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Experiences of Advanced Driver Assistance Systems amongst Older Drivers

Technical Report

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1 Literature search

All relevant studies on ADAS and older drivers were identified through four steps:

1. **Identification of seed studies:** Seed studies are studies that were used to gain an understanding of the key terms used in the literature and begin to compile a list of relevant studies. Seed studies were identified by the Department for Transport (DfT), transport experts and through exploratory web searches using Google Scholar.
2. **Citation analysis:** For each relevant seed study identified, forward (documents that cited the study) and backwards (documents cited in the steed study) citation analysis was conducted.
3. **Grey literature search:** Grey literature is literature that is not published in a scholarly journal, such as government reports or conference proceedings. A grey literature search was carried out on websites and databases suggested by transport experts that covered ageing, motoring, research and development, transport, consumerism, and health.
4. **Database search:** Using a search string developed through identifying key terms in the literature, testing the number and relevance of results of different strings, and in consultation with DfT and transport experts, a search was conducted in Web of Science. After noticing that the majority of results obtained dealt with Alzheimer's or autism (because ADAS also stands for terms related to both conditions) these terms were specifically eliminated from the search. Alzheimer's was eliminated at the title level because this removed studies that were only about Alzheimer's but retained studies that dealt with Alzheimer's (as ADAS can be used by drivers with mild symptoms of the condition). Autism was eliminated at the topic level because drivers with autism were not the focus of this study. The search string is defined below:

1	TS=("Driv* Assistance System*" OR "Transport technolog*" OR "Automotive technolog*" OR "In-vehicle system*" OR "connected vehicle*" OR "Connected car*" OR ADAS OR in-vehicle automatic parking OR in-vehicle automatic braking OR in-vehicle blind spot* detection OR in-vehicle collision avoidance system* OR in-vehicle cruise control OR in-vehicle detection system* OR in-vehicle drowsiness detection OR in-vehicle GPS OR in-vehicle satellite navigation OR in-vehicle hill descent control* OR in-vehicle intelligent speed assistance OR in-vehicle lane departure warning* OR in-vehicle light* control* OR in-vehicle night vision OR in-vehicle smart vehicle* OR in-vehicle stability control* OR in-vehicle tire pressure monitor* OR in-vehicle vehicle head-up display* OR in-vehicle warning system*)
2	AND TS=("old* driver*" OR "old* adult*" OR "old* road user*" OR old* people* OR "elder* driver*" OR "elder* adult*" OR "elder* road user*" OR elder* people* OR ageing OR aging OR senior)
3	NOT TI=(Alzheimer*)
4	NOT TS=(autism)
5	Refine by: Document Types (article OR review)
6	Refine by: Languages: (English)
7	Refine by: Research areas: behaviour sciences OR geriatrics OR gerontology OR psychology OR neurosciences neurology OR robotics OR transportation OR engineering OR social issues OR public environmental occupational health OR business economics OR computer sciences OR rheumatology OR social sciences other topics OR urban studies OR science technology other topics OR geography OR sociology OR communication
8	Refine by: Publication Years: (2018 OR 2017 OR 2016 OR 2015 OR 2014)

Note: TS= Title Search (The term must be in the title); TI= Topic Search (The term must be a topic).

During each stage of the search process, article titles and abstracts were screened by three researchers. To be retained, studies had to meet the following criteria:

1. Cover at least one type of ADAS. See the glossary in the main report for a complete list of ADAS.
2. Cover at least one relevant outcome. Table 1:1, provides a detailed list of outcomes.
3. Offer original findings. Studies either had to be empirical or, if a literature review, offer original conclusions rather than simply summarize findings.

Figure 1:1 presents the results of the search and screening process.

Figure 1 Flow diagram of search and screening results

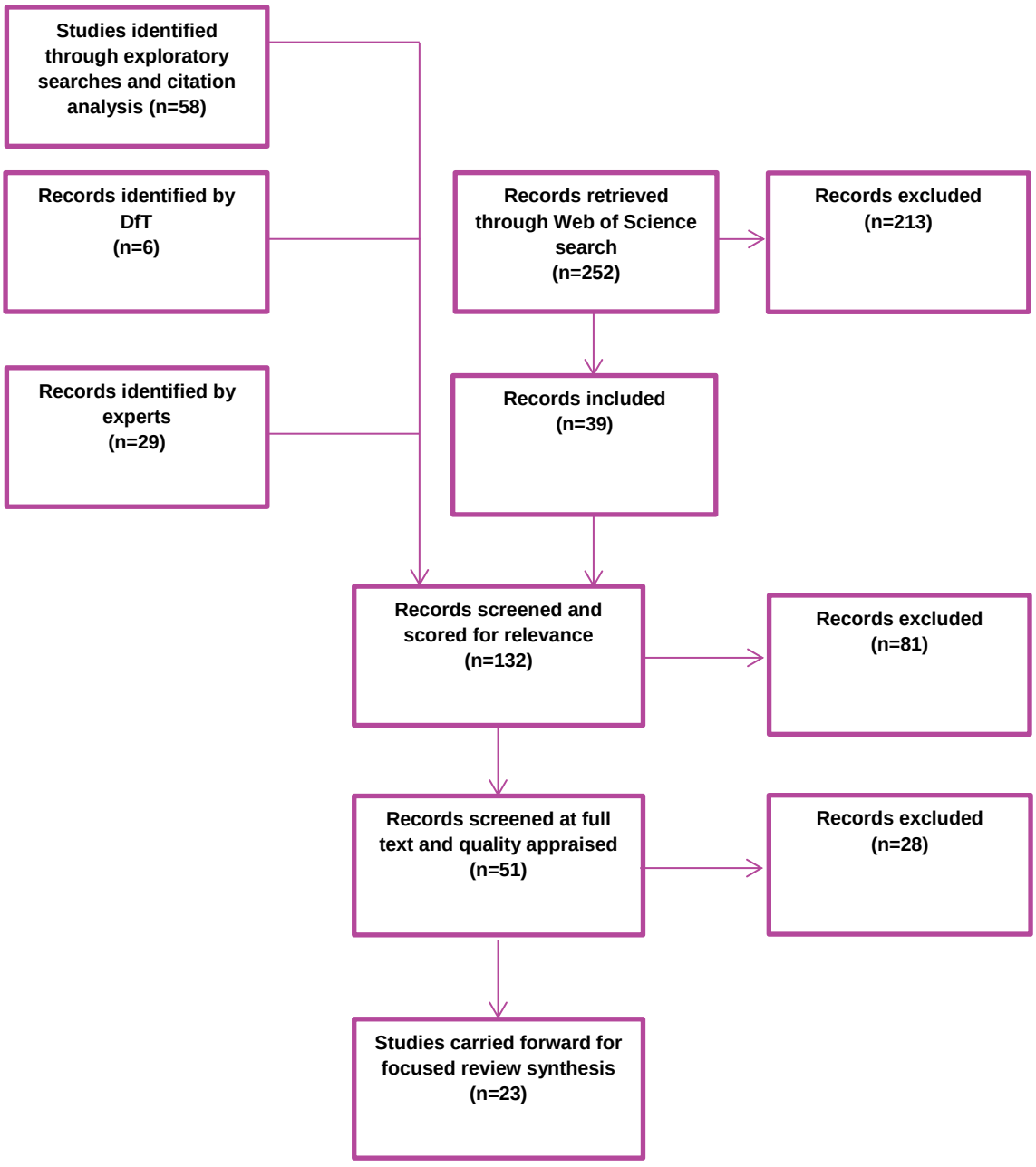

Table 1 Outcomes of interest	
Outcome	**Definition**
Attitudes and perceptions	
Acceptability	Drivers' overall attitudes towards ADAS.
Perceived utility	Drivers' attitudes towards how useful ADAS are to help with their driving or solve a specific mobility problem or impairment (e.g. poor vision).
Perceived user-friendliness	Drivers' attitudes towards how easy ADAS are to use and understand.
Perceived effectiveness	Drivers' attitudes towards how effective ADAS are at solving a certain driving, mobility, or issues stemming from age-related impairments.
Awareness and knowledge	The levels of awareness and knowledge participants have about ADAS.
Perceived affordability	Drivers' attitudes towards how affordable ADAS are either on their own or to buy a car with ADAS.
Trust in system reliability	Drivers' attitudes towards how reliable ADAS are.
Confidence in driving abilities	The level to which ADAS affects a respondents' confidence in their driving abilities.
Adverse effects	Whether having ADAS in vehicles increases negative attitudes about driving.
Driving behaviours	
Driving performance	How ADAS positively affect driving performance and driving behaviours.
Adverse effects	How ADAS negatively affect driving performance and driving behaviours.
Transport mode of choice	Whether and how ADAS affect drivers' choice about what mode of transportation to use.
Type of road drive on	Whether and how ADAS affect the type of road drivers choose to driver on.
Age at which people stop driving	Whether and how ADAS increase the age at which people stop driving.
Frequency of vehicle use	Whether and how ADAS affect how often drivers use their vehicle, either positively or negatively.
Time of day when drive	Whether and how ADAS affect what time of day a driver drives at.
Distance travelled	Whether and how ADAS affect the average distance a driver travels during a time period.
Long-term health and social outcomes	
Injury and accident prevention	How the implementation of ADAS in vehicles has contributed to injury and accident prevention over the long term.
Mental health	Whether and how ADAS affect the mental health of drivers, either positively or negatively.
Integration/loneliness	Whether and how ADAS affect the integration and loneliness of drivers.
Physical health	Whether and how ADAS affect the physical health of drivers, either positively or negatively.

2 Relevance appraisal

In total, 131 of the studies identified through the search process met the inclusion criteria. At this stage in the review process, the goal was to identify the 50 most relevant studies. To do so, the abstract of the 131 studies was read and scored for relevance. Scoring of abstracts was carried out by two coders. A random selection of 18 percent of these studies was double scored to ensure consistency.

Studies were scored on five different areas of relevance and scored out of a possible five points. Scores of zero or one were given. Table 1:2 outlines the five areas and the criteria by which a score of zero or one was awarded and table 1:3 reports the frequency of each relevance score.

Table 2 Relevance scoring criteria

Relevance Area	Score of 0	Score of 1
Number of ADAS covered	Only 1 ADAS covered	More than 1 ADAS covered
Sample used	Older adults not covered	Focus on older adults only or as a group
Date of publication	Published before 2013	Published during or after 2013
Number of outcomes	Only 1 outcome covered	More than 1 outcome covered
Study setting	Set outside of the UK	Set in the UK
Relevance score	Lowest possible= 0	Highest possible= 5

Table 3 Relevance score frequency

Relevance Score	Frequency
5	4
4	24
3	40
2	36
1	24
0	3
Total	**132**

3 Screening

It was decided that studies with a score of four or five would be included in the list of 50 as these were the most relevant studies. However, only 28 studies had a score of four or five. Therefore, studies with lower scores were selected to be included in the list of 50.

The approach used is similar to that of purposive sampling done in qualitative studies; studies were selected on the basis of relevance and outcome covered to ensure that a wide range of outcomes were represented. In consultation with DfT, it was decided that as many outcomes as possible should be covered in list of 50. The types of ADAS and outcomes covered in the 28 studies, and how often each was covered, was recorded. After doing so, the outcomes that were not covered in the 28 studies, or covered only once or twice, were identified. Based on this information, studies that covered these outcomes were selected. Studies with a relevance score of 3 were prioritised, but if there was no study with a score of 3 covering a relevant outcome, studies with a lower score were included. Once as many outcomes as possible were covered, studies that were set in the UK and included older adults only were prioritised. In the end it was decided that 51 studies met the criteria.

After narrowing the number of studies to 51, it was then possible to screen at the full text level. At this stage, the goal was to identify the most relevant studies of the highest quality. To do so, studies were screened for the relevance of results (meaning the relevance of the specific results for answering the review questions, studies were *not* selected on the basis of reporting positive or negative results) and the quality of the study methods.

Quality appraisal was done following the Weight of Evidence (WoE) framework that assesses quality of a study on three dimensions: the quality of the execution of the study, the appropriateness of the study method in relation to the review question, and the relevance of the focus and approach of the study in relation to the review question (Gough, 2007). Using this framework, quality and relevance criteria specific to the review was developed and studies were assessed out of possible score of 24. Table 1:4 outlines the weight of evidence criteria and basis for scoring. Full text screening was performed by 4 coders. For each study, a quality appraisal and key finding form was completed. Table 1:5 outlines the frequency of WoE scores.

Once all studies were appraised and summarised, a matrix, figure 1:2, was developed to provide an overview of which outcomes and ADAS were covered in the 51 studies and how often. Each row represented a type of ADAS and each column represented an outcome. In each cell, the number of studies that covered that outcome and technology was recorded. This allowed us to see which outcomes and technologies were covered the most often, (and therefore which outcomes and technologies had the largest evidence base). By doing this, it was possible to see that the attitudinal outcomes were covered the most often, followed by driving behaviour. In consultation with DfT, it was decided that the attitudinal outcomes, along with two driving behaviour outcomes (the age at which people stop driving and frequency of driving) would be the focus of the review. This was done because even though it was desired that as many outcomes as possible would be covered in the review, this had to be balanced with the need for multiple studies on a topic in order strengthen the validity of the findings; if each outcome was only covered by one study, it would be difficult, and unreliable, to draw substantial conclusions.

After narrowing down the outcomes, studies covering these outcomes were selected based on their WoE score. The average WoE score was 15. There were 20 studies

that covered the desired outcomes and with a WoE score of 15 or above. Three other studies with a score below 15, were included because one covered important outcomes (for example, confidence in driving) and two were literature reviews, that because of the nature of the quality appraisal scoring, scored low but were in fact a high quality reviews. Therefore, 23 studies were included in the final review.

Table 4 Weight of evidence appraisal

Quality of execution	Codes	Reason	
Clarity of the research question	2	Clear research question(s)	
	1		
	0	No research question(s)	
Quality of the contextualisation	2	Has a literature review with depth and recent sources	
	1		
	0	No literature review, or literature review is very short and sources are out of date	
Transparency of recruitment and sampling procedure	2	It is clear how participants were recruited and how the sample was chosen	
	1		
	0	There is no explanation of how participants were recruited and how the sample was chosen	
Sample Representativeness	2	The sample is a random sample or there has been effort to include a sample that is as representative as possible	
	1		
	0	The sample is not random and there has been no effort to make the sample representative	
Transparency and accuracy of the methodology	2	Methodology clear and transparent	
	1		
	0	No or little description of methodology	
Transparency and accuracy of findings		Quantitative:	Qualitative:
	2	Statistics, sizes and values indicated	Factors driving opinions are explained
	1		
	0	Statistics, sizes and values not indicated	Factors driving opinions NOT explained
Transparency and accuracy of the discussion/conclusion	2	Question(s) answered and supported by findings	
	1		

	0	Question(s) NOT answered and supported by findings
Appropriateness of methodology		**Reason**
Appropriateness of the study conclusions to the design	1	No strong causal claim OR used experimental design
	0	Strong causal claim WITHOUT experimental design
The use of a quantitative/qualitative design is justified	1	Design supports research question/aims
	0	Design does NOT support research question/aims
The sample size is appropriate to the study	1	Sample size large enough to draw conclusions
	0	Sample size NOT large enough
Key concepts and instruments are properly defined and (for quantitative studies) operationalised (for s)	1	Concepts and instruments properly defined and operationalised
	0	Concepts and instruments NOT properly defined and operationalised
No generalisations to other places/times are attempted unless warranted by the sample	1	Generalisations NOT made beyond study characteristics
	0	Generalisations made beyond study characteristics
Relevance of topic and focus	**Codes**	**Reason**
The study is based on a British sample	1	Fully or partially in the UK
	0	NOT set in the UK
The study focuses on older adults	1	Focus or sub analysis of older adults
	0	Does NOT focus or sub analyse older adults
Number of relevant outcomes covered	1	Covers two or more relevant outcomes
	0	Covers one relevant outcome
The outcome of interest is central to the study	1	Outcome(s) of interest main or major focus
	0	Outcome(s) of interest briefly analysed
The study was published less than 2 years ago	1	Published in 2017 or 2018
	0	Published in 2016 or later

Table 5 Weight of evidence score frequency	
Relevance Score	**Frequency**
Over 20	7
16-20	19
11-15	19
5-10	3
0-5	2

4 Data extraction and synthesis

The final step consisted of extracting all relevant results from the 22 studies and synthesising each result to draw conclusions about older adults' experience with ADAS. A result was a finding or conclusions, originating from a survey or interview question that pertained to a specific outcome or comparison of groups. For example, the difference in the utility of a lane departure warning among older and younger drivers. Two coders used a data extraction tool to extract the following information for each result in a study:

- What was analysed/asked?
- The result
- How the analysis was performed/ how was the question answered
- General study methodology
- The sample used (sample characteristics, recruitment, country)
- Other important information/comments (including study limitations)

In total, 169 separate results were extracted from the 22 studies. Figure 1:3 shows the outline of the data extraction tool and an example of the data that was extracted for both a quantitative study and qualitative study.

To synthesise and develop the findings outlined below, the results were sorted into 11 categories, following the different outcomes investigated in the studies. Within each topic, the results were then analysed and compared for similarities and differences. For example, all results about the perceived utility of ADAS were placed together and then sorted by the problem solved and the type of ADAS. Based on the patterns emerging from this analysis, the results were further sorted into the themes outlined in the findings. Within each theme, results about ADAS generally were explored, and then results about specific types of ADAS were used to further explain the nuances in the data. Throughout this process, the quality of the studies (particularly the sample size and sample characteristics) were taken into consideration.

Table 6 Matrix of the type of ADAS and outcomes covered in the 50 studies

	Acceptability	Utility	User-friendliness	Effectiveness	Awareness & Knowledge	Affordability	Trust in system reliability	Confidence in driving abilities	Adverse effects	Driving performance	Adverse effects	Type of road drive on	Age at which people stop driving	Frequency of vehicle use	Time of day when drive	Distance travelled	Mental Health	Social integration / loneliness	Health	Row Total
General ADAS	24	12	4	3	13	4	7	3	8	5	0	1	3	2	0	0	1	1	2	93
Apps	1	0	1	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	4
Automatic parking	1	1	1	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	5
Automatic & Proactive braking	2	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	3
Backup camera & Backing aids	2	1	2	0	0	0	0	1	2	1	1	0	0	0	0	0	1	0	0	11
Blind spot detection	1	1	1	0	0	0	0	0	0	1	1	0	0	0	0	0	1	0	0	6
Collision avoidance system	2	1	1	0	0	0	0	0	0	2	1	1	0	0	0	0	1	0	0	9
Cruise control	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
Drowsiness detection	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
GPS/Satellite navigation	3	3	2	1	0	0	3	3	2	0	1	3	0	0	0	1	0	2	0	24
Hands-free communication	2	1	2	0	0	0	2	0	0	1	1	0	0	0	0	0	0	0	0	9
In-vehicle information system	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
Intelligent speed assistance	4	2	2	0	0	0	0	2	2	3	3	0	0	0	0	1	1	0	0	20
Intersection assistance	1	1	1	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	5
Lane-keeping assistance	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	2
Light control	1	1	1	0	0	0	0	1	1	0	1	0	0	0	1	0	0	0	0	7
Night vision	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Steering assistance	1	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	3
Vehicle head-up display	1	1	0	0	0	0	0	0	0	2	1	0	0	0	0	0	0	0	0	5
Column Total	49	28	19	5	12	4	15	10	16	20	11	5	3	2	1	3	5	3	2	213

Table 7 Data extraction tool template

Study	Country	Source (Page number, table number, row or para number)	What was analysed/ asked?	Results (headline finding, secondary findings, nuances)	How was the analysis performed/question answered?	Study method	Sample (size, characteristics, major limitations, where sample drawn from)	Other important information/comments
Quantiative Example								
Motamedi and Wang, 2017	United States	Pg. 509 Table 3 Perceived usefulness	Perceived usefulness of In-Vehicle Technology (Perceived usefulness defined as degree to which driver believes using particular technology could be helpful for driving performance)	Side View Assist perceived as most useful (mean rating=4.255) & Automatic Windshield Wipers perceived as least useful (mean rating=3.036) Middle is Adaptive Cruise Control (mean=3.691), Night Vision Camera (mean=3.991), Automated Pedestrian Detection (mean=4.027), Lane Departure Warning (4.138) Perceived usefulness of technologies significantly different (F=14.59, p=<0.001)	Descriptive analysis- mean score for each technology 1-5 rating scale (5=very useful) ANOVA table to compare technologies	Gave older drivers questionnaire on in-vehicle technologies that mitigate driving challenges; identified driving challenges, type of required assistance and in-vehicle systems that could assit Gave another questionnaire on acceptance of feasible in-vehicle technolgoies that could provide assistance (questionnaire developed based on new adapted conceptual model for older adult drivers' technology acceptance-model based on two main effective factors user decision (perceived usefulness and perceived each of use and percieved safety and perceived anxiety)	N=115 Location: Rhode Island Gender: Female (61%), Male (39%) Age: 61-90 (95%), >90 (3%), <60 (2%) Length of driving: <15 minutes (55%), 15-60 minutes (27%), >1 hour (15%), Other (3%) Driving Frequency: > Once a day (56%), Once a day (24%), 1-3 times a week (16%), 1-2 times a month (4%) Health: More than half reprotes some health issues Crash experience: No crash experience (59%) Recruited from Univerist of Rhode Island, Osher Lifelong Learning Institue and local community centres and churches (recruited for 1st questionnaire (N=135) and then contacted again)	Sample is small for a questionnaire and from small, wealthy state
Qualitative Example								
Gish et al., 2017	Canada	Pg 4 Para 3	Older drivers' perceptions of Assisted Vehicle Technologies based on driving experience and how perceptions relate to an aging body	Theme: AVTs as devices of convenience. Participants described AVTs as convenient devices that made drivers feel more comfortable behind the wheel. Comfort equated with convenience, ease of use, and increased feelings of safety. Made it easier to perform complex manoeuvers due to the visual and auditory information conveyed by AVTs. For example "beeps" when parking. AVTs felt to reduces workload by 'driving for you', for example, cruise control.	In-depth qualitative interviews. Thematic analysis of semi– structured interview data using Nvivo Framework.	In-depth qualitative interviews with 35 older drivers who owned a vehicle with at least two Assisted Vehicle Technologies (AVTs). One in-depth interview of 1–2 hours with each participant. Participants asked to describe reasons for purchasing a new vehicle, to describe how certain AVTs worked in their vehicle and to provide examples of how they used AVTs while driving. They were also asked to discuss what they liked or disliked about driving with AVTs. Each interview was digitally recorded and transcribed verbatim.	N= 35 Age: 60–85: 60-69 (15), 70-79 (15), 80+ years (4), Unreported (1) Income: $20–$49k (1), $50–$79k (11), $80k (18), Unreported: 5 Education: High school/some college (8), University (12), Post graduate (11), Other/Unreported (4) Recruiment: community posters/flyers, notices in local e–newsletters of retiree associations and use of University research database of seniors residing in community. Eligibility criteria: (1) possessed a valid driver's license, (2) drove at least one day a week, and (3) owned a vehicle that had at least two AVT features.	Eligibility requirements excluded many interested seniors from the study, so reduced age eligibility criteria from 70 to 60 years of age. Sample contains a relatively privileged group with high-end automobiles: People from lower socioeconomic backgrounds more likely to own 'low–tech' vehicles that do not contain the latest safety innovations.