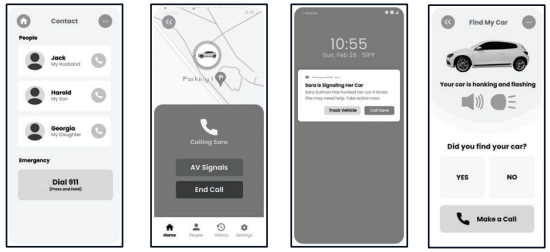
MOST HELPFUL FEATURES FOR SENIORS

- Simultaneous alerts deemed useful for quicker vehicle recognition
- Option to call caregivers was deemed necessary for seniors who struggle with reasoning and decision making

OTHER AREAS OF IMPROVEMENT

- Flexibility for caregivers to alter the time span of history for the senior's activities.
- Notifications on senior adult's whereabouts, including departure and arrival
- Caregivers would like a more precise map to be able to guide the senior when they call
- Options to allow for screen readers and bilingual text
- Option for multiple caregivers to track a senior simultaneously
- Add doctors as a contact so the senior can get help entering and leaving a clinic
- Compatibility with tablets to take advantage of a larger screen (i.e. improve legibility)

REITERATION : PROTOTYPE CHANGES



CONCLUSIONS

LIMITATIONS

- Sample Size: Cognitively impaired seniors were hard to find
- Focus Group format provided limited chance for follow-up questions

NEXT STEPS

- Recruit seniors for additional in-depth prototype feedback
- Diversity research methods for greater design insights
- Explore the possibility of commercializing the product

ACKNOWLEDGEMENT

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Improving the in-vehicle experience to help the elderly and their caregivers to feel connected during an emergency and provide trouble-free navigation

Students: Khajista Zainab, Ashwitha Jathan, Siddhi Durve, Manasi Kulkarni, Taylor Fitzgerald, Christopher Mazziotta, Juby Wu, Idara Ubong Class: HCDE 510 taught by Dr. Feng Zhou UMTRI, Group: Behavioral Sciences

Introduction

Development of automated vehicles, by removing the responsibility of operating the vehicle from the hands of human drivers, is committed to providing potential benefits such as increased safety on the roads, reducing the overcrowding of the cars and successively reducing air pollution. However, AVs are readily adopted by some population over the other. Older adults can be identified as individuals who are at the age of 65 or older. Such individuals are characterized by reduced physical and cognitive abilities which are further linked to decreased ability to function as a whole. Automated cars may provide the potential solution to their problem, by facilitating mobility and awarding independence to the older drivers and people with disabilities[1].

Studies have demonstrated that in order for the older adults to recognize the possible benefits of automated cars, it is essential for them to put their trust in the technology and work to have a better understanding of it. Furthermore, higher trust and perceived safety of the automated cars has been noted when the older individuals were subjected to a simulator study. In the due process, increasing the understanding and experience of older adults related to automated vehicles will not only decrease their concerns and increase their trust in it, but also convey a confidence for future use[2]. This study was undertaken in an attempt to study the population of older adults and their willingness to adopt AVs through the lens of human centered design processes.

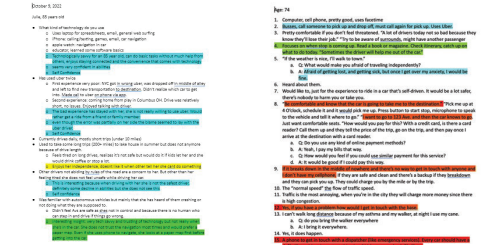
Objectives

- Improve Elderly acceptance of CAVs
- Evaluating the role of automated cars in increasing the mobility of older adults
- Assessing the experience of elderly with technology

Methods

- **Interviewing** - Empathize with elderly individuals through interviews for initial understanding of the problem. A list of questions was used to identify concerns and issues associated with elderly perceptions of CAVs. Responses from interviews were coded to identify emerging themes for solutions.
- **User Models** - Personas that represent the targeted users identify key needs, desires, goals. The personas may then be used to create hypothetical scenarios in which these characters would utilize our solutions in order to better understand the user experience.
- **Crazy 8's** - Iterative process of generate 8 unique ideas within 8 minutes, allocating 1 minute for each idea. Process is repeated after reviewing and voting for best solutions. Ideas with the most votes are incorporated into the next iteration of generating 8 new ideas.
- **Prototype Testing** - Low-fidelity and medium-fidelity prototypes were created to test the functionality of our solution. The prototypes identified areas of improvement which were implemented in additional, reworked prototypes.

Methods - Interviewing



Sample Size	Drivers	Non-Drivers	Age Range	Females	Males
7	6	1	>60	5	2

Interview Process

- General opener questions were used to start the conversation and warm people up. Structured questions identified user needs, desires, and goals.
  Example Question:
  What challenges do you face now while driving?

Data Analysis

- To analyze the data, interviews were chunked then coded to reveal the underlying meaning of user responses. The coded data may then be interpreted to create solutions problems discover from the interviews.
- Our codes from analyzing the interviews:
  - Self Confidence
  - Independence
  - Distrust of technology if not in control
  - Data Driven/Logical
  - Concerns about emergency situations
  - Concerns about surrounding drivers
  - Navigation (knowing where they are and where they are going)
  - Comfort in vehicle
- These categories were then used to create emerging themes to narrow our focus for solutions.

Methods - Personas

I always have my kids help me update my phone and recently they helped set up a new smart TV.

Hank

Age: 83
Location: Ithaca, New York
Occupation: Retired-Construction
Education: High School

DRIVING HABITS
- Knows how to drive, but arthritis prevents him from driving for long
- Gets nervous on sharp turns
- Uses Google Maps to optimize driving routes

HEALTH
- Has high blood pressure
- Arthritis

DESIRES
- Stay connected to the family
- Stay independent
- Stay healthy

NEEDS
- Being able to visit children and grand children,
- help with technology, staying in contact with children
- Needs to review routes at home before driving
- Needs to be able to visit the doctor whenever possible
- Believes he can be independent but is cautious due to health problems that are unpredictable

FRUSTRATIONS
- Forgetful, bad sense of direction unless in a frequented area
- Difficulty finding parking lots
- Doesn't trust technology & machines he has no control over

TECH LITERACY: LOW
- Phone
- Car (voice navigated GPS on phone)
- Heavy machines

ACTIVITIES
- Carpentry
- Family gathering
- Watching news on TV

FAMILY
2 Children living short mile away

Bobby (Caregiver)

Age: 44
Occupation: Project Manager
Location: Albany, New York
Education: Graduation

NEEDS
- Be able to know the whereabouts of his old father
- Able to track his father's health information while he drives
- Schedule and alter rides whenever needed

DESIRES
- Be stress-free about father's health and doctor appointments
- Stay connected to family

FRUSTRATIONS
- Unable to keep in touch with his father due to his tough schedule
- Difficult to track doctor appointments of father

TECH LITERACY: HIGH
- Phone
- Laptop
- Car HMI

ACTIVITIES
- Business meetings
- Family gatherings
- Sci-fi TV shows

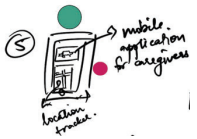
FAMILY
- Lives with wife and 2 children
- Meets his father every weekend

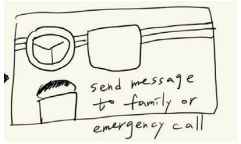
Methods - Crazy 8's

The ideation method used was Crazy 8's. For remote Crazy 8's, Miro was used to collaborate with each other in real-time.

Process

- Each team member had one piece of paper folded into 8 sections. With eight minutes on the clock, team members sketched out eight different ideas based on the How Might We statement.
- Ideas were then shared with the team and everyone brought their unique perspective on the targeted user and the problem to solve.
- Following discussion, team members voted on the top ideas presented.
- This process was followed for a total of 3 times. The team continued to discuss the ideas in more detail and attempted to narrow down the ones our team could move forward with.





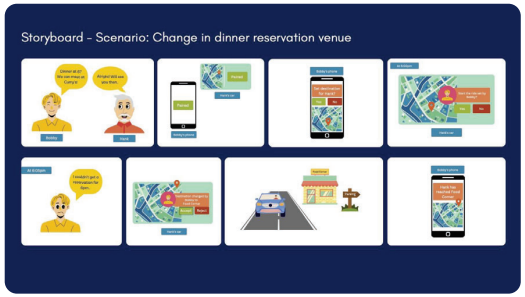
In the final round, the team chose to focus on the features for the passenger and caregiver to feel connected in the autonomous vehicle. Therefore, the team decided that by allowing passengers to choose caregiver permission settings by themselves would allow them control, while also allowing them to feel connected to their caregivers who they trust during emergency situations.

Improving the in-vehicle experience to help the elderly and their caregivers to feel connected during an emergency and provide trouble-free navigation

Students: Khajista Zainab, Ashwitha Jathan, Siddhi Durve, Manasi Kulkarni, Taylor Fitzgerald, Christopher Mazziotta, Juby Wu, Idara Ubong Class: HCDE 510 taught by Dr. Feng Zhou UMTRI, Group: Behavioral Sciences

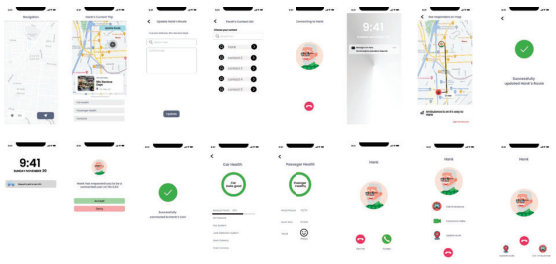
Methods: Prototype

1) Low-Fidelity: We created storyboards based on the scenarios (emergency and less critical) and tested them with the users. The users were explained the scenario and were interviewed based on the scenarios. Their reactions and opinions were noted.



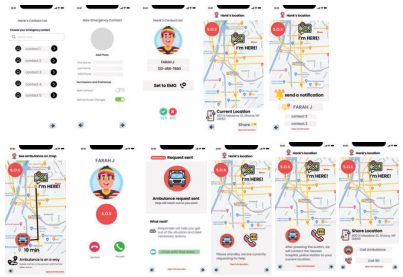
2) Medium-Fidelity prototypes: Mobile and HMI screens were designed in collaboration on the Figma application. The mobile app was designed for the caregiver (outside the FAV) and the passenger (in the FAV) as users and HMI was designed for the passenger in the FAV. Users were given certain tasks to complete, and their feedback was noted. Some examples of the tasks are: Pair your phone with Hank's Car, Update the route for Hank, Send non-emergency and emergency notification, Call ambulance from passenger's end. We created six flows that we have tested with different users.

Prototype - Caregiver



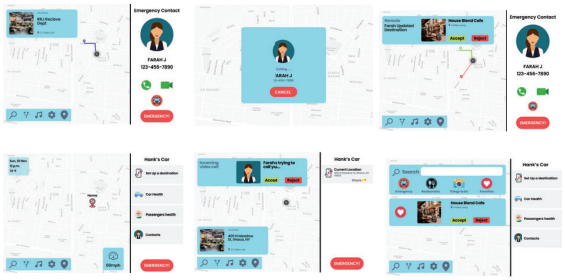
Through this application, the caregiver can track the status of the passenger. Incase of an emergency, the caregiver can reroute the cars navigation to a safe place. This application can also help communicate with the passenger whenever necessary.

Prototype - Passenger



Through this application, the passenger can call in for the emergency help support. This application gives user the ability to save his emergency contact information. This application helps connect with the caregiver whenever necessary.

Prototype - Vehicle HMI



This HMI helps our user to know the vehicle better, connect with their emergency contact or caregiver. This HMI reroutes the navigation according to the update given by the caregiver.

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Testing Prototype

Fidelity	Participants	Feedback from the User
Low	5 (Caregivers=2, Older Adults=3)	• Emergency button • Ambulance request from the car and app which shares the live location with the ambulance and the caregiver • Video call feature • Voice notification • Concerns about the privacy with a third party (car company, battery charging place or maintenance)
Medium	7 (Caregivers= 3, Older Adults= 4)	• Integrate crash detection apps - Apple, Google. (In case of accidents) • Select 'passenger' or 'caregiver' while setting up the app • Cancel button for ambulance • Information about the S.O.S button • Automated messages • Update profile picture in the emergency contact list • Voice instruction

Conclusions

We recognized that providing emotional support to older adults through connections to caregivers and/or family might increase their adoption of automated vehicles. Our initial findings motivated us to design an application where through the acknowledgement of caregivers ability to decree navigation remotely, and abilities to monitor the health of the car and older adults in real time, provides a reassurance to older adults. Based on the feedback we found that, this is extremely reliable in cases of emergencies and critical scenarios which require quick action. Caregivers should be able to communicate with them through video calls, upon request make changes in their navigation route, and call an ambulance in cases of medical emergencies. Through testing we gained more insights about providing control to the older adults by helping them determine who they choose to be their point of contact in the AV. Allowing the user to choose the contact also provides an added layer of security. Therefore, it is possible to increase the trust and acceptance of older adults when riding independently in automated vehicles.

Acknowledgement

Thank you to the Center for Connected and Automated Transportation (CCAT) for the financial support for this project, *Promoting Inclusive Design and Deployment of Connected and Automated Vehicles for Older Adults Through Education and Training of Engineering Students and Older Drivers*, and to the project's investigators Dr. Lisa J. Molnar (UMTRI), Dr. David W. Eby (UMTRI), Dr. Carol Flannagan (UMTRI), Dr. Feng Zhou (UM-Dearborn), and Dr. Ping Yi (The University of Akron). CCAT is the U.S. Department of Transportation's Region 5 University Transportation Center aimed at significantly impacting the evolution of the U.S. next-generation transportation system. Find out more at ccat.umtri.umich.edu.

Navigating in the Dark - Designing Autonomous Driving Features to Assist Older Adults with Visual Impairments

Students: Lashawnda Bynum,Jay Parker, Kristy Lee, Nia Nitschke, Melanie LaFlam, Jennifer Marcussen, Jana Taleb, Aleyna Dogan
Class: HCDE 510 taught by Dr. Feng Zhou **UMTRI Group:** Behavioral Sciences

Introduction

Vision Changes with Age

Age-related macular degeneration (AMD) is a disease affecting the central retina causing vision loss and accounts for a leading cause of blindness worldwide [1]. It is often a difficult decision for older adults to give up driving completely. One study found that a little over a third of older adults may restrict their activities due to lack of transportation options or will often adjust their driving behavior around their disability [2].

Designing Autonomous Vehicle (AV) Solutions for Trust

AVs pose a potential transportation solution for older adults who are no longer able to drive. The most sophisticated automated driving capabilities in the US market are currently only at SAE level 2, requiring drivers to remain attentive [3]. Older adult users must feel considered in the design of these features to encourage use of them to supplement their driving.

Objectives

- Identify aging adult users' current behaviors and needs while operating vehicles
- Design a system that allows visually-impaired drivers to easily engage and use automated driving navigation features

Methods

Preliminary User Research

Interviewed 5 individuals over age 55 with age-related visual impairments – then categorized interview responses into key topics that recurred among respondents to identify frequency of behavioral characteristics & themes.

Response Themes

Topic	Theme		Topic	Theme	
Adjusting as a passenger	Assist Driver	3	Learning about technology	In-Person	4
	Modify Settings	3		Internet	3
	Other	2		Difficulties	2
	Leisure	2		Reading Manuals	2
Adjustments to driving as vision changed	Change in Driving Behavior	4		Auditory Learning	1
	Using Visual Aids	3		Prefers External Technology	1
	Physical Adjustment	2		Structured Learning	1
	Have Someone Else Drive	1		Visual Learning	1
Ending a ride	Audio Cue	2	Preparing for travel	Bringing Assistive Items	2
	Visual Cue	1		Vehicle Location	2
Experience with ADAS	Avoidance	6		Emotional/Mental Prep	1
	Safety Concern	2		Prep Vehicle Settings	1
	Useful	2	Ride share services	Safety Concern	5
Experience with voice control (non-ADAS)	Avoidance	2		Cost	1
	Distracting	4		Other	1
	External Device	4		Public Transport	2
	Inaccurate Information	2		Short Trips	3
If still driving, what would make you stop?	Freedom	4		Environmental	1
	Cognitive Decline	3		Technology Barrier	2
	Cost	1		Lack of Freedom	1
	Societal Pressure	2	Role of car in daily life	Freedom	1
	Familial Need	1		Fully Rely on Car	4
	Other Transportation Options	1		Public Transport	1
	Physical Decline	1		Rides with Others	1
	Visual Decline	1	Thoughts about FAVs	Safety Concern	3
Issues Driving Non-Autonomous Vehicles	Visual Impairment	7		Mistrust of Technology	3
	Distracted Driving	3		Semi-Autonomous	3
	Accessibility	1		Driver Monitoring Features	2
	Relying on Other Visual Cues	1		Environmental	1
	Relying on Sound Cues	1		Lack of Control	2
Thoughts about FAVs	Safety Concern	3		Lack of Results	2
	Mistrust of Technology	3		Positive	2
	Semi-Autonomous	3	What a car trip involves	Cost	1
	Driver Monitoring Features	2		No Additional Prep	3
	Environmental	1		Adjust Vehicle Settings	1
	Lack of Control	2		Check Vehicle Health	1
	Lack of Results	2		Day Trips	1
	Positive	2		Distance	1
	Negative	1		Drive to Work	1
				Traffic/Pressure from Other Drivers	1

Figure 1. Key themes extracted from interviews based on the number of times they were mentioned

Methods

Developed a user persona based on the results and a use-case scenario for testing and prototype design. We focused on designing for a user affected by macular degeneration with a long history and experience with driving, the desire for freedom, and who still has/wants to have an active life on their own schedule.

Persona:

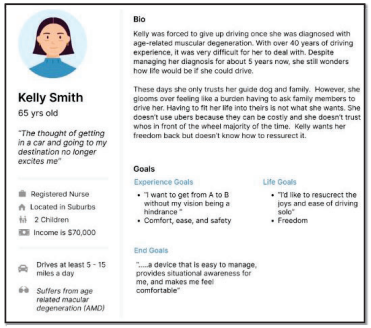

Figure 1. Persona of average older adult user, behaviors, and transportation needs based on interview data, and use case scenario

Scenario:

1. Kelly is ready to visit her new friend. She is able to find and get into her car with the help of her guide dog.
2. Kelly gets into her vehicle and would like to know that the car is aware that she and her guide dog are inside.
3. Kelly wants to communicate with the vehicle her intended destination and which route she would like to choose. She does not feel comfortable going on the highway on her way home, so she chooses the route without.
4. She also wants to make sure everything is in order before the vehicle drives off. She's worried her car might not have enough battery/fuel to complete the trip and would appreciate reassurance from her vehicle.
5. As the vehicle is driving, Kelly realizes she's a little anxious because she is not familiar with the route and would like details of where she is and every step of the way.

How might we make navigation features easier to engage with in fully-autonomous vehicles for visually impaired adults with age-related macular degeneration (AMD) during a trip?

Methods

Prototype

After brainstorming different ideas using the Crazy 8's method, we developed a "test drive" scenario in which participants would have their vision restricted (via closing eyes, blindfold) and would engage with pre-recorded voice prompts that would be given by the "AV system". Users were asked to respond to prompts for the following 5 tasks involved in a simulated trip in the AV:

	Description
Task 1	Prompt to turn car on with voice command
Task 2	Vehicle checklist: vehicle diagnostics, seatbelt, cabin conditioning (AC, radio, seat adjust); Prompt navigation level select: 1 (advanced) or 2 (basic)
Task 3	Prompt to provide destination and select a route; prompt to accept or cycle through additional route options
Task 4	Informing user of trip start and vehicle action (ie. Backing out of parking space)
Task 5	Inform user of navigational movements; prompt user for any actions to take en route (ie. Turn on red, take detour)

The prototype includes a button to activate the system on the side of each seat, dashboard camera to confirm user presence, and retractable microphone for voice commands. Users were also shown this sketch prior to the test drive, indicating their position within the vehicle and where key components of the system are located.

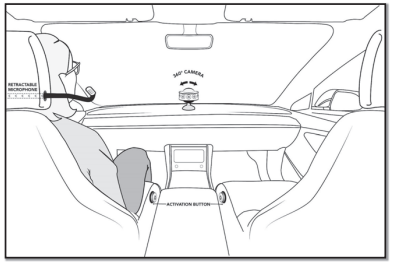

Figure 2. Prototype sketch for future fully-autonomous models (levels 4-6).

Task 2 presented two levels of navigation experience for the user to choose from based on their needs:

Level	Navigation Detail
Basic	Hazards, weather conditions, speed limits, some information about car behavior
Detailed	Road types, speed limits, hard braking & acceleration, weather conditions, oncoming emergency vehicles, police officers, hazards/construction, detailed information about car behavior.

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Methods

Usability Testing

Testing was conducted with n=4 individuals over the age of 60 using Wizard of Oz methods. Participants were blindfolded or asked to close their eyes to simulate blindness and given a list of recordings to simulate the test drive. Participants were asked to navigate to a provided local grocery store location, selecting the option to avoid highways. Based on user voice input, the researcher played the appropriate pre-recorded response to simulate a natural interaction with an AV system.

Usability Test Objectives

1. Observe and evaluate user's comfort with the design
2. Test how easily the user is able to navigate and use the design
3. Determine if the design eases pain points voiced in preliminary user research
4. Observe areas of confusion or hesitation with design

Focus Points:

1. What is the users comfort level/trust level of autonomous vehicles?
2. How many levels of control should the navigation system have?
3. What should each level of control include?
4. How much control does the user need/want in a fully autonomous vehicle?
5. Where is the best location in the car to place the physical items of the navigation system?

Results

User feedback could be classified into 4 main feature comments:

Feature Comment	Participants	Suggested Adjustment (If Applicable)
Liked detail of initial checklist	P2, P3, P4	Make initial checklist a setup task that recalls user preferences for future trips
Liked button on seat	P2, P4	None
No way to tell if object is in front of car	P1, P3, P4	Add sensor to detect objects in front of vehicles and add alerts to voice system
Too much detail in voice navigation at lower level	P2, P4	Add lesser level of navigation detail

Results

Iterative Process

Level	Navigation Detail
1	Road types, speed limits, hard braking & acceleration, weather conditions, oncoming emergency vehicles, police officers, hazards/construction, detailed information about car behavior.
2	Hazards, weather conditions, speed limits, limited information about car behavior

Level	Navigation Detail
Limited	Information about route changes
Basic	Hazards, weather conditions, speed limits, some information about car behavior
Detailed	Road types, speed limits, hard braking & acceleration, weather conditions, oncoming emergency vehicles, police officers, hazards/construction, detailed information about car behavior.

Conclusions

Additions Added to FInal Prototype:

1. Addition of sensors to provide information about external objects
2. A lower level of Limited navigation
3. Detail the user can select, and one-time user preference selection (not illustrated).

Level	Navigation Detail
Limited	Information about route changes
Basic	Hazards, weather conditions, speed limits, some information about car behavior
Detailed	Road types, speed limits, hard braking & acceleration, weather conditions, oncoming emergency vehicles, police officers, hazards/construction, detailed information about car behavior.

Conclusions

Final Prototype

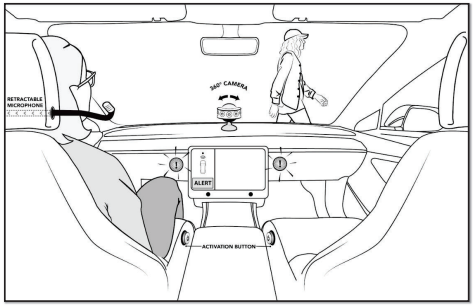

Figure 3. Final prototype sketch incorporating external sensors and voice alert system.

Acknowledgement

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