Problem

Senior drivers typically experience age-related declines in sensory, cognitive, and psychomotor abilities that might affect their driving ability and safety (e.g., Anstey et al., 2005). Many researchers optimistically propose in-vehicle automation technologies as a potential solution to the declining abilities of senior drivers for maintaining their safety and mobility (e.g., Meyer, 2009; Paris et al., 2014). However, empirical research confirming the safety and mobility benefits is in paucity. Further, the benefits of automated features depend on the degree of comfort and facility with which they use these technologies. Senior drivers need longer to learn how to use in-vehicle technologies (Caird, 2004). Hence, enabling senior drivers to adopt automated vehicle technologies may be the first step towards sustaining their mobility and road safety.

Methods

We conducted a naturalistic driving study recruiting 18 drivers aged 70-79 to drive vehicles with automated features - BSA, LA, LKA, and ACC. Each participant is given a study vehicle for six weeks. Each vehicle is instrumented with a custom data acquisition system (DAS) incorporating several camera views and other sensors (e.g., GPS, vehicle kinematics) to collect data on driving behaviors. We also collect data on attitudes towards the in-vehicle technologies at several points during their participation (Figure 2).

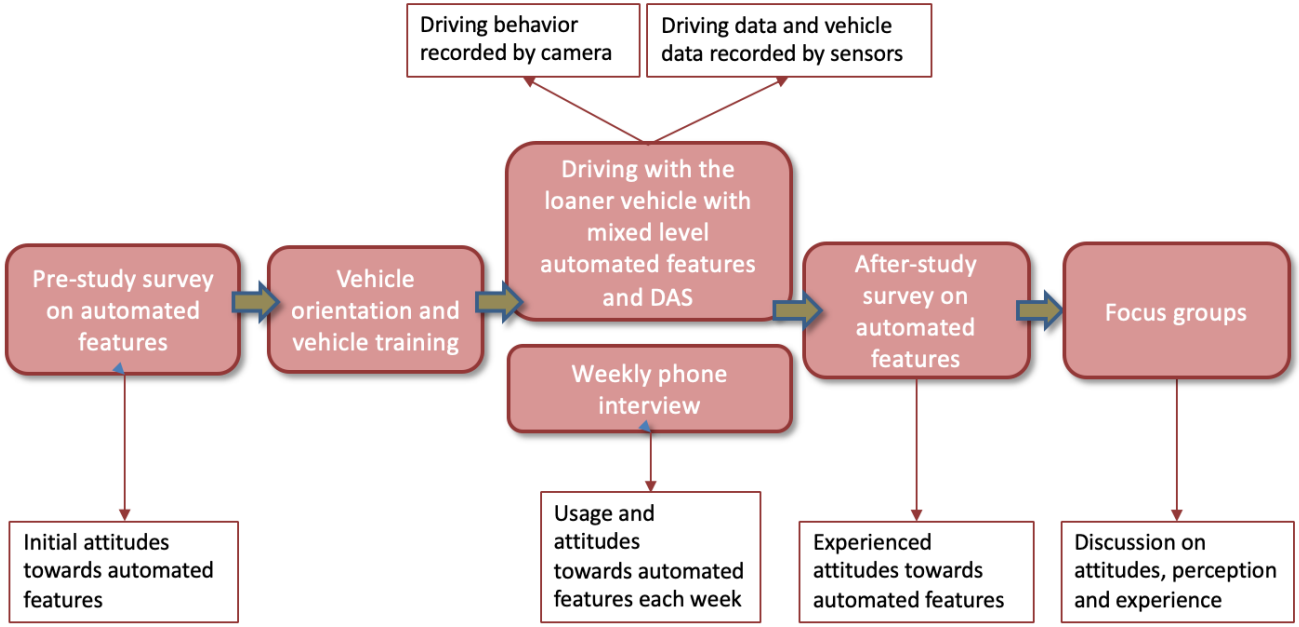


Figure 1. Overview of Study Procedure

Pre and Post Questionnaire Results

Lane control features

- participants perceived fewer false alarms *[t(17)=2.61 , p=0.02];*
- participants felt more familiar with the lane control features *[t(17)=4.25, p<0.001];*
- participants felt safer *[t(17)=2.61, p=0.02];*
- participants felt greater confidence in the lane control features *[t(17)=2.29, p=0.03]*

Acceleration and braking features

- participants perceived fewer false alarms *[t(16)=3.73, p<0.01];*
- participants felt more familiar with the acceleration and braking features *[t(17)=3.43, p<0.01];*
- participants felt marginally safer *[t(17)=2.11, p=0.05];*
- participants had greater confidence in the *acceleration and braking* features *[t(17)=2.33, p=0.03].*

Focus Group Findings

Table 1. Focus group probe questions.

Topics		Probe Questions
Attitudes	*Q1.*	*What one word describes how you felt about the advanced features in your vehicle when you began the study? What one word describes how you feel about the advanced features in your vehicle now, at the end of the study?*
	Q2.	*What caused your feelings to change or remain the same?*
Perception	*Q3.*	*What would make you feel more comfortable with these features?*
Feature Likes/Dislikes	*Q4.*	*What is one thing you liked best about these features? What is one thing you liked least about the features?*
Safety	*Q5.*	*Suppose a friend is considering purchasing a car with these features and they ask you if you think if they improve driving safety or not. What would you say?*

Attitudes

Finding 1: Negative initial attitudes towards the advanced features

e.g. "Nervous", "confused" and "anxious"

Finding 2: Positive post attitudes towards the advanced features

e.g. "*Positive" and "Confident*"

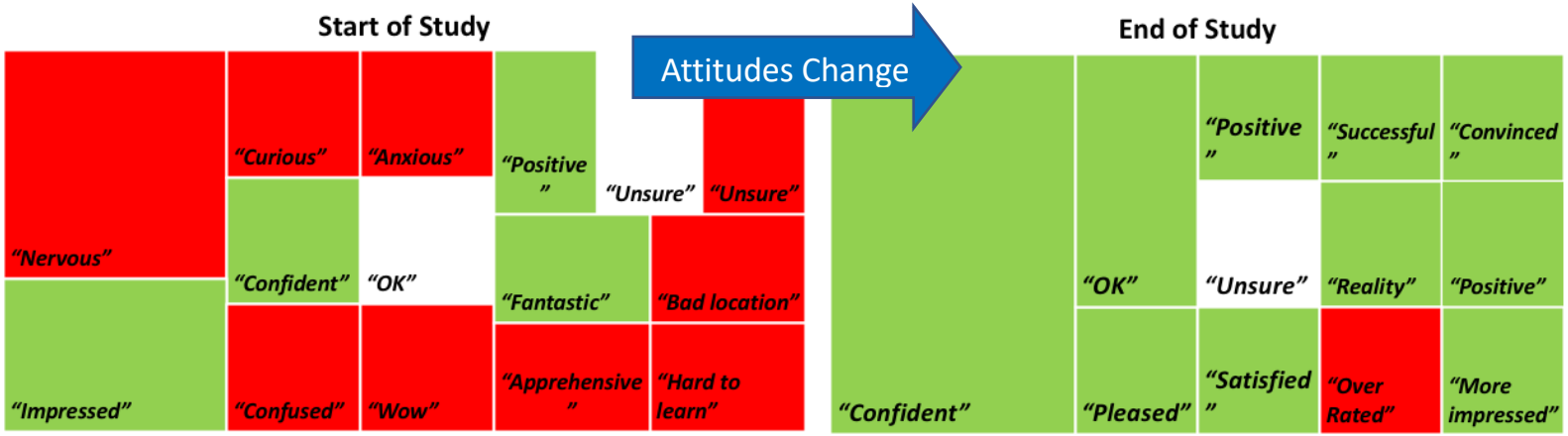


Figure 2. Words selected by the participants to describe their feelings towards AVTs at start (left) and end (right) of the study.

Finding 3: Usage experience improved attitude

"I think practice made the awkward just go away"

Finding 4: Reading manual improved attitude

"The manual I have outlined the limitations very clearly, so all of that made me feel … better about the system"

Perception

Finding 5: Better training

Finding 6: More intuitive control

- Intuitive placement of the control

  "I think the display could be much more intuitive"

- Touchscreen

  "So the screen was not a dedicated screen to control"

  "when you were touching the screen, it didn't always recognize you were touching the screen"

Liked Features Best/Least

Finding 7: Like BSA Best

- Improves visibility

"that mirror (blind spot alert) told you there was something there you need to see"

- Increases confidence

"It did increase my confidence in driving. In traffic, I'd like to have that."

Finding 8: Like LKA Least

- Trust issue

“I felt like I couldn’t trust it”

- Too many limitations

“It didn’t work well in bad weather”

“The limitations of that system made it something that I wouldn‘t want to have”

“if it doesn’t have that painted line, it won’t see anything”

Safety Perception

Finding 9: Most agreed that the features improve safety

- Learning how to use first

  “Learn first then buy”

- Too many limitations

  “*Don’t get complacent”*

YES

"You will love the blind sport alert"	*"Mostly it is a good backup"*	*"Learn about 1 feature at a time"*	*"Yes, but still be responsible"*	*"Yes and learn how to use"*	*"Safer"*
"I'm still in control"	*"It definitely helps me feel safer"*	*"See if settings stay when car is turned off "*	*"These features help but don't rely on it."*	*"Go for it"*	*"Have limitations, not self-driving "*
"Sure get it you will love it"	*"Yes, but there is a learning curve"*	*"Features will "assist" you"*	*"These safety features definitely help with…*	*"Be sure to get lane keeping features"*	*"Be sure to get blind spot alerts"*
"Learn first then buy"	*"Safety is increased"*	*"Yes, blind spot at any cost"*	*"Makes changing lanes safer"*	*"I feel the vehicle safety features improve…*	*"The features support good driving (safe)"*

NO

"Wait for the pull"	*"Lane control isn't necessary"*

MAYBE

"Not all of the controls are for everyo…	*"Don't get distracted by it"*	*"Consider the cost"*	*"Have salesperson ride with you…*		*"Use only features that you like"*
"Must study it and pay attention "	*"Don't get complacent"*	*"Do not become dependent on them"*	*"Not for tight spots (bank)"*	*"Yes – if features are used"*	*"Make sure controls are accessible"*

Figure 3. Participant's responses assume that their friend is asking if AVTs improve safety or not, the responses agreed to safety improved are under "YES", safety maybe improved are under "MAYBE", safety not improved are under "NO".

Driving performance analysis

Comparison of Seniors Driving Between SHRP2_PENN and SMX

Result

Table 2. Driving Performance: SHRP 2_PENN vs. SMX (Sample Size: 30 for SHRP 2_PENN, 18 for SMX)

Measure	Test Statistics	Degrees of Freedom	*P*-Value
Number of lateral events/km	$T = -1.74$	28.88	0.09
Variance in acceleration magnitudes across lateral events	$T = 24.49$	32.15	<.001
Number of longitudinal acceleration events/km	$U = 106$	-	<.001
Number of longitudinal deceleration events/km	$U = 412$	-	0.002
Variance in acceleration/deceleration magnitudes across longitudinal events	$T = 4.19$	29.80	<.001

Note: T = Welch's t-test; U = Mann-Whitney-Wilcoxon test

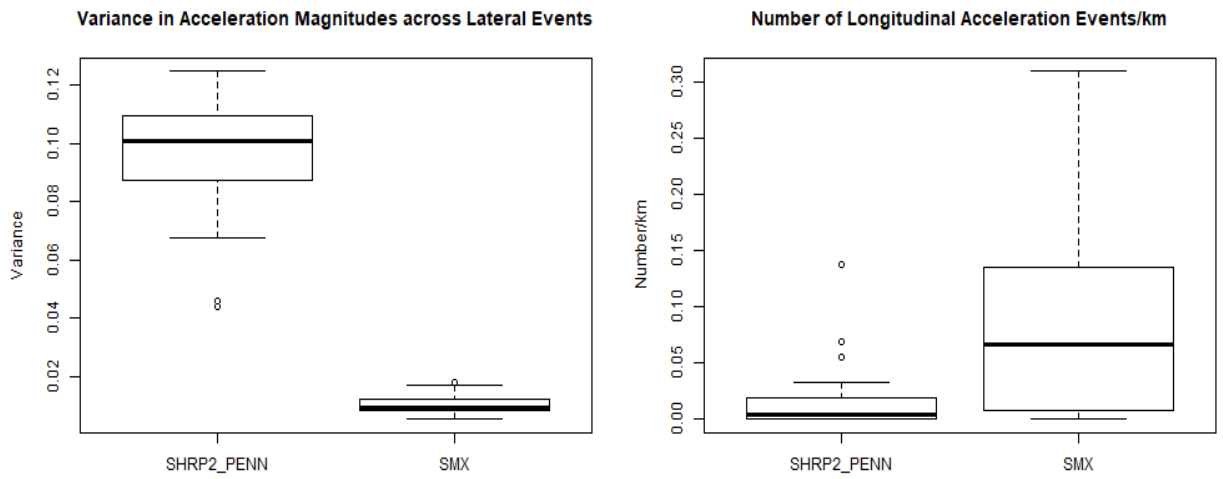


Figure 4. Boxplots. Variance in acceleration magnitudes across lateral events (left) and number of longitudinal acceleration events/km (right) of SHRP 2_PENN and SMX.

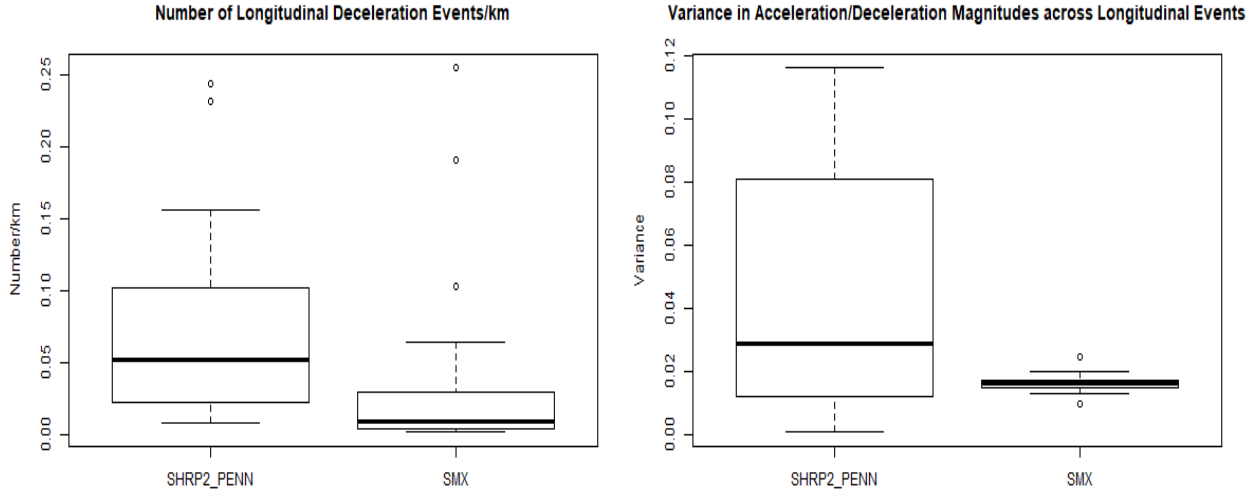
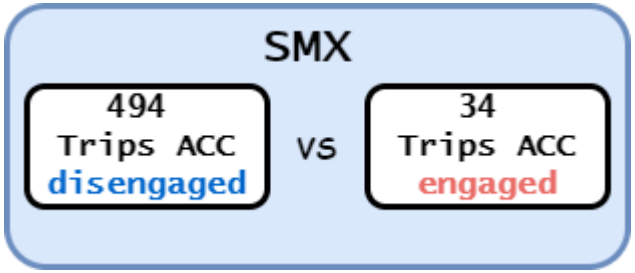


Figure 5. Boxplots. Number of longitudinal deceleration events/km (left) and variance in acceleration/deceleration magnitudes across longitudinal events (right) of SHRP 2_PENN and SMX.

Comparison of Trips Between ACC Disengaged and Engaged in SMX



Result

Table 3. Comparison of Trips Between ACC Disengaged and Engaged in SMX (Sample Size: 494 for ACC Disengaged and 34 for Engaged).

Measure	Test Statistics	df	*P*-Value
Number of lateral events/km	*U* = 9,724	-	0.12
Max lateral acceleration	*T* = 0.08	38.52	0.93
Number of longitudinal acceleration events/km	*U* = 11,488	-	<0.001
Number of longitudinal deceleration events/km	*U* = 8,013	-	0.56
Max longitudinal acceleration	*T* = 2.37	37.99	0.02
Max longitudinal deceleration	*T* = 1.33	38.41	0.19

Note: T = Welch's *t*-test; *U* = Mann-Whitney-Wilcoxon test

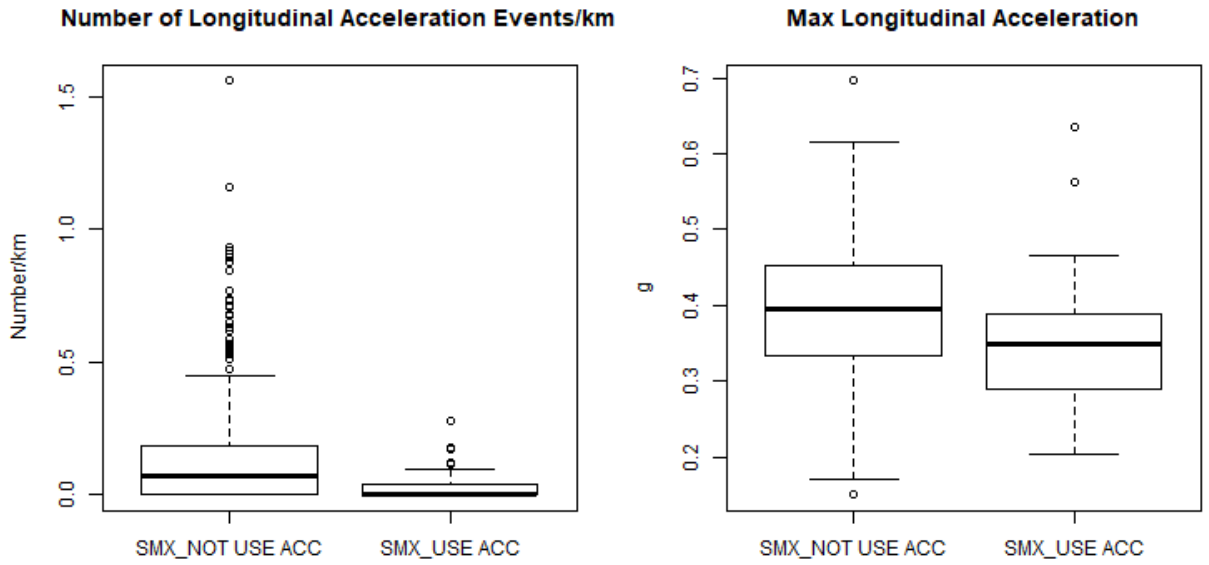


Figure 6. Boxplots. ***Number of longitudinal acceleration events/km*** **(left) and** ***max longitudinal acceleration*** **(right) for trips in SMX without and with ACC engaged.**

Driving Performance Findings

- **Smaller variance in acceleration magnitudes across lateral events** - More stability and better lateral control performance for seniors driving the ADAS-equipped vehicles.
- **Smaller variance in acceleration/deceleration magnitude across longitudinal events** - Equipped with ADAS may help seniors better manage their speed, for example, reducing hard braking, which can help with headway management.

The findings should be interpreted with caution because confounding factors, such as road and traffic

environment, as well as other familiarity with car dynamics, cannot be fully controlled in our analysis.